VIRTIS
EXPERIMENT USER MANUAL
ProtoFlight Model

Issue 3

July 2003

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DOCUMENTATION CHANGE RECORD

Issue	Revision	Section	Date	Changes
1Draft	0	ALL	15/09/00	First Draft Issue
1Draft2			27/07/01	Preliminary revision
2		ALL	7/5/2002	Full revision
3				1. Paragraph 3.3 removed 2. Fig. 3.2. State Transitions changed 3. Added NCR induced constraints 4. Updated Mass Budget (metrology reports from PFM_ADP) 5. Updated Power Budget 6. Chapters 5.4 and 5.3 exchanged 7. Updated Flight Operation Sequences 8. Chapters 4.4 and 5.2. Recovery OBCP removed. Updated description of Failure On-Board Actions 9. Added AD : RSOC ICD 10. Updated Attachment List 11. Updated In-Flight Calibration sequence description for M and H

RELATED DOCUMENTS

Applicable Documents

AD1	RO-EST-RS-3001/EID-A Issue2 rev.1, October 2000	
AD2	RO-EST-RS-3015/EID-B Issue 2 rev.0, March 2001	
AD3	RO-EST-RS-3001/EID-C Issue1 rev.3 December 1999	
AD4	RO-ESC-TN-5022 Issue 1, March 2001	Commissioning Operations
AD5	RO-ESC-TN-5018 Issue 1, December 2000	Planets swing-by Operations
AD6	RO-ESC-TN-5019 Issue 1, December 2000	Near Sun Cruise Operations
AD7	RO-ESC-TN-5017 Issue 1, December 2000	Asteroids Fly-By Operations
AD8	RO-DSS-RS-1024 Issue1, December 2001	VIRTIS OBCP URD
AD9	VIR-GAL-IC-028, Issue 7,July 2001	VIRTIS S/W Internal ICD
AD10	VIR-GAL-UR-040, Issue 5, July 2001	VIRTIS S/W User Req.
AD11	RO-ESC-PL-5000, Issue 2, August 2002	Flight Operation Plan
AD12	RO-EST-IF-5010, Issue 1, February 2002	RSOC to PI ICD

Abbreviations

ANC	Condition Analog T/M
CCD	Charged Coupled Device
CCE	Cooler Controller Electronics
CE	Close Encounter
DHSU	Data Handling and Support Unit
DMS	Data Management System (the on board computer)
ECA	Emergency Cover Actuator
EGSE	Electrical Ground Support Equipment
HRD	High Speed Link
IRFPA	InfraRed Focal Plane Assembly
ME	Main Electronic Module
MLC	Memory Load Commands
OBCP	On-Board Control Procedure
OBDH	On-Board Data Handling
OTS	DMS Timing & Syncro Signal
PDU	Power Distribution Unit
PEM-H	Proximity Electronics Module H
PEM-M	Proximity Electronics Module M
PFM	Proto-Flight Model
PS	Power Supply
ROIC	Read-Out Interface Circuit
RTU	Remote Terminal Unit
SCET	Space Craft Elapsed Time
SDT	Serial 16 bit Digital Telemetry
SSMM	Solid State Mass Memory
VIRTIS	Visual, InfraRed and Thermal Imaging Spectrometer
VIRTIS-H	High Spectral Resolution Optical Head
VIRTIS-M	Mapping Spectrometer Optical Head

IAS-CNR   **Rosetta Virtis**

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1 General Description

1.1 Scientific Objectives

VIRTIS is a sophisticated imaging spectrometer that combines three unique data channels in one compact instrument. Two of the data channels are committed to spectral mapping and are housed in the Mapper (**-M**) optical subsystem.   The third channel is devoted solely to spectroscopy and is housed in the High resolution (**-H**) optical subsystem.

The nature of the solid compounds of the comets (silicates, oxides, salts, organics and ices) is still largely unknown. These chemical compounds can be identified by infrared spectroscopy using high spatial resolution imaging to map the heterogeneous parts of a *nucleus* and high spectral resolution spectroscopy to determine the composition unambiguously. The visual and infrared spectrum of the comet *coma* is characterised by a number of components comprising both gas emission bands and a dust continuum. Ground-based visual spectroscopy has detected various atomic, radical and ionic species formed through photo-dissociation by solar ultraviolet radiation of the so-called "parent" molecules which are sublimated from the nucleus and possibly from a halo of volatile grains. Previous IR comet observations have shown that various hydrocarbons show emission bands between 3 and 4 μm.

A Multispectral Imager - covering the range from the near UV (0.25 μm) to the near IR (5.0 μm) and having moderate to high spectral resolution and imaging capabilities - is an appropriate instrument for the determination of the comet global (size, shape, albedo, etc.), and local (mineralogical features, topography, roughness, dust and gas production rates, etc.) properties.

The VIRTIS instrument shall be capable of achieving the VIRTIS Rosetta Science Team objectives outlined below.

1.1.1 VIRTIS Science Objectives

The primary scientific objectives of the VIRTIS during the Rosetta mission are:
- to study the cometary nucleus and its environment,
- determine the nature of the solids of the nucleus surface,
- identify the gaseous species,
- characterise the physical conditions of the coma,
- measure the temperature of the nucleus.

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

Tertiary objectives include the detection and characterisation during flybys of the asteroids Siwa and Otawara.

1.1.2   VIRTIS-M Nucleus Science Objectives

- Identify different ices and ice mixtures and determine their spatial distribution for an albedo ranging from 0.02 to 0.4. This requires sensors (in the Vis and IR) with good dynamics and high sensitivity at low photon numbers . *The Vis and IR sensors procured for VIRTIS are designed in order to satisfy the previous requirements.*
- Identify the carbonaceous materials and determine the overall continuum slopes of the spectra. This requires S/N> 100. *The characteristics of the thermal design of VIRTIS are such to guarantee that a reduced background noise; the characteristics of the optical design of VIRTIS guarantee a low stray light.*
- Determine the physical microstructure and nature of the surface grains by measuring the spectrophotometric phase curve with a relative radiometric accuracy of 1%. *The thermal stability of the instrument obtained by design, permits to achieve this goal. The calibration procedures defined both for in-flight and ground calibration will permit to reach this goal.*
- Identify the silicates, hydrates and other minerals with a spectral resolution of $\lambda/\Delta\lambda >$ 100 in the full spectral band. *The selected sensor and the optical design of the instrument are optimised in order to achieve these objectives.*
- With a spatial resolution of a few tens of meters, globally map the nucleus and determine the spatial distribution of the various mineralogical types and their mixtures using both the spectral features and the overall brightness. *The procured sensorand the optical design are optimised in order to achieve these objectives. Moreover the presence of the scanning mirror in VIRTIS M will permit to map specific areas on the surface and, if needed in order to achieve a higher S/N, to compensate the relative motion S/C – surface on specific regions of the comet nucleus.*
- Detect and monitor active areas on the comet surface, such as gas volcanism, to understand the physical processes operating and identify the associated material types. *The presence of the scanning mirror in VIRTIS M will permit to follow the evolution of active areas on the surface.*

1.1.3   VIRTIS-M Coma Science Objectives

- With a resolving power of 100, determine the global distribution of gas and dust in the inner coma with to absolute and relative radiometric accuracy < 20% and 1% relative. *The procured sensor and the optical design are optimised in order to achieve these objectives. The presence of the scanning mirror in VIRTIS M will permit to map a larger part of the coma.*
- Determine the thermal properties of the dust.
- Identify and map the strong molecular emissions in the near ultraviolet and visible spectral band including the main water dissociation product OH at 0.28 mm and 0.31 mm, CN,C3, NH, CH and CO$^+$ ions, and the neutral radicals CN and C$_2$. With a high spatial resolution of 250 μrad and a moderate spectral resolution of 500, correlate the evolution of radicals with that of their parent molecules. *The procured sensor and the optical design are optimised in order to achieve these objectives The presence of the scanning mirror in VIRTIS M will permit to map a larger part of the coma.*
- Correlate the results of these measurements with ground based telescopic observations.

- Map the composition and evolution of gas and dust jets in the coma and correlate it with the mineralogical composition and spatial morphology of active regions on the nucleus surface. *The presence of the scanning mirror in VIRTIS M will permit to follow the evolution of active areas on the surface.*

1.1.4 VIRTIS-H Nucleus & Coma Science Objectives

- With a S/N > 100 and resolving power higher than 1000, determine the composition of ices on the nucleus surface by resolving the absorption bands of condensed molecules between 2 and 3 microns
- In the 2 to 5 micron band, identify molecules in the gas, and measure rotational temperature. With a resolving power of 1500 at 3.5 micron, identify the hydrocarbon emission in the 3 to 4 micron band. *The needed spectral resolving power is achieved by the design and thanks to the characteristics of the procured IR sensor.*
- Determine the composition of the dust grains in the coma by observing emission features in the fundamental bands between 2.5 and 5 microns at less than 2 A.U.

1.1.5 VIRTIS Asteroid Science Objectives

The asteroid part of Rosetta mission includes the encounter with two asteroids. The present selection of the Rosetta target-asteroids has been agreed by ESA with the support of the scientific community. It should be stressed out the selection of two asteroids different in size and in composition like 140 Siwa and 4979 Otawara will strongly increase the scientific return. 140 Siwa is a large object of 110 km size, with a rotation period of more than 22 hours. The spectra obtained seem to indicate a C class with no alteration. So it will be possible to observe a C type asteroid for the first time.
VIRTIS should allow the determination of the global and local properties of the target asteroids. The scientific goals achievable with a minor planet encounter are:
The characterisation of global shape of the asteroid and the knowledge of its physical properties: size, shape, pole and rotational period, dimension, density.
The study of the morphological characteristics (local features, craters distribution, evidence of possible regolith) and mineralogical composition (heterogeneity of the surface, identification of local chemical provinces, first layer texture).
The analysis of the asteroid environment to detect the presence of dust or gas.
The characteristics of the optical and thermal design of the two channels as well as the characteristics of the 3 FPAs of VIRTIS guarantee the achievement of the previously listed scientific requirements.
The scanning mirror of VIRTIS M will be particularly useful in order to map different areas on the asteroid surface and , if needed , to point particularly interesting zones compensating the S/c motion during the 2 fly-bys.

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1.2   *Experiment Overview*

In table 1.1 are reported the main characteristics of the VIRTIS instruments along with the required radiometric performances.

1.2.1   General Instrument Description

VIRTIS is an imaging spectrometer that combines three data channels in one compact instrument. Two of them are devoted to spectral mapping (Mapper optical subsystem: -M). The third channel is devoted to spectroscopy (High resolution optical subsystem:-H).
As shown in the functional block diagram of Figure 1.1, VIRTIS is made of 5 Modules: an Optics Module containing the –M and –H Optical Heads, the two Proximity Electronics Modules for –M and –H and the Main Electronic Module.
The Optics Module is externally mounted to the -X panel of the spacecraft with the -M and -H Optical Heads co-aligned and boresighted in the positive Z direction. Both optical systems have their slits parallel to the Y axis; the -M has the ability to point and scan by rotating the primary mirror around the Y axis. Two views of the Optics Module are given in figures 1.2 and 1.3.
The -M utilises a silicon charge coupled device (CCD Thomson TH7896) to image from .25 um to 1 μm and a mercury cadmium telluride (HgCdTe) infrared focal plane array (IRFPA from Raytheon) to image from 1 μm to 5 μm. The -H uses the same HgCdTe IRFPA to perform spectroscopy in selected bands from 2 μm to 5 μm (see table 1.1).
The Optics Module is electrically connected by the Inter-Unit Harness.to the -M and -H Proximity Electronics Modules and to the Main Electronics Module, which are internally mounted to the spacecraft on its -Y panel.
The electronics boards required to drive the CCD and the two IRFPAs and to acquire H/K information from the optical heads are housed inside the Proximity Electronics Modules, while the Main Electronics Module takes care of the control of the interfacing with the PEMs and with the S/C, of the control of the cryo-coolers, of the power conditioning and distribution, and performs all the digital data analysis.

The infrared detectors require active cooling to minimise the detector dark current (thermally generated Johnson noise). Their operative temperature is 70K. To minimise the thermal background radiation seen by these two IRFPAs, the Optics Module is divided in two parts:

- The Pallet which is directly interfaced to the warm S/C (i.e. thermally controlled by the S/C) and contains the two cryo-coolers.
- The Cold Box which is a structure rigidly mounted to the much warmer Pallet while remaining thermally insulated from it. The Cold Box contains the cold detectors and the two Optical Heads and is thermally disconnected from the S/C and passively cooled to 130 K by radiating one of its surfaces toward cold space. The optical heads are mounted on the Cold Box Ledge

VIRTIS MAIN CHARACTERISTICS AND REQUIREMENTS			
	VIRTIS – M Visible	**VIRTIS – M InfraRed**	**VIRTIS - H**
Spectral Range (nm)	220.1 – 1046.0	952.8 – 5059.2	*Order* 0 4.05-5.03 *Order* 1 3.47-4.32 *Order* 2 3.04-3.78 *Order* 3 2.70-3.37 *Order* 4 2.43-3.03 *Order* 5 2.21-2.76 *Order* 6 2.03-2.53 *Order* 7 1.88-2.33
Spectral Resolution $\lambda/\Delta\lambda$	100 – 380	70 – 360	1300-3000
Spectral Sampling (nm) (1)	1.89	9.44	0.6
Field of View (mrad x mrad)	63.6 (slit) x 64.2 (scan)	63.6 (slit) x 64.2 (scan)	0.583 x 1.749
Max Spatial Resolution (μrad)	248.6 (slit) x 250.8 (scan)		
Pointing	+Zsc and Boresighted with Osiris, NavCam		
Telescope	Shafer Telescope	Shafer Telescope	Off axis parabolic mirror
Pupil Diameter (mm)	47.5		32
Imaging F#	5.6	3.2	2.04
Etendue (m^2 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 (2)	CdHgTe (2)
Sensitivity Area Format	508 x 1024	270 x 436	270 x 436
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	$< 1\ e^{-1}/s$	< 10 fA @ 70K	< 10 fA @ 70K
Radiometric Resolution SNR	> 100	> 100	> 100 @ 3.3 μm
Radiometric Accuracy Absolute Relative	 < 20% < 1 %	 < 20% < 1 %	 < 20% < 1 %

(1) Depends on selected mode of operation; here is reported the maximum value (no pixel summing)
(2) VIRTIS-M and –H use identical IR detectors.

Table 1.1 - VIRTIS characteristics and Performances Overview

Two cold fingers connect the two active coolers inside the Pallet to their corresponding IRFPAs inside the Cold Box; they must maximise the thermal pathway from the coolers to the IRFPAs while remaining mechanically pliant; in contradistinction, the stand-off insulators (eight Titanium rods) connecting the Cold Box to the baseplate of the Pallet must minimise the thermal pathway between the warm spacecraft and the cold optical subsystems while remaining mechanically rigid. In this way the structure and the delicate subsystems that it supports are not only guaranteed to survive launch vibrations, but the structure can also help in minimising the usual thermal gradients that adversely affect the alignment of low temperature optical systems.

Since the CCD is a frame transfer device, and the IRFPAs are direct injection devices, exposure times can be controlled electronically. However, measurement of the detector dark current plus background radiation requires calibration shutters to be placed at the entrance light limiting slit of each spectrometer (telescope background contribution is negligible because of its low temperature and the narrow width of the slit).

The M and H channels are equipped with a protective cover to protect the instrument from dust contamination and damage when not operational. The covers are located between the baffles and the entrance borehole; they are commanded by the ME and controlled by S/W. Each cover is also equipped with an emergency actuator to force open the cover in case of malfunctions.
The covers have an additional use as they are machined as retro-reflectors for the in-flight spectral calibration. The instrument with he cover close shall then be calibrated in-flight. This features comes useful also for the on ground testing of the instrument.

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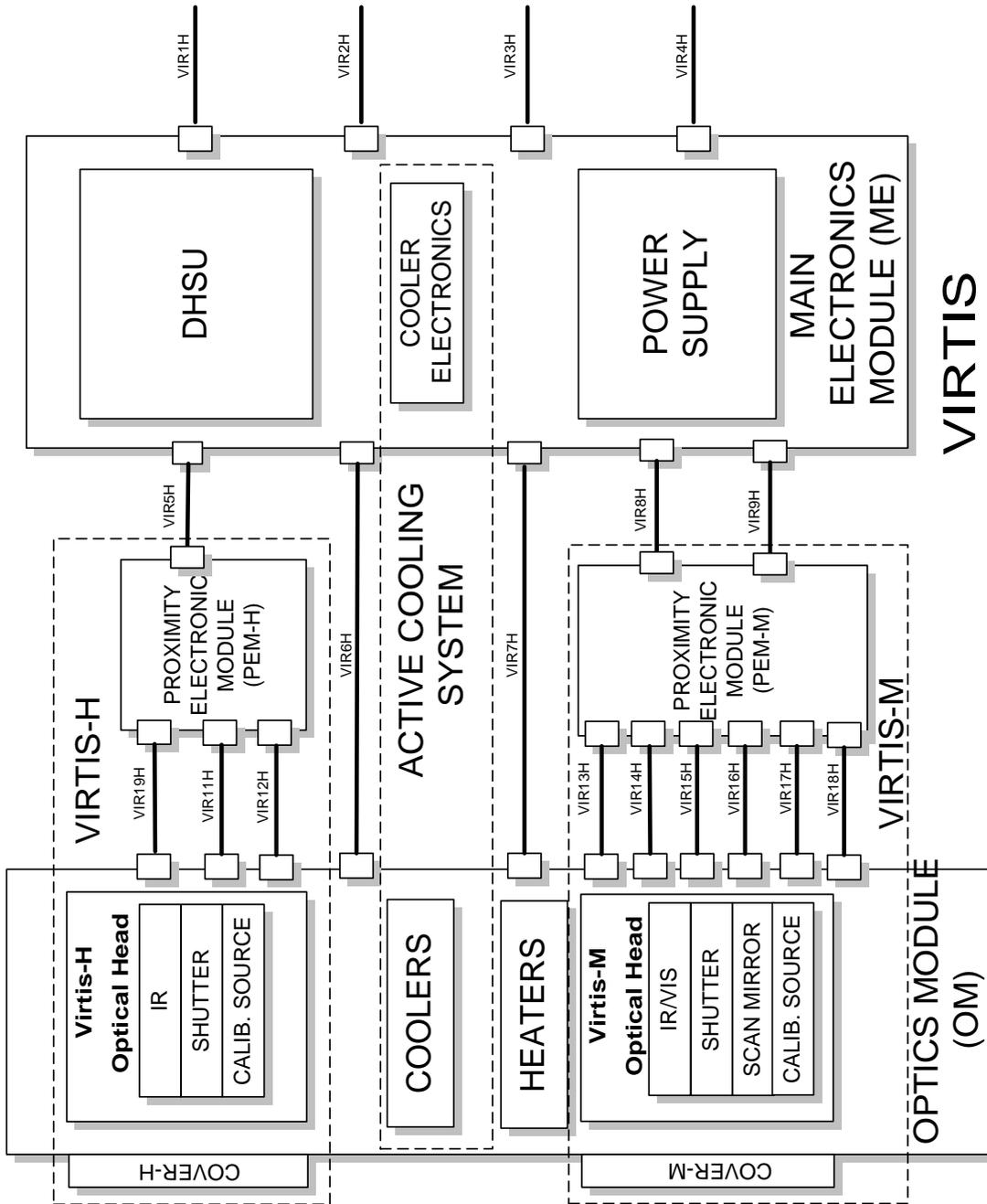
Figure 1.1 VIRTIS Functional Block Diagram

VIRTIS-M Optical Head

Radiators support stubs

VIRTIS-H Optical Head

MLI cover

Optical Heads supporting ledge

Figure 1.2:   VIRTIS Optics Module

Cryo-cooler

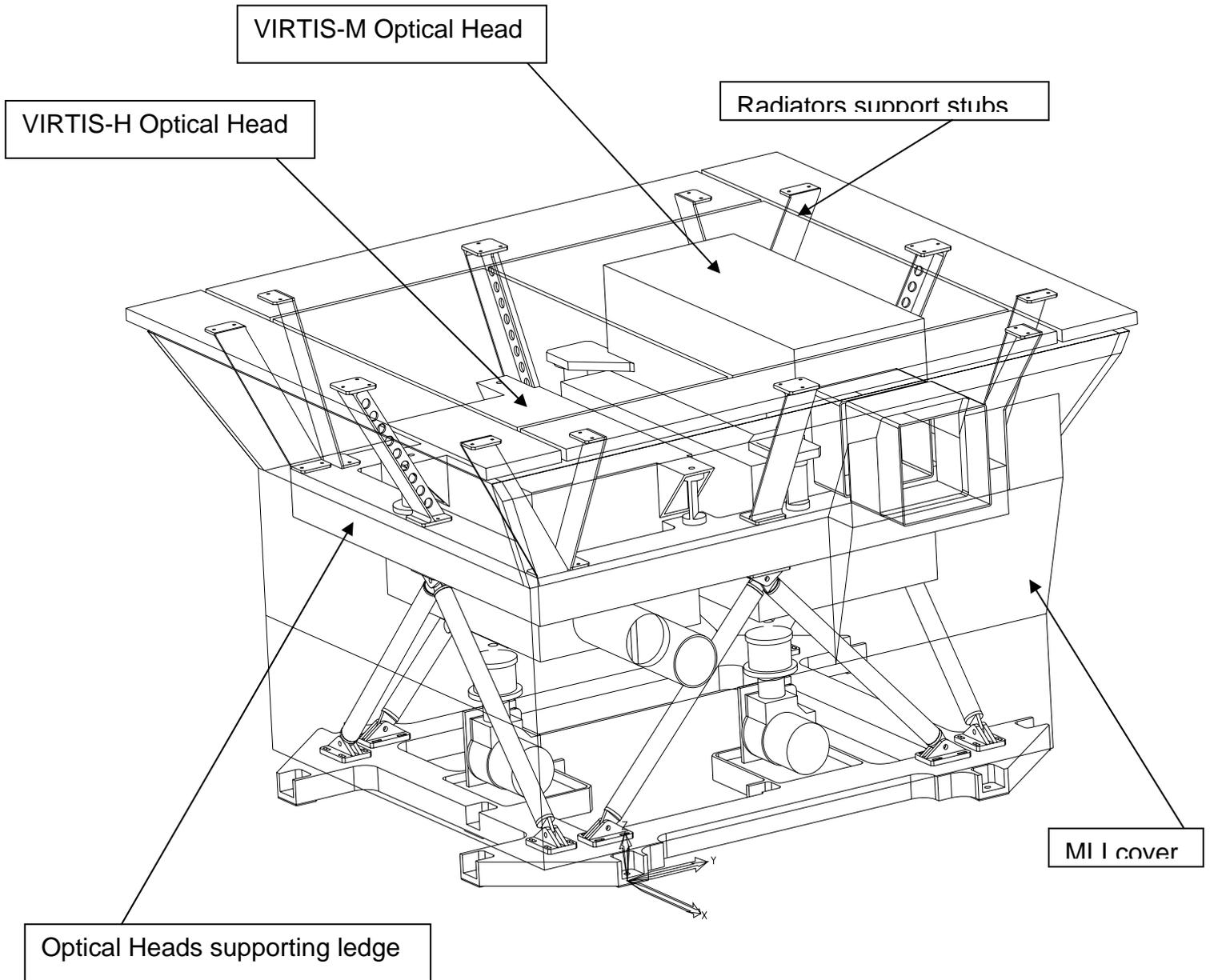Optical Heads supporting ledge

Titanium Rod

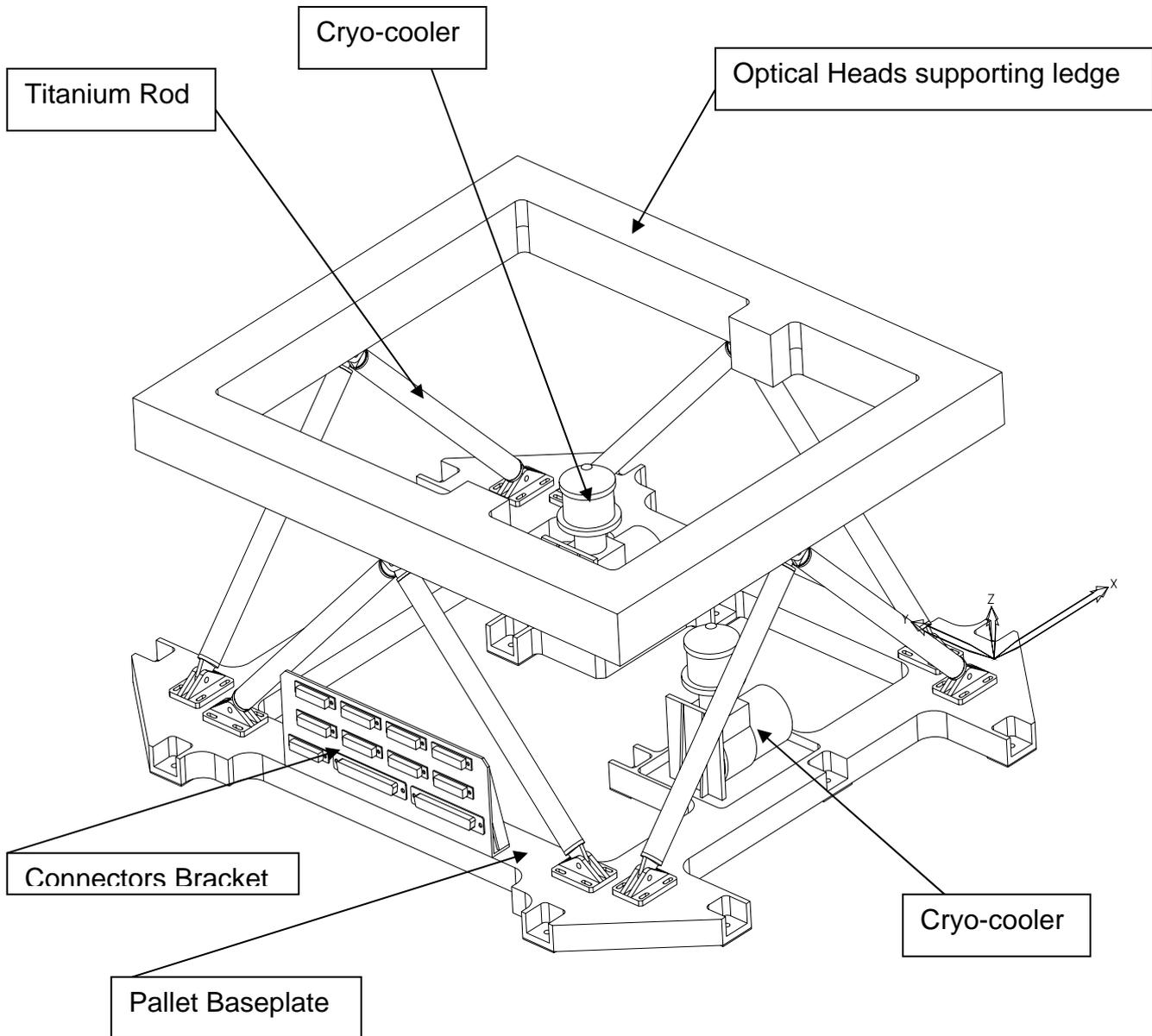Connectors Bracket

Cryo-cooler

Pallet Baseplate

Figure 1.3:   VIRTIS Frame showing : a) the baseplate pallet with the two cryocoolers and the connector bracket; b) the 8 titanium rods used to fix the Cold Box mounting Ledge on the baseplate; c) the empty ledge to which the two Optical Heads are rigidly connected.

2   Experiment Configuration

2.1   Physical I/F

The VIRTIS mechanical interfaces drawing (MICD) for the Proto Flight Model (PFM) are given in attachment 1.
To improve the mechanical description of the instrument in attachment 1 are also given the top level assembly drawings describing the various experiment modules.

2.2 Electrical I/F

2.2.1 Power Interface Circuit

The primary power (+28 V) will be received from the S/C power bus via a main and redundant interface. This voltage supplies the VIRTIS main components (ME, VIRTIS-M, VIRTIS-H) using the architecture shown in Figure 2.1
The main and redundant input lines are directly connected to the Main/Redundant DHSU converter without cross-coupling. In accordance with the VIRTIS reliability approach, only the power converter for the DHSU is redundant, while non redundant power converters are used to provide power to both optical modules (-H and -M subassemblies) and Cooler Control Electronics (CCE).
VIRTIS is switched on by applying a voltage higher than 25V to the main/redundant bus.
The DC/DC converters frequency is 131 KHz ± 5%.
In addition to the primary power interface 2 heaters are requested;
- Two for the Decontamination Heaters located in proximity of each optical Head (VIRTIS-H and VIRTIS-M) for optics decontamination and/or de-icing of radiators and covers (TBC). Two different heater circuits are implemented and are directly connected to LCL switches located in the S/C PCU, that will be ON simultaneously. **For design reasons one of the heaters is located on the main power bus line and the other on the redundant one, but they shall be on at the same time**.
- Two for the CCD non-ops heater which shall be used to control the CCD temperature during the hybernation phases.

The required power interfaces for VIRTIS are shown in table 2.1

Function	Main Lines	Redundant Lines	LCL Class
+ 28V Main Bus	1	1	F
+ 28V Decontamination Heater Line(1)	1	1	D
+28V CCD non-ops heater line (1)	1	1	A
Keep-Alive Supply	N/A	N/A	N/A

(1) The two decontamination heaters are located on the main and redundant lines but is intended that they must be on at the same time to achieve the required heat input to perform their required function.

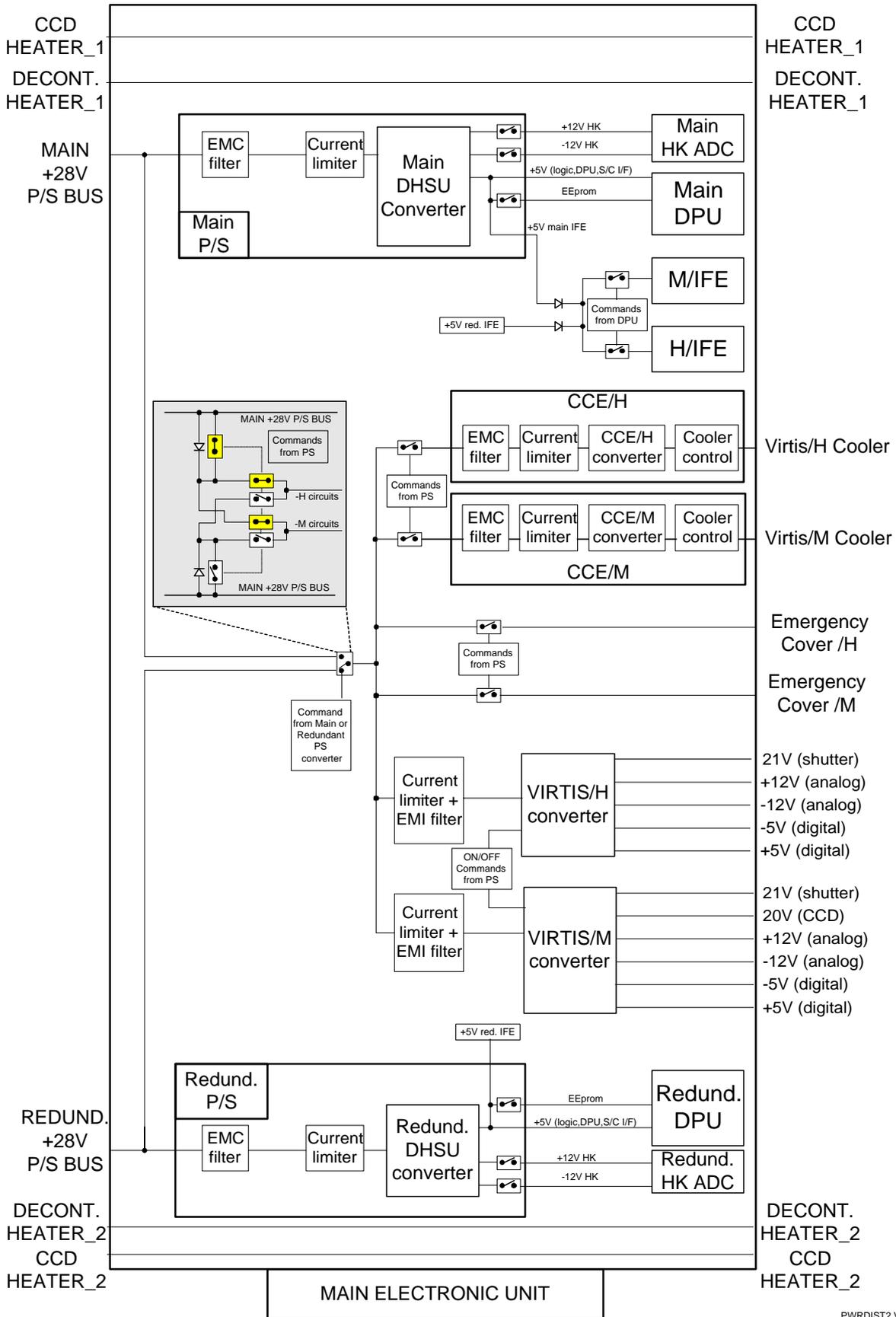Table 2.1 Power Supply Interface Requirements

Figure 2.1 Power switching and Distribution block diagram.

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The internal power distribution shown in figure 2.1 contains 6 DC/DC converters with their own current limiters and EMI filters:

- ❖ Main and Redundant DHSU. Generate the ME internal voltages in cold redundancy. These converters are switched on exclusively by the S/C power I/F
- ❖ VIRTIS-M and VIRTIS-H converters. Generate all voltages for VIRTIS-M and VIRTIS-H subsystems
- ❖ CCE-H and CCE-M converters. Generate all voltages for cooler control circuit voltages.

DHSU and VIRTIS-M/H converters are located in the PS unit while the CCE-M and CCE-H are located in two independent Cooler Control Boards (one for H one for M).

All converters can be on at the same time, however at power on (from the S/C) only the DHSU (Main or Redundant) shall be active. All others converters shall be powered by DHSU, via power switches controlled by the DHSU on the primary voltage side.

The characteristics of the power line is summarised in table 2.2

POWER LINE CHARACTERISTICS	
Maximum Average Input current (@28V)	
Nominal Operations	2.35 A
Occasional Decontamination	2.8 A
Inrush Characteristics	
Peak Current @28V for t < 8 ms measured on the EQM	5.8 A
Current for 8 ms < t < 65 ms measured on the EQM	4 A
Isolation	
Primary power from structure	> 1 MΩ
Primary from secondary power	> 1 MΩ
EMI Characteristics	Power converters are internally synchronised at 131 kHz +/- 5 %

Table 2.2 Operational Power Interface Characteristics

2.2.2 Pyrotechnic Interface Circuits
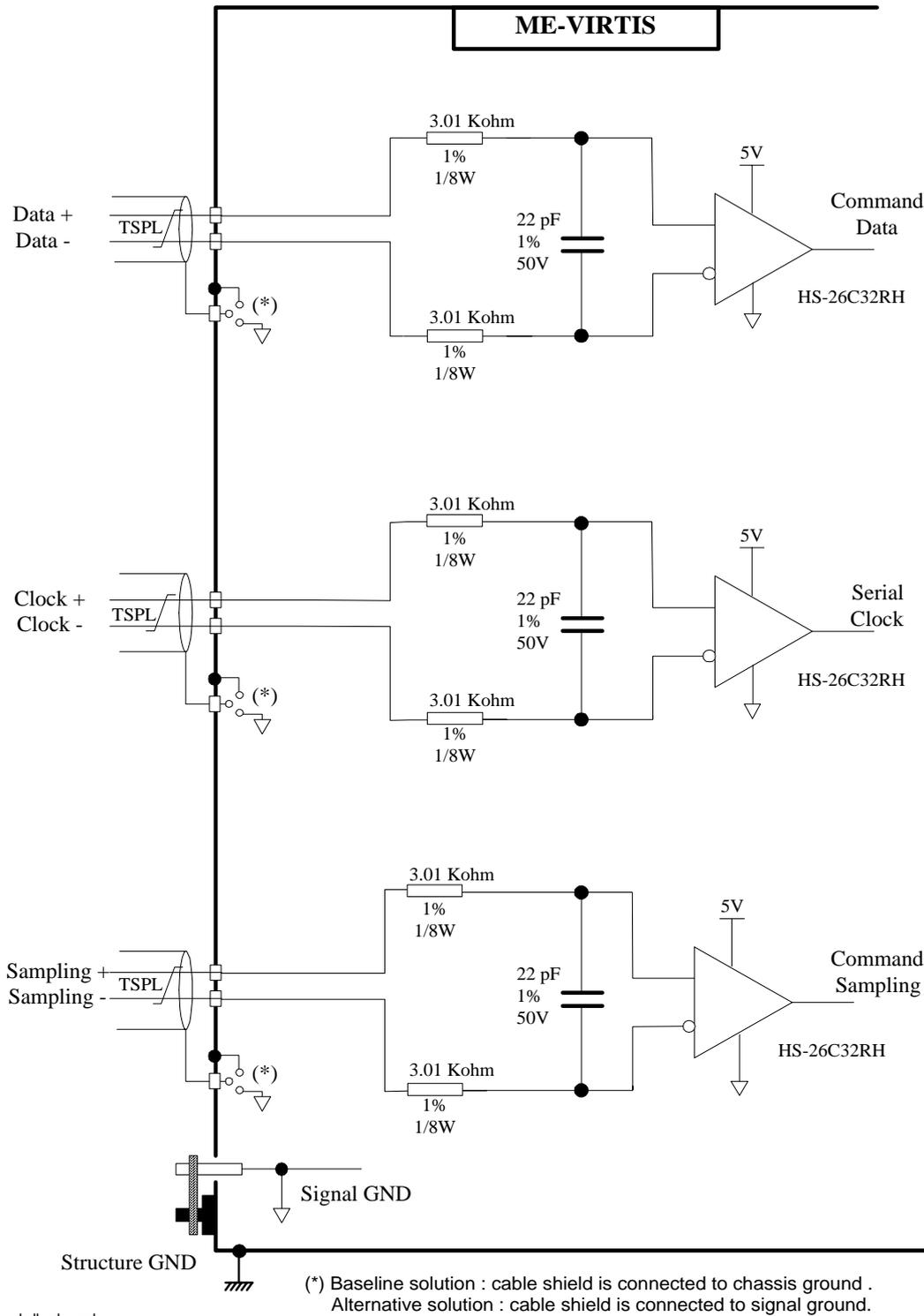
VIRTIS does not uses pyrotechnic devices.

2.2.3 OBDH Interface Circuits

The communication interfaces with the S/C are reported in table 2.3 along with their type and functions. All interfaces are connected to the Remote Terminal Unit of the S/C (RTU) , while the High Speed Data are directly delivered through a special link to the SSMM.

INTERFACE	SIGNAL TYPE OR FUNCTION	MAIN	REDUNDANT
Telecommand Channels	Memory Load Commands	1	1
	High Power ON/OFF Commands	0	0
Telemetry Channels	16bit serial digital channel	1	1
	High Speed telemetry channel	1	1
Monitor Channels	S/C powered thermistors	2	2
	Bi-level channels	0	0
	Analogue channels	0	0
Timing Channels	High frequency clock	1	1
	Broadcast pulse	1	1

Table 2.3 Experiment OBDH Interface Channels/Functions

In the following figures (from 2.2 through 2.10) and tables (from 2.4 through 2.8) are reported the interface circuits for Memory Load Commands (MLC), Serial 16 bit Digital Telemetry (SDT), High Speed Link (HRD), DMS Timing & Synchro Signal (OTS) and for the Conditioned Analog T/M (ANC).

ME-VIRTIS

Data +
Data -
TSPL

3.01 Kohm
1%
1/8W

22 pF
1%
50V

3.01 Kohm
1%
1/8W

5V

Command
Data

HS-26C32RH

(*)

Clock +
Clock -
TSPL

3.01 Kohm
1%
1/8W

22 pF
1%
50V

3.01 Kohm
1%
1/8W

5V

Serial
Clock

HS-26C32RH

(*)

Sampling +
Sampling -
TSPL

3.01 Kohm
1%
1/8W

22 pF
1%
50V

3.01 Kohm
1%
1/8W

5V

Command
Sampling

HS-26C32RH

(*)

Signal GND

Structure GND

(*) Baseline solution : cable shield is connected to chassis ground .
Alternative solution : cable shield is connected to signal ground.

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Figure 2.2 MLC (Memory Load Command) interface circuit
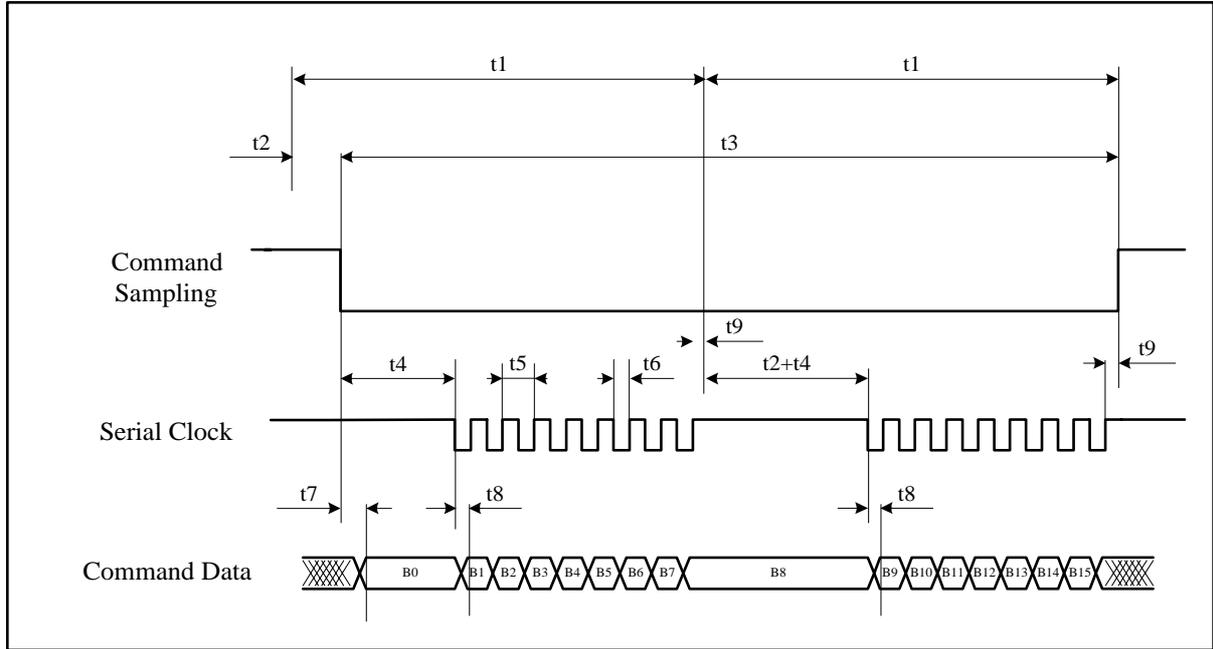
Acquisition rate		131 Kbps
t1		61.0us
t2		3.8us+1.5us/-1.0us
t3		118.3us+1.0us/-1.5us
t4		26.7us+1.0us/-1.5us
t5		3.8us
t6		1.9us+/-0.5us
t7		</= 3.8us
t8		1.4us+.5us/-0.6us
t9		>/= 1.4us
Sample	tr	< 700ns
	tf	< 700ns
Serial Clock	tr	< 700ns
	tf	< 700ns
Command Data	tr	< 700ns
	tf	< 700ns

Serial Clock / High Frequency Clock relationship
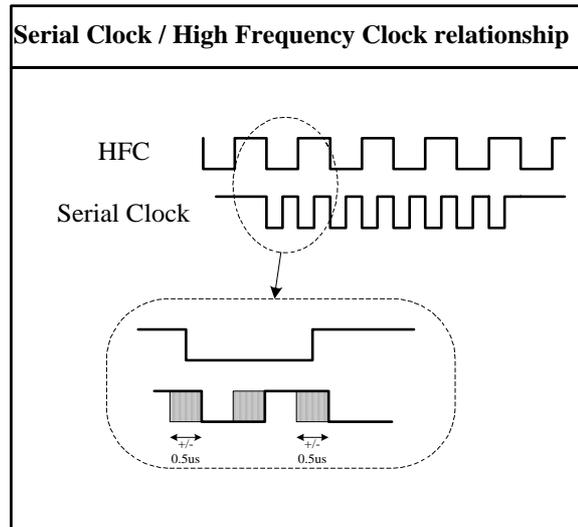
Figure 2.3 MLC (Memory Load Command) timing characteristics

I/F Designation	**Memory Load Command (MLC)**	**1 of 1**
The interfaces comprises the following three circuits :		
• MLD - memory load command data receiver		
• STC - serial data transfer clock receiver		
• MLS - memory load command sampling receiver		
Receiver Specification		
Circuit Type	differential receiver , CMOS compatible	
Transfer	DC coupled	
Differential Input Voltage $(-1V \geq V_{cm} \leq +1V)$	Low : <= -1V (bit logic value 0) High : <=+1V (bit logic value 1)	(1)
Quiescent state	MLD true line = Low level (0V)	(2)
	STC true line = High level (5V)	(2)
	MLS true line = High level (5V)	(2)
Hysteresis	N/A	
Common Mode Isolation	In accordance with par. 2.9.2.1.3 of AD1	
Diff. Input Impedance	>= 10 KΩ	(3)
Noise Rejection	In accordance with par. 2.9.4.2.4 of AD1	
Maximum Fault Voltage	Tolerance : −0.5V to +7V	(4)
	Emission : -0.0V to 5.5 V	(5)
Operating frequency	262 KHz (burst)	
Harness Specification		
Wiring Type	Twisted Shielded Pair - Low Capacitance	
Core to Core Cap.	< 700 pF	
Core to Shield Cap.	< 1 nF	
Shield Connection	connected to chassis ground	
Notes		
(1) At experiment connector level. (2) Outside of the memory load data transfer. (3) Considering minimum input resistance of HS-26C32RH = 4 Kohm (-7V < VCM < +7V) (4) With input current limited to 1.5mA (5) Digital supply voltage designed to be below 7.0V in case of fault.		

Table 2.4 MLC (Memory Load Command) interface characteristics
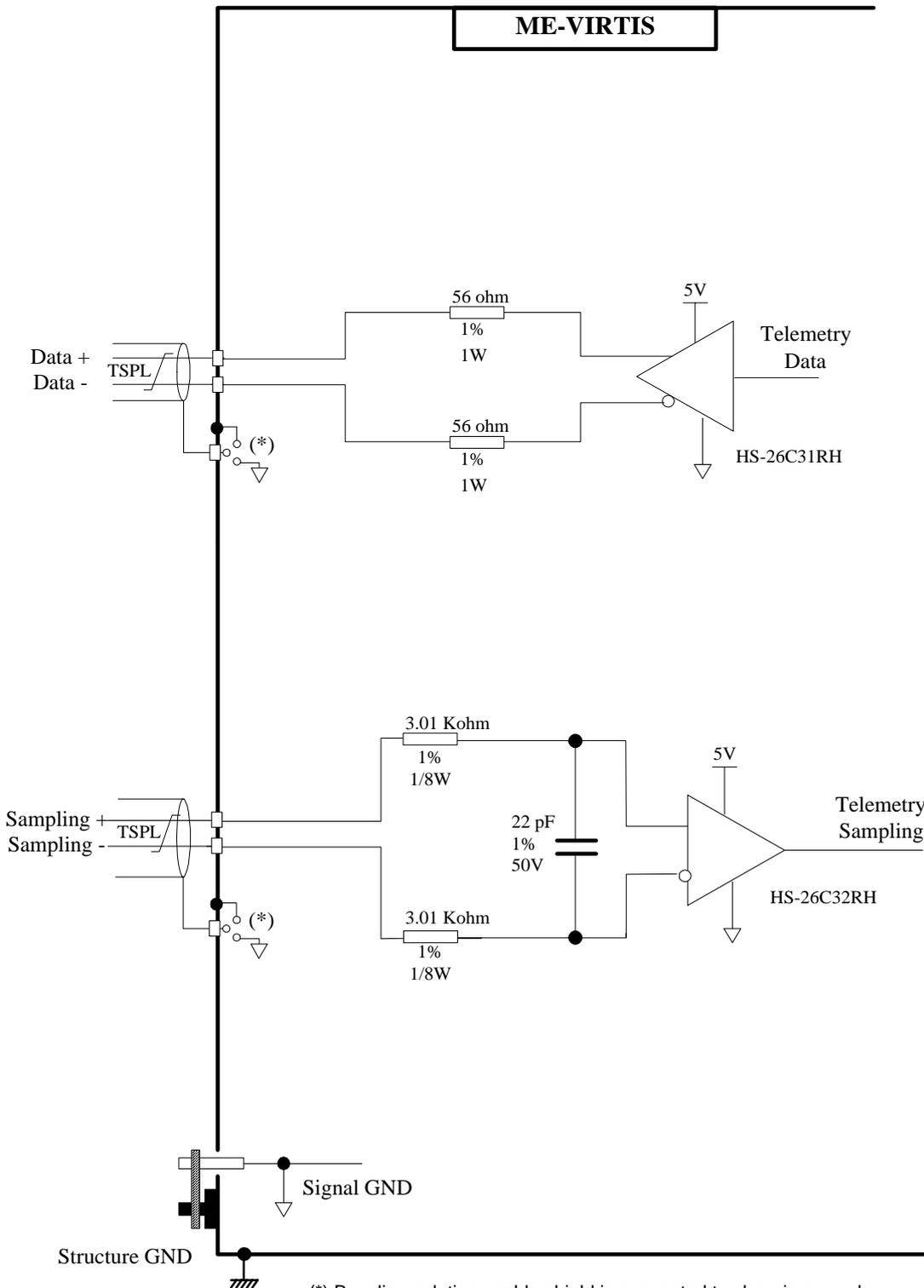
obdhsdt.vsd
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(*) Baseline solution : cable shield is connected to chassis ground .
Alternative solution : cable shield is connected to signal ground.

Figure 2.4 16Bit Serial Digital Telemetry (SDT) interface circuit

Acquisition rate		131 Kbps
t1		61.0us
t2		3.8us+/-1us
t3		118.3us+/-1us
t4		26.7us+/-1us
t5		3.8us
t6		1.9us+/-0.5us
t7		$</=$ 15.3us
t8		$</=$ 1.1us
t9		$>/=$ 1.4us
Sample	tr	< 700ns
	tf	< 700ns
Serial Clock	tr	< 700ns
	tf	< 700ns
Command Data	tr	< 700ns
	tf	< 700ns

Serial Clock / High Frequency Clock relationship

HFC

Serial Clock

+/- 0.5us   +/- 0.5us
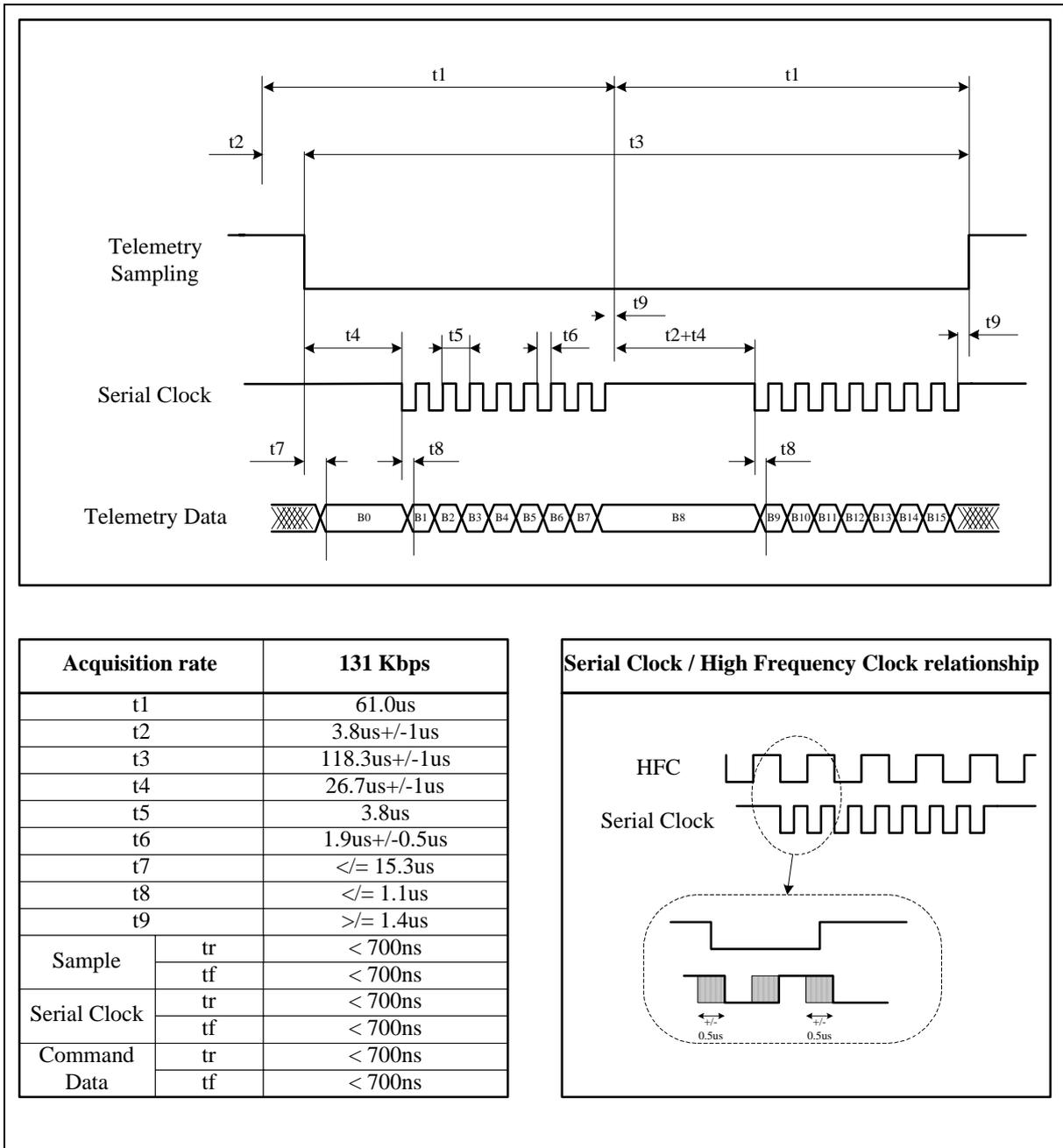
Figure 2.5 16Bit Serial Digital Telemetry (SDT) timing

I/F Designation	**Serial 16 Bit Digital TeleMetry (SDT)**	**1 of 2**
The interfaces comprises the following three circuits : • SDD - serial 16 bit digital TeleMetry data transmitter • STC - serial data transfer clock receiver • SDS - serial 16 bit digital TeleMetry sampling receiver		
Source Specification		
Circuit Type	balanced CMOS driver	
Transfer	DC coupled	
Zero Reference	signal ground	
Coding	NRZ-L	
Bit Rate	262 Kbps (burst)	
Low level output voltage	$0\ V \leq V_{OL} \leq 0.5\ V$	(1)
High level output voltage	$2.5\ V \leq V_{OL} \leq 5.5\ V$	(1)
Differential output Voltage	Low (bit logic value 0) : $-5.5V <= V_{OD} <= -2.0\ V$ High (bit logic value 1) : $2.0\ V <= V_{OD} <= 5.5\ V$	
Rise and Fall Times	$tr < 400ns$ $tf < 400ns$	(3)
Spurious noise	In accordance with character 2.9.4.1.6 of AD1	
Current Drive and Sink Capability	Sufficient to drive 1.2nF within fall/rise time below 400nsec. , and resistor limited.	
Short Circuit Current	90 mA	(2)
Max fault Voltage	Tolerance : −0.5V to +7.0V	9
	Emission : −0.0V to 5.5V	(5)
Quiescent state	SDD true line = High level	(6)
Receiver Specification		
Circuit Type	differential receiver , CMOS compatible	
Transfer	DC coupled	
Differential Input Voltage $(-1V \geq V_{cm} \leq +1V)$	Low : $<= -1V$ (bit logic value 0) High : $<= +1V$ (bit logic value 1)	(7)
Quiescent state	STC true line = High level (5V)	(6)
	SDS true line = High level (5V)	(6)
Hysteresis	N/A	
Common Mode Isolation	In accordance with par. 2.9.2.1.3 of AD1	
Diff. Input Impedance	>= 10 Kohm	(8)
Noise Rejection	In accordance with character 2.9.4.2.4 of AD1	
Maximum Fault Voltage	Tolerance : −0.5V to +7V	(4)
	Emission : −0.0V to 5.5V	(5)
Operative frequency	262 Khz (Typ.)	

I/F Designation	**Serial 16 Bit Digital TeleMetry (SDT)**	**2 of 2**
Harness Specification		
Wiring Type	Twisted Shielded Pair - Low Capacitance	
Core to Core Cap.	< 700 pF	
Core to Shield Cap.	< 1 nF	
Shield Connection	Connected to chassis ground	
Notes		
(1) true and comp line with ref. to signal ground. (2) Short circuit to ground (3) when loaded with differential 1.2 nF (4) with input current limited to 1.5mA (5) Digital supply voltage designed to be below 7.0V in case of fault. (6) Outside of the load data transfer. (7) At experiment connector level. (8) Considering minimum input resistance of HS-26C32RH = 4 Kohm (-7V < VCM < +7V) (9) with power off, 0.5V to 5.5V with power on.		

Table 2.5 16Bit Serial Digital Telemetry (SDT) interface characteristics
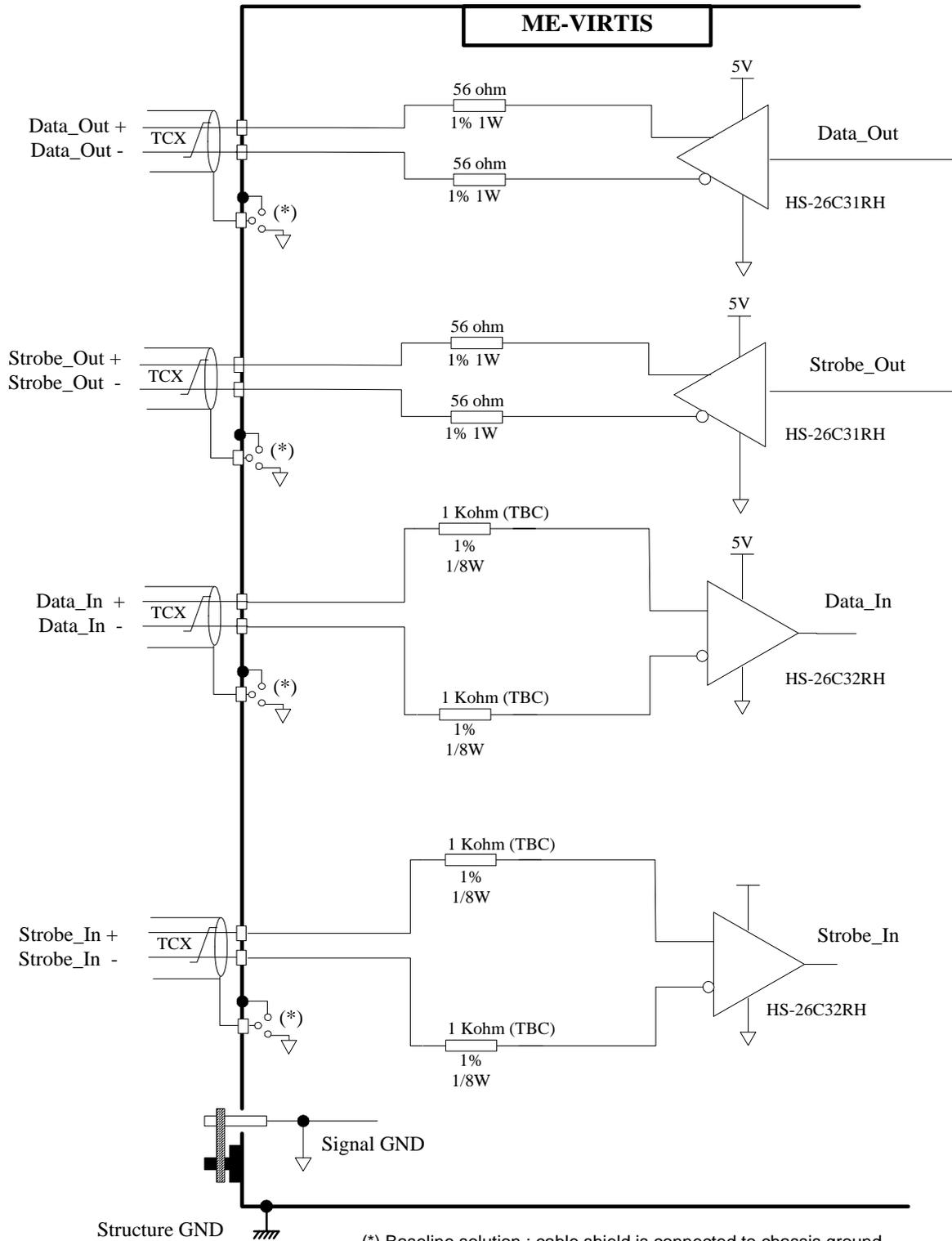
ME-VIRTIS

Data_Out +
Data_Out -   TCX

56 ohm
1% 1W

56 ohm
1% 1W

5V

Data_Out

HS-26C31RH

(*)

Strobe_Out +
Strobe_Out -   TCX

56 ohm
1% 1W

56 ohm
1% 1W

5V

Strobe_Out

HS-26C31RH

(*)

Data_In +
Data_In -   TCX

1 Kohm (TBC)
1%
1/8W

1 Kohm (TBC)
1%
1/8W

5V

Data_In

HS-26C32RH

(*)

Strobe_In +
Strobe_In -   TCX

1 Kohm (TBC)
1%
1/8W

1 Kohm (TBC)
1%
1/8W

Strobe_In

HS-26C32RH

(*)

Signal GND

Structure GND

(*) Baseline solution : cable shield is connected to chassis ground .
    Alternative solution : cable shield is connected to signal ground.

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Figure 2.6 High Rate Data (HRD) link interface circuit

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| 0 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | Digital Data |

DS Data

DS Strobe

DS Data -

1.5V

DS Data +

DS Strobe -

1.5V

DS Strobe +

t1	< 10ns
t2	> 20ns
tr	< 20ns
tf	< 20ns

t1= 2xtdso
tdso= output skew data/strobe at receiver side
t2= tdsi= minimun separation between consecutive edges on
the Data and Strobe inputs
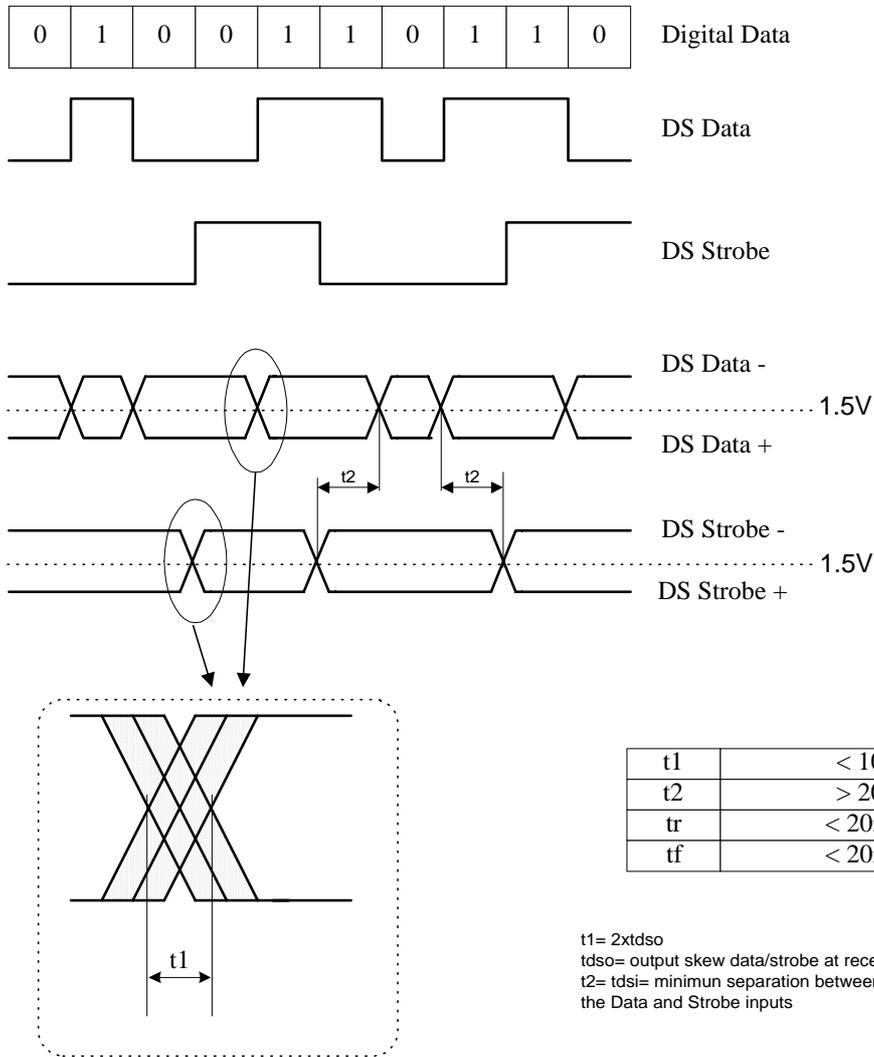
Figure 2.7 High Rate Data (HRD) Timing

I/F Designation	**High Rate Data Link (HRD)**	**1 of 2**
The interfaces comprises the following four circuits :		
• HDO - DS_Data_Out transmitter		
• HSO - DS_Strobe_Out transmitter		
• HDI - DS_Data_In receiver		
• HSI - DS_Strobe_In receiver		
Source Specification		
Circuit Type	balanced CMOS driver	
Transfer	DC coupled	
Zero Reference	signal ground	
Coding	TBD	
Bit Rate	<= 10 Mbps , nominal 5 Mbps	
Low level output voltage	$0\ V <= V_{OL} <= 0.55\ V$	(1)
High level output voltage	$2.45\ V <= V_{OH} <= 5.45\ V$	(1)
Differential output Voltage	Low (bit logic value 0) : $-5.45\ V <= V_{OD} <= -1.9V$ High (bit logic value 1) : $1.9\ V<= V_{OD} <= 5.45\ V$	
Rise and Fall Times	$tr < 40\ ns$ $tf < 40\ ns$	(2)
Output to Output Skew	$toos <= \pm20ns$ (TBC)	(2) (3)
Spurious noise	In accordance with character 2.9.4.1.6 of AD1	
Current Drive and Sink Capability	Sufficient to drive 125 ohms TCX cable with the required rise/fall times.	
Short Circuit Current	<90 mA	(10)
Max fault Voltage	Tolerance : +0.5V to +7V	(11)
	Emission : -0.5 V to 7V	(5)
Quiescent state	High impedance	(6)

I/F Designation	**High Rate Data Link (HRD)**	**2 of 2**
Receiver Specification		
Circuit Type	differential receiver , CMOS compatible	
Transfer	DC coupled	
Differential Input Voltage	Low : <= -0.6V (bit logic value 0) (TBC) High : <=+0.6V (bit logic value 1) (TBC)	(7)
Hysteresis	N/A	
Common Mode Isolation	In accordance with par. 2.9.2.1.3 of AD1	
Diff. Input Impedance	>= 5 Kohm	(8)
Noise Rejection	In accordance with character 2.9.4.2.4 of AD1	
Maximum Fault Voltage	Tolerance : +0.5V to +7V	(4)
	Emission : 0V to +5.5V	(5)
Harness Specification		
Wiring Type	125 Ohm TwinAx (TCX)	(9)
Shield Connection	External harness : connected to chassis ground	
Notes		
(1) true and comp line with ref. to signal ground at output current of 1mA. (2) at receiver input when loaded with cable of TBD length (3) difference in propagation delay time between complementary outputs at 50% point (4) With input current limited to 1.5mA (5) Digital supply voltage designed to be below 7.0V in case of fault . (6) Outside of the data transfer. (7) At experiment connector level. (8) Considering minimum input resistance of HS-26C32RH = 4 Kohm (-7V < VCM < +7V) (9) Cable to be used : GORE GSC 6509 , Rev. 6 or space qualified equivalent. (10) Short circuit to ground (11) With power off; -0.5V to +5.5V with power on		

Table 2.6 High Rate Data (HRD) Interface characteristics
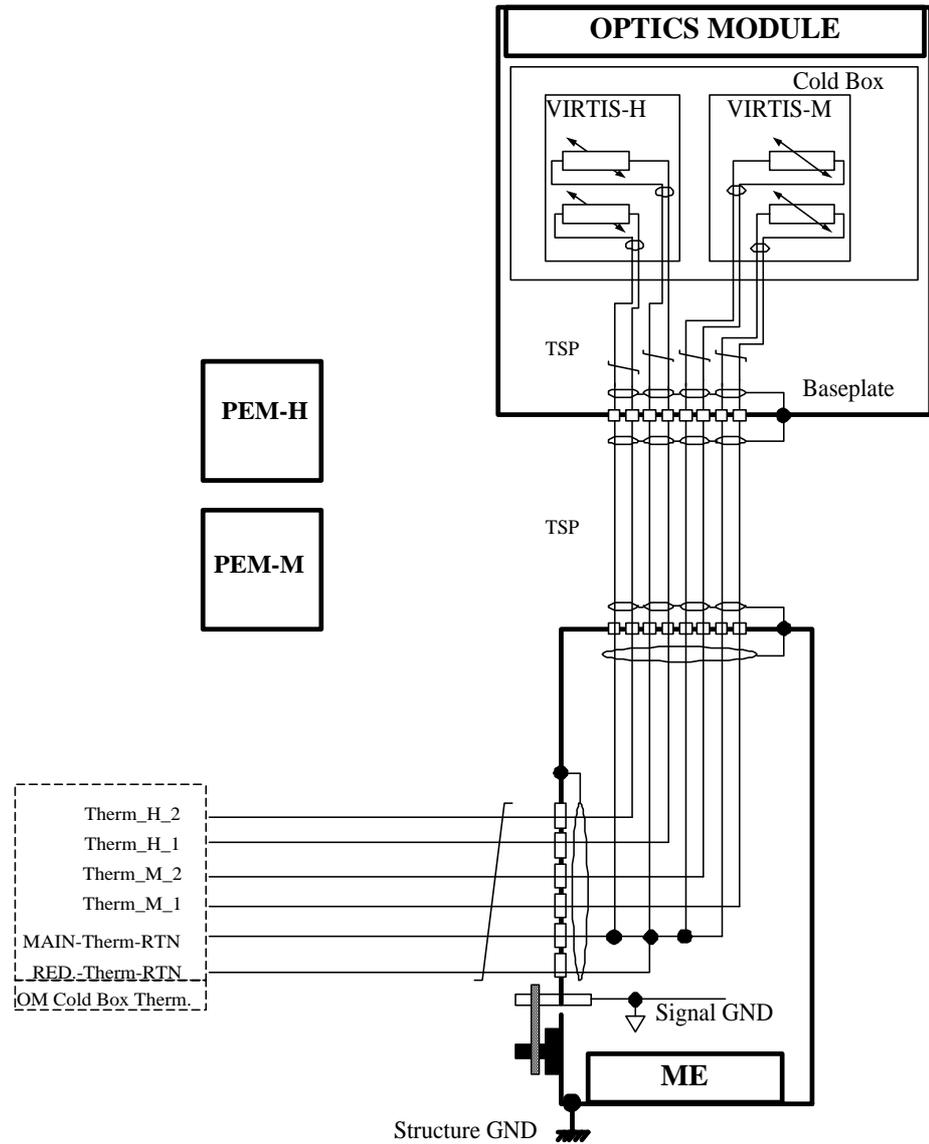
Figure 2.8 Conditioned Analogue Telemetry (ANC) interface circuit

I/F Designation	**Conditioned Analogue T/M (ANC)**	**1 of 1**
The interface comprises the following circuit : • OM Cold Box thermistors		
Source Specification		
Circuit Type	Thermistor	
Transfer	DC coupled	
Thermistor Type	Rosemount 118MF 2000 Ohm	
Operating temperature Range	from 100 K to 360 K	
Isolation	to signal ground : >1Mohm to chassis ground : >1 Mohm isolated load	
Max fault Voltage	Tolerance : N/A	
	Emission : N/A	
Harness Specification		
Wiring Type	Twisted 6 tuple(T6)	(1)
Notes		
(1) Minimum of 2 common returns for channel.		

Table 2.7 Conditioned Analogue Telemetry (ANC) interface characteristics

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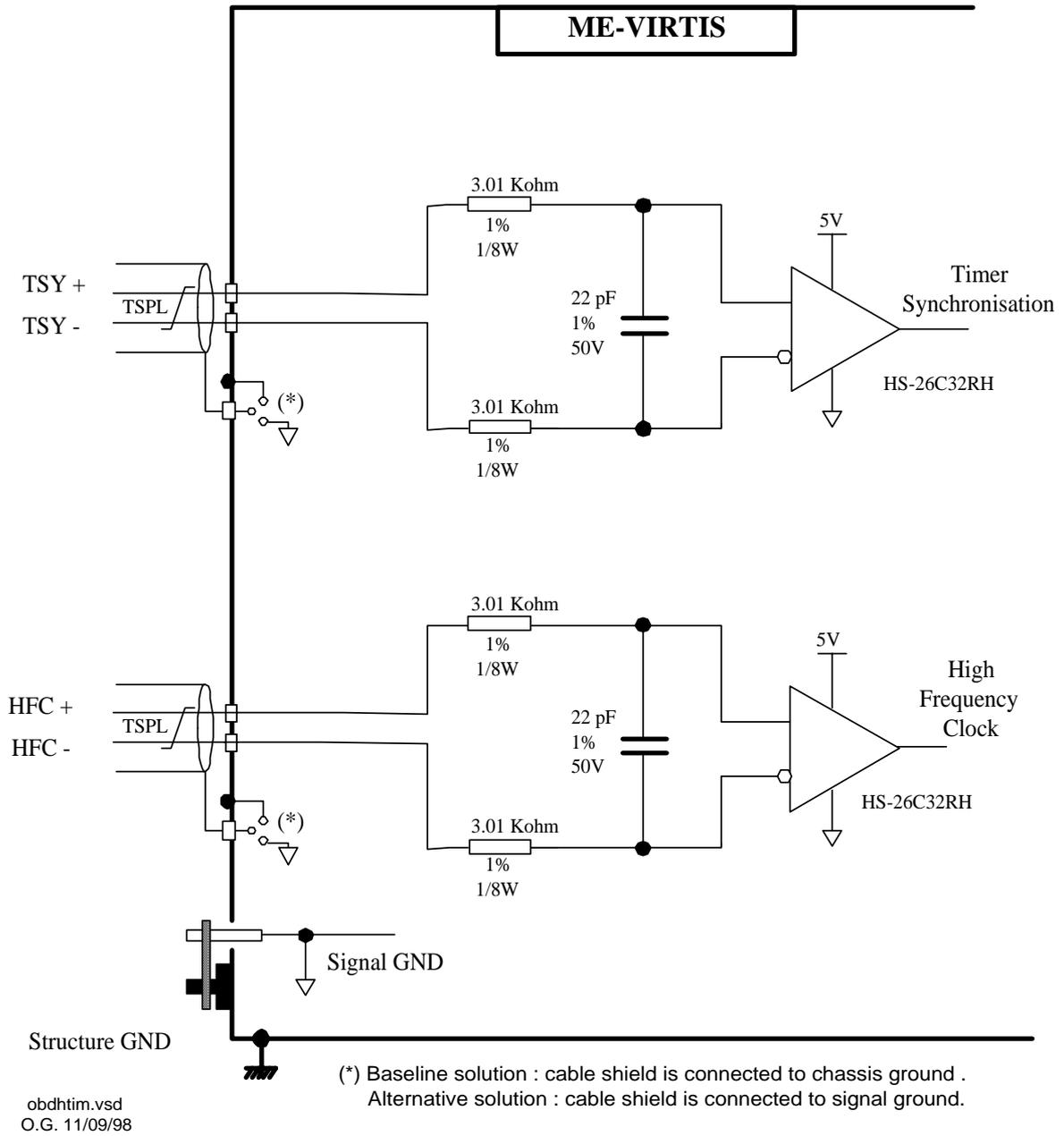# Rosetta Virtis

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ME-VIRTIS

TSY +
TSY -
TSPL
3.01 Kohm 1% 1/8W
22 pF 1% 50V
3.01 Kohm 1% 1/8W
5V
Timer Synchronisation
HS-26C32RH
(*)

HFC +
HFC -
TSPL
3.01 Kohm 1% 1/8W
22 pF 1% 50V
3.01 Kohm 1% 1/8W
5V
High Frequency Clock
HS-26C32RH
(*)

Signal GND

Structure GND

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(*) Baseline solution : cable shield is connected to chassis ground .
    Alternative solution : cable shield is connected to signal ground.

Figure 2.9 DMS timing & synchronisation signal (OTS) interface circuit

High Frequency Clock

Serial Data Transfer Clock

t1	7.63us
t2	3.81us +/-10%
tr	< 700ns
tf	< 700ns

Time Packet via MLC
(VIRTIS switch ON and
after request)

Timer Synchronisation Pulse

t1	3.8 - 62us (TBC)
t2	8 sec. (TBC)
t3	< 2us
tr	< 700ns
tf	< 700ns
t4	6 sec. (TBC)
t5	0.5 sec. (TBC)

t1 = TSY pulse width

t2 = TSY repetition rate

t3 = TSY jitter

t4 = Margin for TC packet generation

t5 = Margin for TC packet decoding . Experiment decoding and
arming of timeset

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Figure 2.10 DMS timing & synchronisation signal (OTS) timing

I/F Designation	**DMS Timing & Sync. Signals (OTS)**	**1 of 1**
The interface comprises the following Two circuits : • HFC - High Frequency Clock receiver • TSY - Timer Synchronization Pulse receiver		
Receiver Specification		
Circuit Type	differential receiver , CMOS compatible	
Transfer	DC coupled	
Differential Input Voltage $(-1V \geq V_{cm} \leq +1V)$	Low : <= -1V (bit logic value 0) High : <=+1V (bit logic value 1)	(1)
Hysteresis	N/A	
Common Mode Isolation	In accordance with par. 2.9.2.1.3 of AD1	
Diff. Input Impedance	>= 10 Kohm	(2)
Noise Rejection	In accordance with character 2.9.4.2.4 of AD1	
Maximum Fault Voltage	Tolerance : –0.5V to +7V	(3)
	Emission : 0V to +5.5V	(4)
Harness Specification		
Wiring Type	Twisted Shielded Pair - Low Capacitance	
Core to Core Cap.	< 700 pF	
Core to Shield Cap.	< 1 nF	
Shield Connection	Connected to chassis ground	
Notes		
(1) At experiment connector level. (2) Considering minimum input resistance of HS-26C32RH = 4 Kohm (-7V < VCM < +7V) (3) With Input current limited to 1.5mA (4) Digital supply voltage designed to be below 7.0V in case of fault.		

Table 2.8 DMS timing & synchronisation signal (OTS) interface characteristics

2.3   Software

In the following is given a general description of VIRTIS S/W. Full details on the mode definitions, mode transitions, TC/TM detailed description is given in chapters 3 and 4 and in attachments 2 and 3.

2.3.1   Software Functions.

The main purposes of the VIRTIS software are the control of the VIRTIS instrument, specifically of the two VIRTIS sub-systems (VIRTIS-H and VIRTIS-M) and the handling of the scientific data.
From the Software design point of view, the software is divided in two parts (i.e. two separate executables), the PROM software and the EEPROM software. The PROM software (also called Primary Boot software) is active after VIRTIS ME power-on. The EEPROM software (also called Secondary Boot software) is started by a special TC, given in Safe mode (i.e. VTC_Enter_Idle_Mode).

Generally the PROM and EEPROM software have the following tasks (FM level):
♦ Managing the start-up procedure after power-on
♦ Verification and check of telecommands (TC) and packing of telemetry ™
♦ Initiating and overall control of the instrument modes
♦ Health checking, diagnostics and error handling including watch-dog control
♦ Management/storage/maintenance of default system parameter configuration and system status
♦ Initialising and command of the –M and –H sub-system
♦ Control of Visible and IR detector units, calibration sources, shutters, annealing heaters
♦ Movement and status control of covers by controlling the stepper motor and Emergency Cover Actuators (ECA)
♦ Commanding and mode control of active cooling sub-systems
♦ Request, acquisition and verification of science data and housekeeping
♦ Calculation and management of pixel map –or -H selective pixel read-out
♦ Performing and managing of operational science and control sequences

2.3.1.1 Specific PROM / Primary Boot Software Functions

The PROM software provides low level functionality and is the 'BIOS' of VIRTIS with the following functions:
♦ Initialization of the ME DPU and ME Power Supply (PS) after power-on
♦ Power-up, reset management and SCET synchronization
♦ Entering the Safe mode (default for VIRTIS operation) or Development mode (only for EEPROM S/W development purposes)
♦ Collection and providing Default HK TM
♦ Low level TC receipt (via MLC interface), verification, acceptance and execution
♦ TM packing, buffering and transfer to S/C via SDT interface
♦ ME DPU Memory Management including upload, dump and check of memory (i.e. RAM, EEPROM and PORTs) performed by separate TCs via MLC interface

- Boot and start of Secondary Boot software in RAM by IEEE-1355 interface (Boot loader provided by ASTRIUM)
- Maintenance of up to 8 different secondary boot executables in EEPROM
- Health check and error/event handling incl. failure override function
- Test display control for displaying Safe mode status and HK information

Note: In Safe mode (i.e. with PROM software) it is never possible for the user to have access to the –M and –H sub-system. Only the memory upload/dump to/from memory ports allows (i.e. very low level) to have access on all H/W interfaces, also to –M and –H.

2.3.1.2 Specific EEPROM / Secondary Boot Software Functions

The EEPROM software provides partially the same functionality as the PROM software and additionally all VIRTIS-M and -H control functions. These are:
- Initialization of the ME M- and/or H-Interface Electronics as well as the –M and –H sub-system after power-on
- Low level and high level TC verification, acceptance and execution
- TM packing, buffering and transfer to S/C
- SCET re-synchronization
- Collection and providing of VIRTIS Default, General and PEM science HK
- Interfacing the M-PEM, H-PEM, coolers and ECAs
- Control and monitoring of –M and –H control, calibration and science sequences
- Entering the ME IDLE mode, instrument control modes and Science modes
- Science data acquisition, TM packing and transfer to the S/C via IEEE-1355 HS link or via SDT interface
- -M and –H science data handling, processing and compression
- Health check and error/event handling incl. failure override function of several error categories
- Test display control for displaying instrument status and HK information

2.3.2 Software Design

The PROM software is hard coded in the Main Electronics/DPU and the EEPROM software is stored in EEPROM and is changeable by memory upload (memory management service).
The PROM software is written in Assembler, the V2.0-1 has a size of 5139 48bit instructions and consists of 66 modules.

After Primary Boot the PROM software runs always in Program Memory (PM) for safety reasons. Primary Boot is performed by the DPU Board and Boot Controller (BBC) after +28V power-on. The PM has a very good Single Event Upset (SEU) performance (almost SEU free) while the Data Memory (DM) is SEU sensitive. Therewith a safe behaviour of all PROM software functions can be assumed.

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The EEPROM software is stored in EEPROM as PM and DM segments with segment checksum for verification during upload and start (i.e. Secondary Boot from EEPROM in RAM). It runs in PM and DM RAM.

The EEPROM software is mainly written in C with low level functions in Assembler for speed and code optimization. The Real Time Operating System (RTOS) VIRTUOSO is used and 51 processes can be active simultaneously (FM software). The Secondary Boot software consists of about 200 functions, excluding VIRTUOSO functions/library.

The size of V3.6 is 83Kwords with 68K Instructions and 15K Program data/parameter. The compressed (mem21k) code stored in EEPROM is 354Kbyte (about 60Kwords). That means 2 FM executables are able to store in EEPROM from the size point of view. Generally about 170K Instructions can be stored in EEPROM as maximum and up to 8 different executables.

2.3.3　Data handling

On-board **data compression** for VIRTIS is important to maximise the scientific return of VIRTIS. Both reversible (loss-less) and lossy compression algorithms are implemented. The reversible algorithm is derived from that developed for the OMEGA and VIMS imaging spectrometers. It takes advantage of spatial / spectral correlations for pre-processing, then a Rice coding is applied on the residuals. This algorithm shall be used for validation purposes early in the mission but also during real observations whenever the data rate and available data volume shall allow. The loss-less algorithm provides typical compression ratios of 2 to 3 depending on the entropy content of the data.

The lossy algorithm is based on *wavelet* transforms. There is a specific compression mode for coma observations by VIRTIS-H, which implements very long observation times (up to 1 hour). In this case, a one dimension wavelet transform is applied, followed by coefficients entropy coding. This provides a minimum compression ratio of 4 within the acceptable distortion limits.
The compression strategy based on wavelet transforms of spectral / spatial rectangles of data, works either on VIRTIS-M detectors data (frames) or on accumulated time series of VIRTIS-H spectra. These rectangles are divided in sub-units of typically 64 pixels x 144 spectrals, hence 4 steps of transform in each direction. Each sub-unit provides a self-consistent telemetry stream, so that a SEU can only result in the loss of a small fraction of the data. The result of the transform is coded using a version of the Said-Perlman tree coding algorithm which has been optimised for speed on a TSC21020E. The processing power obtained with the breadboard is 500 k data per second, which is adequate for VIRTIS. With this algorithm, the compression ratio can easily be modified as a TC parameter. Tests on AVIRIS, ISM and VIMS data show that compression ratios of 8 to 12 provide distortion levels of less than 2 DN.

We have implemented 4 compression schemes shown in table 2.9

Algorithm	Compression Factor	Comments
Reversible (lossless)	2…5	Varies according to the entropy of the data
Wavelet – F1	8	2bit/16bit

Wavelet – F2	10.67	1.5bit/16
Wavelet – F3	16	1bit/16bit

Table 2.9 Compression schemes adopted for both VIRTIS-M and VIRTIS-H

2.3.4 Software Concept and Functional Requirements

2.3.4.1 Software Overview

This section contains all the SW related information about the interface between the VIRTIS experiment and the ROSETTA Spacecraft. Interface functional aspects and data formats are described for either DMS/RTU channel as well High Speed link (see Figure 2.11). As VIRTIS is a 3 data channel spectrometer, science data from each channel are formatted in separate science TM packets transmitted on the HS link while other TM packets (e.g. H/K, event) are transmitted to the RTU.

The electrical requirements of the interface are defined for all ROSETTA instruments in AD1 while the derived VIRTIS implementation is described in AD2. In the same way, the functional requirements of the interface are defined for all ROSETTA instruments in AD1 while this section specifies VIRTIS derived definitions.

Unless explicitly specified, all TM and TC data between VIRTIS and OBDH described in the current document is aligned on 16-bit words, with the following bit numbering convention:

  Bit 0 = MSB = first transmitted bit;
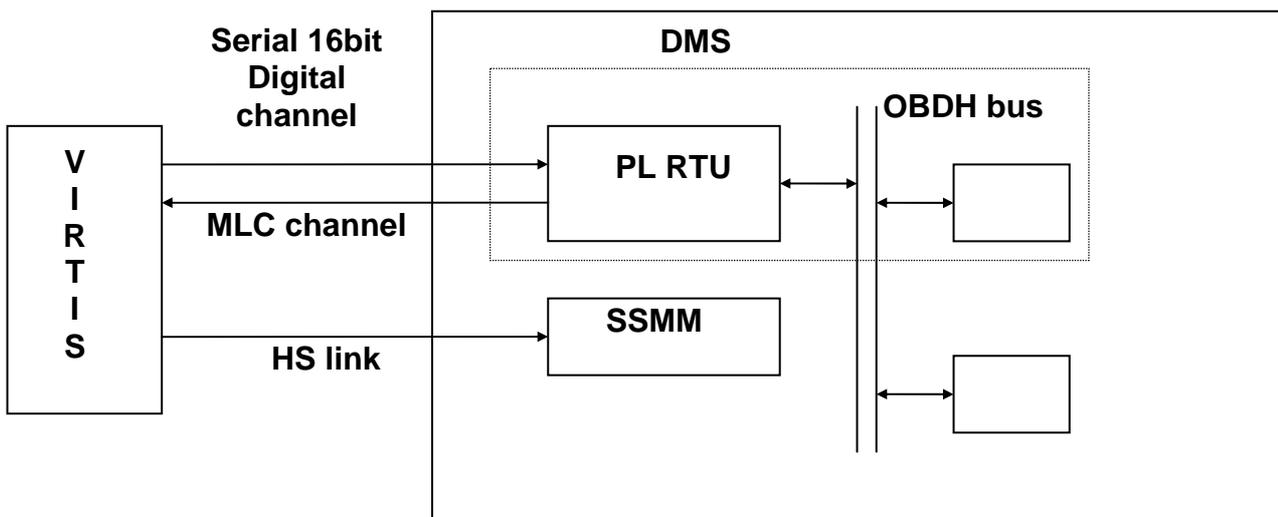 Bit 15 = LSB = last transmitted bit.

Figure 2.11 VIRTIS - S/C Interface

2.3.4.2 Autonomy Concept

The VIRTIS software will detect Anomalous Events, related to malfunctions, and will perform recovery, safing and reporting actions. The recovery/safing actions can be inhibited by the VTC_Override TC.
Anomalous Events will be classified as:

- Category I: events which do not prevent to continue with operations;
- Category II: events for which it is possible to attempt to recover by a "Retry" procedure (i.e. retry to send to the H/W the command which was not properly executed);
- Category III: events for which it is possible to attempt to recover by a "Reset" procedure (i.e. reset the H/W which shows the malfunction);
- Category IV-H: events which prevent to continue with PEM-H operations but allows to continue with PEM-M operations;
- Category IV-M: events which prevent to continue with PEM-M operations but allows to continue with PEM-H operations;
- Category V: events which do not allow to continue with operations and for which an OBDH action is required (typically, switch to redundant electronics);
- Category VI: events which do not allow to continue with operations and for which Ground action is required.

These internal categories correspond to the following TM event reports subtypes:

Internal Category	S/C TM Event Report
Category I	Anomaly Warning – subtype 2
Category II	Anomaly Warning – subtype 2
Category III	Anomaly Warning – subtype 2
Category IV	Anomaly Warning – subtype 2
Category V	On Board Action – subtype 4
Category VI	On Ground Action – subtype 3

Whenever an event report of subtype 4 is received by DMS, a recovery OBCP is started see chapter 5.2.

2.3.4.3 Software Maintenance Approach

Except for the PROM, all VIRTIS memories (EEPROM, RAM) can be uploaded by the Load_Memory TC.
This means that it is possible to upload the software in EEPROM, if needed; moreover, in case e.g. the EEPROM fails, it is possible to load the Program Memory content and start execution directly from it.

The software is physically divided into segments, and each segment can be uploaded separately; this allows to patch the software by uploading only one segment and not the whole software.
The segment approach also allows to manage the case in which one or more of the 8 EEPROM chips fails, while the other ones are still working, by uploading the segments in the failed chips into other ones (assuming of course that enough free EEPROM is available).

2.3.4.4 Data Delivery Concept

VIRTIS will produce the following types of TM data :
- TC verification reports;
- H/K data reports;
- Event reports;
- Memory reports;
- Science reports.

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 HS link. In this case the Science reports are transferred via the RTU I/F like the other TMs.

Data delivery is performed according to AD1. As explained below, packets are internally collected in TM blocks (one TM block is 512 words or 1024 octets) that are put in a H/W FIFO (size :4096 words) and transferred to the DMS when requested by it.

Data Collection for RTU link (non degraded mode)

TC verification, H/K, Memory and Event packets are collected in a SW buffer to form TM blocks (i.e. a group of whole packets plus one word with the block length in words) . A block is considered formed if:

- the size is not more than but near by the maximum of the allowed block size, i.e. it is not possible to add one more packet because the block size would exceed the maximum,or
- a predefined collection period (16 sec) is expired, or
- for TC requiring an Acceptance Report, 2 sec after TC receipt.

Usually blocks will be formed for collection period expiration only, as the first criterion will apply only for memory dump (in Safe Mode) and for degraded Science mode (in both cases, the produced data volume on the RTU link could be quite high). Therefore if the mode is neither Safe nor Degraded Science, the max block size is less than 1k word assuming that:
- each H/K packet size = less than 100 word;
- collection period = 10 sec;
- margin for TC verification and Event reports = 200 words;
in one collection period there are:
- ME H/K packets (default and general);
- 2 H/K packets for each of the 3 channels (5 sec min. repetition time).

When a block is formed, its length is written as first word of the block and data are transferred to the I/F FIFO. If its length exceed the FIFO size or its free area, the words that cannot be accommodated in the FIFO are kept in the SW buffer and are written in the FIFO only later. Note that the writing of one word in the H/W FIFO is about 100 times faster ($<$1μsec) than the reading by the DMS (min. 122 μsec). After closing one block, a new one is prepared on the SW buffer to accommodate the new packets.

Science Data Delivery on RTU link (degraded link mode)

When the HS link is not available, a Degraded Science Mode can be commanded in order to transfer Science data on the RTU link. As a smaller data rate can be sustained on this link, less data are prepared and transmitted to the DMS.
In the degraded mode a budget of 600 bps and 900 bps have been allocated for M and H respectively, giving a data rate of 1.5 kbps for the overall VIRTIS.

H/K packets

They contain data required both for monitoring the operational aspects of the instrument and for interpreting science data. H/K parameters are self standing (i.e. not require data from other packets or TC history to be interpreted) and have the same structure and interpretation in all TM packets in which they appear.

SID	H/K description	Generation Conditions	Generation rate	
			Science Modes	*All other Modes*
1	ME Default H/K	At power on	Every 10 s	
2	ME/M general H/K	If M/Cooler and/or M/ECA are on	Every 10 s	
3	ME/H general H/K	If H/Cooler and/or H/ECA are on	Every 10 s	
4	V-M-VIS H/K	Only if PEM-M is On	M repetition rate	Every 10 s
5	V-M-IR H/K	Only if PEM-M is On	M repetition rate	Every 10 s
6	V-H H/K	Only if PEM-H is On	H repetition rate	Every 10 s

Table 2.9: VIRTIS HouseKeepings

There are 6 H/K packet types identified by means of their Structure Identification (SID) included in the packet and used on ground together with APID, Service Type and Sub-Type, to identify the report and its content . The packet types, their generation conditions and generation rates are given in table 2.9. They are automatically enabled when the generation conditions are met, however, they can be disabled by a specific TC.

Event packets

Event reports represent an higher level of information than H/K reports, therefore they are the preferred method to perform monitoring activities. They report to ground or DMS unambiguous operational information such as:
- failures and/or anomalies detected on-board;
- autonomous on-board actions;
- normal progress of payload operation/activities.

Event packets :
- include an unique identifier of the event, its occurrence time and related data;
- are generated only once per event occurrence and are concise;
- includes the nature/severity of the event;

- are self standing (i.e. not require data from other packets or TC history to be interpreted);

Each event report type has its Event Identifier (like H/K reports have their SID) derived from a selected list controlled by the project. Event reports have fixed structure per EID. Definition of Event Category is given in chapter 2.3.4.2

PID	Packet Category	Packet Type	Usage
51	12	TC	For ALL telecommand packets to VIRTIS
51	1	TM/ 1	Telecommand acknowledge packets
51	4	TM/ 3	Housekeeping data reporting from VIRTIS (note that there will be 6 SIDs within this App Id)
51	7	TM/ 17	Event reporting from VIRTIS (note that there will be N TBD EIDs within this App Id)
51	7	TM/ 5	Test reporting from VIRTIS
51	9	TM/ 6	Memory download from VIRTIS
52	12	TM/ 20	Science data from unit VIRTIS M-VIS and VIRTIS M-IR(1)
53	12	TM/ 20	Science data from unit VIRTIS H (1)

Table 2.10: VIRTIS Application Process Ids

NOTES TO Table 2.10:
(1) Two Process Id are requested for VIRTIS science data as independent on-board and ground processing is necessary for the two independent data streams from the units V-M and V-H.

2.3.4.5 Timing Requirements

Time references in TCs, TMs and on-board procedures are in SCET, i.e. the time the DMS will maintain and distribute on the OBDH bus. This time value is transmitted to the experiment as 6 octets, (32 bit unit seconds, 16 bit fractional seconds, see RD1, 2.8.1.8) and has a resolution of 15,3µs (1/65536 sec) while the experiment time-stamps its TM packets with a time reference whose MS bit is usually set to 0 unless for any reason synchronisation is missing (e.g. no time update from the S/C) or lost (e.g. payload failure). Note that the distributed SCET has ALWAYS the MS bit =0.

To perform a correct synchronisation of the user internal timer to the SCET, the user complies with the Timer Synchronisation Protocol defined in 2.7.3.3. and 2.8.1.8. and 2.8.1.9 of RD1, specifically using both TSY (period 8 sec) and HFC lines as follows:

- the user is able to receive the first Time Update TC Packet with a delay from power-on of min. 20 sec and max. 60 sec (RD1, Sec. 2.8.1.9); if no time update is received within 60 sec, the user starts anyway sending its TM using a non-synchronised value i.e. with the MS bit set to 1;
- the frequency of Time Update is in the order of several hours ($\approx$1.8 TBC);

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- the Packet is decoded in a short time less than the margin of 0.5 sec that will be included by DMS for the experiment to process this type of packet before the following TSY is received;
- with the next rising (first) edge of TSY pulse an interrupt is generated and the received time value is written into the 48 bit internal timer (in the OBDH FPGA on DPU extension). The HFC clocks this FPGA timer (as well all other H/W timers);
- the internal timer is used to time stamp VIRTIS TM Packets (e.g. for Science data time stamp, the timer is read out in the interrupt routine which transfers the science data out from the -M or -H IFE FIFO and the value is written in the related Science data TM packets);
- if for any reason (e.g. instrument failure) the synchronisation is lost, the user time-stamps its TM with a non-synchronised value (i.e. MS bit =1).

The update will be performed in all operative modes when the TSY is received, by overwriting the VIRTIS internal timer with the SCET. Additionally, if the difference between these timers is found greater than 20 ms, a warning event is issued (see 2.8.3.2.1, Event Reporting TMs).

The loss of accuracy due to the possible time drift is anyway very small (e.g. 0,1 msec if the time update were performed once in 1000 days) and the VIRTIS-ME time stamp accuracy for Science TM would result still better than 8.2 ms as described in what follows (all values are worst case estimations):
- S/C HFC drift: 0,1 ms (1000 days * 0,1 μs/day, see RD1);
- S/C TSY jitter: 2μs (see RD1);
- TSY interrupt acceptance time (incl. C call int. dispatcher, 112 Instr.): 5,6 μs;
- TSY interrupt routine run time until the timer is started: 1 μs;
- -M/-H data receipt interrupt acceptance time: 56 μs (Science mode) (10 Interrupts at the same time x 8,1μs (162instr.)/interrupt);
- -M/-H data receipt interrupt routine (first FIFO interrupt, during one of the Science mode) run   time until the timer is read: 4 ms (as the 3 channels can issue an interrupt at the same time, the worst case is when two channels have to be read out before   the 3d. channel data are read out i.e. 10Instr x 50ns/Instr x 4000bytes (half FIFO) x 2channels =   4,1672 ms (+ 100% margin).

2.3.5 Safety

The software for **Safe Mode** is stored in the radiation-hard PROM and executed after primary boot by the BBC hardware only in the PM RAM which is radiation-hard too and has a low SEU sensitivity.

The PROM software contains all functionality for the safe operation of the instrument, especially for:
- Execution of a reduced list of TCs (timer synchronisation, memory up- and download, failure override and "Enter_IDLE" TC)
- Health check including acquisition of a small list of timer triggered HK and TM packet transmission
- Execution of the secondary boot either from EEPROM or from S/C to -RAM

- Start of the ME IDLE mode

Before executing of the secondary boot from EEPROM a check of EEPROM content will be performed by using of the stored checksums.
Severe errors detected by the instrument control software leads to entering of the **Safe Mode.**
Error/event handling can be avoided by a special "failure override" TC.

2.3.6 Reliability

There is a **watch-dog** implemented for detecting of lock-ups and endless loops which can be caused by i.e. an Single Event Upset (SEU).
The program code and parameter of the EEPROM are stored with **checksum** in order to verify the content before using.
The software for the **Safe Mode** which contains up- and download functionality is stored in the radiation-hard PROM and is always executed in the radiation-hard PM RAM.
In case of detection of severe failures VIRTIS enters into the **Safe Mode.** It provides the possibility for **verification** of the program code or parameter by downloading or a **correction** by uploading.

2.3.7 Maintainability

The VIRTIS software (code + parameter) is organised in **segments**
The segments or patches can be uploaded by transferring of TC packets and will be permanently stored in the EEPROM or directly written into the RAM (if the EEPROM fails).
An EEPROM error will be detected by means of the stored checksum.

2.3.8 Verifiability

The whole EEPROM content can be checked for validity of the content by the checksum stored for each EEPROM segment
The PROM software provides periodically Default HK TM packets which contains the operational status of VIRTIS, e.g. the current active instrument mode.

2.3.9 H/K and Events to be monitored by DMS

Refer to chapters 3.7 and 5.7 for a detailed description on this subject.

2.3.10 H/K and Events triggering OBCPs

Refer to chapters 3.7 and 5.7 for a detailed description on this subject.

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 below:

	Measured Mass (g)
PEM-M	2900.5
PEM-H	1270.0
Optics Module	19460.0
External Baffles	162.0
Lateral MLI	603.0
ME box	5460.0
TOTAL VIRTIS	**29855.5**
Inter Unit Harness	1822.8

The overall mass is compliant with the anticipated value of 29.957 Kg.

2.4.2 Operating Power

In the following two tables are given the power consumption of each subsystem under different operating conditions and different operative modes (table 2.9A). The sources for these values are the electrical tests performed on PFM units and the S/C TBTV tests. The overall power consumption of the experiment, in different modes, is reported then in table 2.9B

#	Modes	Average	Long Peak
A	ME Safe	6.1	9.8
B	ME Idle	6.4 / 6.7	6.4 / 6.7
C	ME Science M+H	8.4 / 10.4	10.4
D	ME Science M	7.9 / 10.0	10.0
E	ME Science H	7.8 / 9.9	9.9
F	ME Test	8.3 / 10.4	10.4
G	H_Idle	6.2	6.2
H	H_Cover		6.5
I	H_Annealing	9.2	9.2
L	H_Science (includes calibration)	7.2 / 7.4	7.2 / 7.4
M	H_Cooler Cool Down	14.3 / 16.5	14.3 / 16.5
N	H_Cooler Steady State	8.6 / 11.7	8.6 / 11.7
O	H_Cooler Open Loop (Max speed)	20.3	20.3
P	H_Cooler Stand-By	2.5	2.5
Q	M_Idle	10.4	10.4
R	M_Cover		11.0
S	M_Science	14.0	14.0
T	M_Calibration	17.0	17.0
U	M_Test	10.4	10.4
V	M_Annealing	13.0	13.0
Z	M_Cooler Cool Down	16.0 / 18.5	16.0 / 18.5
Y	M_Cooler Steady State	9.1 / 14.8	9.1 / 14.8
X	M_Cooler Open Loop (Max Speed)	19.9	19.9
W	M_Cooler Stand-By	2.5	2.5
	Emergency Cover Actuator (each)	15.0	15.0

Table 2.9A VIRTIS Subsystems power consumption.

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	VIRTIS Power Consumption Main Power Bus Vs. Operating modes	Average (BOL) [W]	Long Peak [W]	Short Peak [W]
1	Science M/H (C+L+N+S+Y)	47.3 / 58.3	49.3 / 58.3	
2	Science M (D+S+Y)	31.0 / 38.8	33.1 / 38.8	
3	Calibration M (D+T+Y)	34.0 / 41.8	36.1 / 41.8	
4	Science H (E+L+N)	23.6 / 29.0	25.7 / 29.0	
5	Calibration H	23.6 / 29.0	25.7 / 29.0	
6	Upload	9.8	9.8	
7	Download	9.8	9.8	
8	Stand-by (B+G+N+Q+Y)	40.7 / 49.8	40.7	
9	Cover actuation (B+G+H+N+Q+R+Y)		47.2 / 60.8 (1)	
10	Cool-down (M and H)	36.7 / 41.7	36.7 / 41.7	
11	Detectors Annealing (B+I+U)	28.6 / 28.9	28.6 / 28.9	
12	Emergency Cover actuation	15.0	15.0	
13	ME Safe Mode	6.1	9.8	
	Maximum	**58.3**	**60.8**	

Table 2.9B VIRTIS overall power consumption.

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 (see attachment 2, chapter 2.8.2, table 3)

- 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 30 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 attachment 2 (chapter 2.8.2, table 3). The maximum expected data rate shall not exceed the 400 Kbit/s over 5 sec periods.

2.4.4   Non-Ops Heaters.

For non-operational heaters we mean heaters to be powered and controlled directly by the S/C.
VIRTIS shall use two types of non-operational heaters: "Decontamination" and "CCD Storage" heaters.

- Two decontamination heaters are located on the passive radiators belonging to VIRTIS-M and VIRTIS-H, and shall be used to remove ice by raising the temperature from the 130K (operative temperature) to 250K. This operation shall be performed with the instrument in off condition.
- The two CCD Storage heaters are both used during the hibernation period to maintain the CCD at its minimum acceptable temperature of 150K.

The power consumption of the non operational heaters is given in table 2.10.
It must be strongly stressed that the two lines for the decontamination heater are formally the main and the redundant line, but nonetheless they must both active at the same time, to achieve the required temperatures.

	Heater Function	Average (BOL) [W]	Long Peak [W]	Short Peak [W]
1	Decontamination Heater_1	40	40	40
2	Decontamination Heater_2	40	40	40
3	CCD_Storage_1	0.5	0.5	0.5
4	CCD_Storage_2	0.5	0.5	0.5

Table 2.10 Heater main bus consumption.

2.4.5   S/C Powered Thermistors

Temperature monitoring on VIRTIS is for information and safety purposes only. The data can be used to infer background radiance values and to signify when temperatures exceed pre-defined limits. There is no relationship between the temperature data collected from the sensors listed in table 2.11 and the operational control of compensation heaters. The spacecraft is, however, permitted to place sensors about the instrument and agreed upon locations to help it maintain the Temperature Reference Points.

Unit	#	S/C powered Thermistors	Experiment Powered Thermistors	Temperature Range	Location
OM	4	Rosemount 118MF	_	100 ÷340	Optics, FPA's
OM	2	-	Lakeshore Diode XDT-570-50 (TBC)	60 ÷150	IRFPA (M/H)
OM	11	-	Rosemount	100 ÷350	VIS FPA, Optics, Cold

			PRT 118MK /118MM		Box, Baseplate
OM	2	-	2N2222	60 ÷100	Coolers cold tip
ME	3	-	AD590	303 ÷398	DPU, PS

Table 2.11 Temperature Sensors

2.4.6 OBDH Channels

VIRTIS communicates with the OBDH via 5 independent and redundant channels: Telecommand, Telemetry (split in High Speed Telemetry and 16bit serial digital telemetry), Monitor and Timing. The details on the interfaces are given in section 2.2.3.

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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. The following documents have been attached and can be found at the end of the document:

VIR-GAL-UR-040, Issue 5, May 2001   VIRTIS SW User Requirements
VIR-GAL-IC-0048, Issue 6, June 2001   VIRTIS OBDH SW ICD
VIR-GAL-IC-028, Issue 7, July 2001   VIRTIS SW Internal ICD
VIR-DLR-MA-006, Issue2 (draft2) February 2002   VIRTIS On-Board S/W User Manual

The last paragraph of this chapter 3 is devoted to the description of how to build a typical observation session.

3.2 Modes Definition

VIRTIS Modes are defined in compliance with requirements expressed in Sect. 2.8.4.3 of AD1. i.e. distinct modes are to be defined where at least one of the following applies:

- Different resource usage (e.g. power, data rate, SSMM demand);
- Specific requirements put on the S/C (e.g. pointing);
- Different operative phase for the instrument.

However, regarding Data Rate a distinction must be made for VIRTIS which uses the IEEE1355 Interface (High Speed Link) to the Mass Memory, with respect to those instrument having data transfer on the Slow channel (RTU). VIRTIS is in fact Data Volume Limited rather than Data Rate Limited. All science data do not use the standard RTU (except in the Degraded operative mode, see later) and thus do not interfere with the other instruments using the standard slow data interface. From this point of view VIRTIS operation can be considered fairly independent from the Data Rate issue.

As required in Sect. 2.8.3.2.3 of AD1, the H/K TMs provide a specific parameter "VIRTIS Mode Id" that unambiguously identifies the instrument mode of operation. This parameter is contained in the "default" H/K report with the format given in table 3.1. The parameter has three field one for each subsystem of the instrument ME, VIRTIS-M and VIRTIS-H.

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ME Operative Mode				V-H Operative Mode						V-M Operative Mode					
b_0	b_1	b_2	b_3	b_4	b_5	b_6	b_7	B_8	b_9	b_{10}	b_{11}	b_{12}	b_{13}	b_{14}	b_{15}
1 ME_Off 2 ME_Safe 3 ME_Development 4 ME_Idle 5 ME_Science 6 ME_Test				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 SCIENCE MODES 9 H_Science_Maximum_Data_Rate 10 H_Science_Nominal_Data_Rate 11 H_Science_Minimum_Data_Rate 13 H_Science_Backup 14 H_User_Defined 19: H_Degraded (**) 63 H_ME_Test (*)						1 M_Off 2 M_Cool_Down 3 M_Idle 4 M_Annealing 5 M_PEM_On 6 M_Test 7 M_Calibration SCIENCE MODES 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 (*)					

(*) H_ME_Test and M_ME_Test, which physically correspond to have PEM off but IFE on, are used in ME_Test mode.

(**) H_Degraded and M_Degraded are used when HS link is not available and therefore science data are sent on RTU Link

Table 3.1 VIRTIS MODE Identification. The HK parameter VIRTIS Mode is such that the bit 0-3 represent ME mode, bits 4-9 VIRTIS-H mode and bits 10-15 VIRTIS-M Mode.

A VIRTIS Mode is a unique combination of these 3 fields. However, several VIRTIS Modes have common properties and hence are classified as belonging to the same Mode Group. This is a naming convention to address without ambiguity general statements which are valid in different modes (e.g., "all Science modes" means "all modes of the Science Mode Group"). The Modes Groups are listed below:

- Off
- Safe
- Idle
- Cool-down
- Annealing
- Calibration
- Science

- Test
- Development (used only by S/W developers and not described further)

A visualisation of the transitions between modes groups is given in figure 3.1 representing the general VIRTIS state diagram. In figure 3.2 the mode group transitions for M and H are reported (M and H mode groups are equivalent).
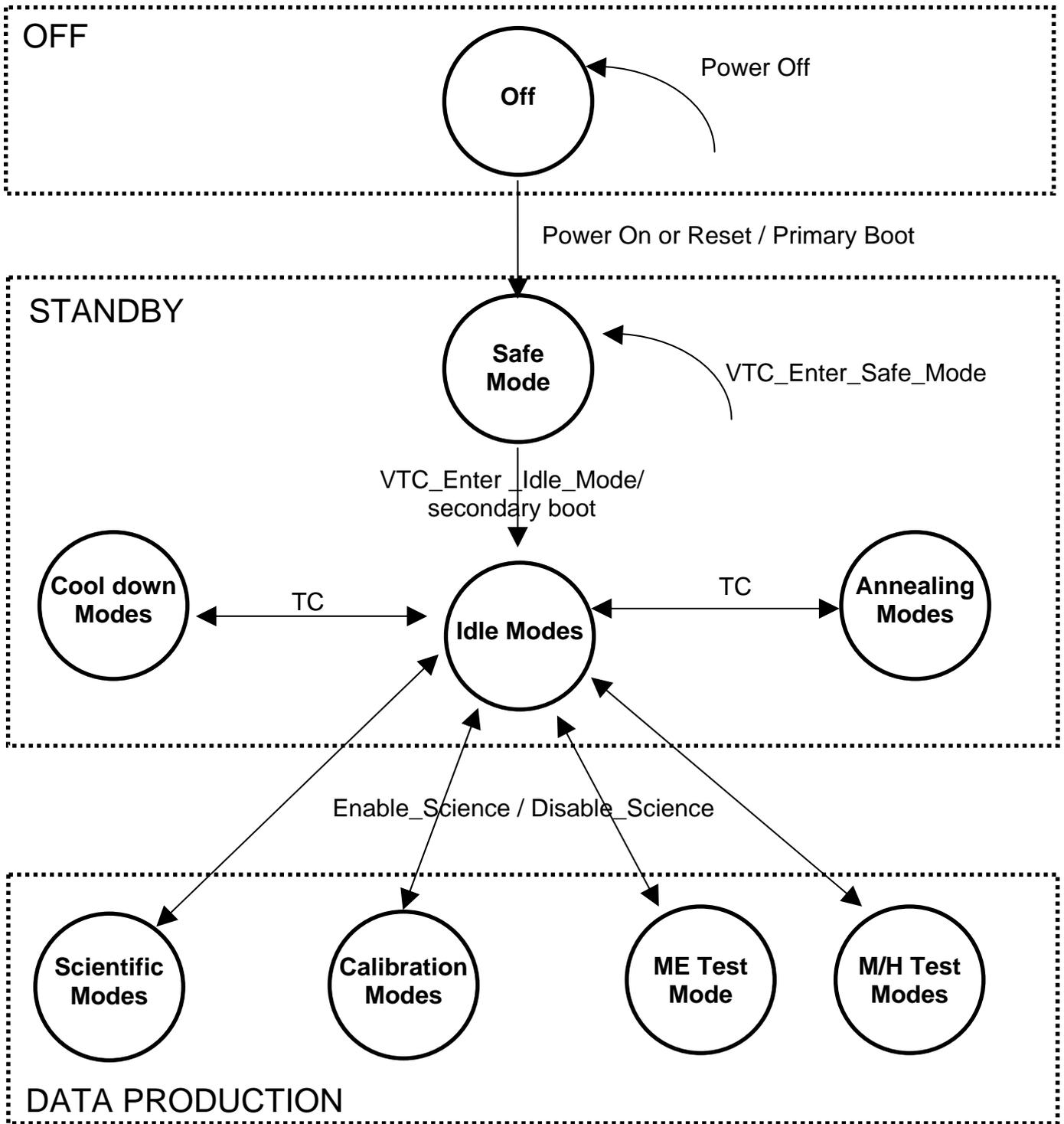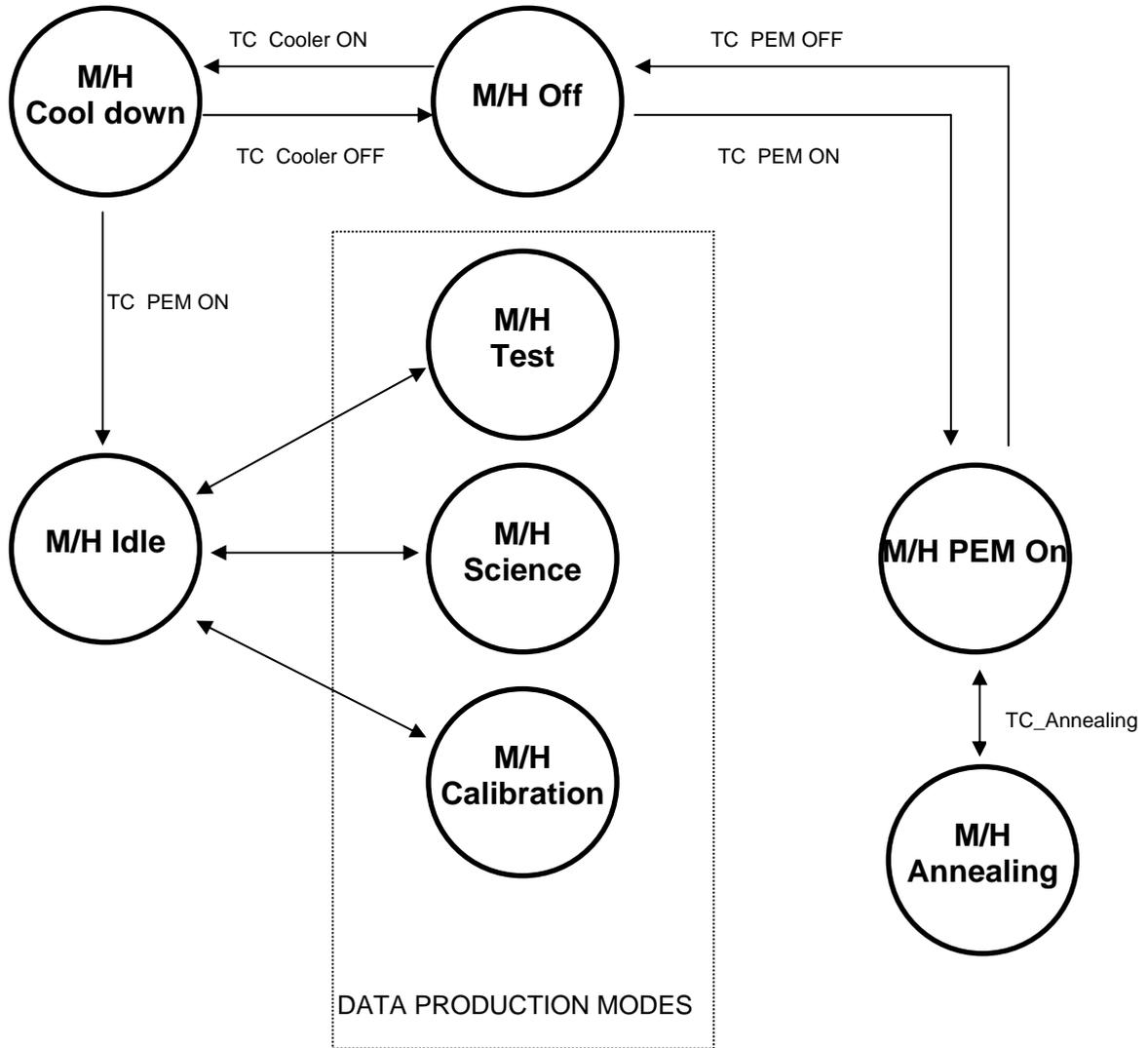
Figure 3.1 VIRTIS Mode Transitions

Figure 3.2 Mode transitions for VIRTIS-M and VIRTIS-H

If we analyse ME, VIRTIS-M and VIRTIS-H separately, we identify the operative modes that can be selected to give the VIRTIS Mode. These operative modes are listed in tables 3.2, 3.3, 3.4. In principle all VIRTIS-M operative modes can be used in combination with almost all VIRTIS-H operative modes as the two channels are fully independent. However, in practice, of the overall allowed combinations we can identify a reduced number according to a series of constraints imposed by logical considerations and/or by H/W constraints. These constraints are applicable to steady state conditions and not during transitions (here V-X and V-Y represent VIRTIS-H and VIRTIS-M indifferently)

- If ME mode is Off, Safe, Development or Test, then both PEMs are Off.
- If V-X mode is Cool_Down, V-Y mode can only be Off or Cool_Down.
- If V-X mode is Annealing, V-Y mode can only be Off.
- If V-X mode is Idle, V-Y mode can only be Off or Idle.
- If V-X mode is one of Science modes, V-Y mode can only be Off, User Defined, Test or one of the Science modes.
- If V-X mode is Calibration, V-Y mode can only be Off or Idle.

Mode	Id	HK Data Rate [kbits/s]	Power [w]
ME_Off	1	0	0
ME_Safe	2	0.075	5
ME_Development	3	0.075	9.5
ME_Science	4	0.075	7.3
ME_Idle	5	0.075	5
ME_Test	6	0.075	10.5

TABLE 3.2 Main Electronics (ME) Operative Modes

Mode #	V-M Mode	Cooler	PEM	M_ACQ_MODE	VIS slice	IR slice	Spatial x Spectral Binning	Science Data Compression Type	External Repetition Time [s]	Science Data Rate (kbps)
1	M_Off	OFF	OFF	don't care	don't care	don't care	don't care	don't care	don't care	0
2	M_Cool_Down	Closed / Open Loop	ON/OFF	don't care	don't care	don't care	don't care	don't care	don't care	0
3	M_Idle	Closed / Open Loop	ON	don't care	don't care	don't care	don't care	don't care	don't care	0
4	M_Annealing	OFF	ON	don't care	don't care	don't care	don't care	don't care	don't care	0
5	M_PEM_On	OFF	ON	don't care	don't care	don't care	don't care	don't care	don't care	0
6	M_Test (1)	ON any state (2)	ON	any	(4)	(4)	(4)	any	any	707.8 MAX
7	M_Calibration (3)	Closed / Open Loop	ON	All_Pixels	256x432	256x432	1x1	no compression	don't care	707.8 (6)
8	M_Science_High_Spectral_1	Closed / Open Loop	ON	high spectral	64x432	64x432	4x1	lossless	T#1 = 5s	88.5
9	M_Science_High_Spectral_2	Closed / Open Loop	ON	high spectral	64x432	64x432	4x1	lossless	T#2 = 20s	22.1
10	M_Science_High_Spectral_3	Closed / Open Loop	ON	high spectral	64x432	64x432	4x1	lossless	T#3 = 60s	7.4
11	M_Science_High_Spatial_1	Closed / Open Loop	ON	high spatial	256x144	256x144	1x3	lossless	T#1 = 5s	118.0
12	M_Science_High_Spatial_2	Closed / Open Loop	ON	high spatial	256x144	256x144	1x3	lossless	T#2 = 20s	29.5
13	M_Science_High_Spatial_3	Closed / Open Loop	ON	high spatial	256x144	256x144	1x3	lossless	T#3 = 60s	9.85
14	M_Science_Nominal_1	Closed / Open Loop	ON	nominal	64x144	64x144	4x3	lossless	T#1 = 5s	29.5
				VIS_Only	64x288	No	4x1			
				IR_Only/Alter_IR	No	64x288	4x1			
15	M_Science_Nominal_2	Closed / Open Loop	ON	nominal	64x144	64x144	4x3	lossless	T#2 = 20s	7.4
				VIS_Only	64x288	No	4x1			
				IR_Only/Alter_IR	No	64x288	4x1			
16	M_Science_Nominal_3	Closed / Open Loop	ON	Nominal	64x144	64x144	4x3	lossless	T#3 = 60s	2.5
				VIS_Only	64x288	No	4x1			
				IR_Only/Alter_IR	No	64x288	4x1			
17	M_Science_Nom_Compress	Closed / Open Loop	ON	Nominal	64x144	64x144	4x3	M_WAVELET F1	5	7.4
18	M_Science_Reduced_Slit	Closed / Open Loop	ON	Reduced	64x144	64x144	1x3	Lossless	5	29.5
19	M_User_Defined (1)	ON any state (2)	ON	any	(4)	(4)	(4)	any	any	707.8 MAX
20	M_Degraded	Closed / Open Loop	ON	nominal	64x144	64x144	4x3	M_WAVELET_F3	T#3 = 60s	0.31
63	M_ME_Test (7)	OFF	OFF	don't care	don't care	don't care	don't care	don't care	don't care	707.8 MAX

TABLE 3.3 V-M Operative Modes

NOTES

(1) M_Test and M_User_Defined modes allow the user to select any combination of the operative parameters.
(2) Cooler states are: Closed Loop, Open Loop and Stand By.
(3) Calibration mode is an automatic sequence, see later in the chapter for definition.
(4) Values according to the M_ACQ_MODE selection.
(5) Only for 30 minutes.
(6) Onle ME is powered on; PEM is off; Simulated data from M/IFE are generated.

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Mode #	V-H Mode	Cooler Mode	PEM	Data Production Mode	Max Science Data Rate (kbps)	Max HK data Rate (kbps)
1	H_Off	OFF	OFF	Don't care	0	0
2	H_Cool_Down	Closed / Open Loop	ON/OFF	Don't care	0	0
3	H_Idle	Closed / Open Loop	ON	Don't care	0	0
4	H_Annealing	OFF	ON	Don't care	0	0
5	H_PEM_On	OFF	ON	Don't care	0	0
6	H_Test	ON any state (4)	ON	H_Image_Slice (1)	270	0.6
7	H_Calibration	Closed / Open Loop	ON	7 H_Image_Slice + 2 H_Spectrum	103	0.28
8	H_Nominal_Simulation	Closed / Open Loop	ON	H_Spectra_Slice (3) + H_Spectrum (2)	3.4	0.06
9	H_Science_Max_Data_Rate	Closed / Open Loop	ON	H_Spectra_Slice + H_Spectrum	84	3
10	H_Science_Nom_Data_Rate	Closed / Open Loop	ON	H_Spectra_Slice + H_Spectrum	27	1.2
11	H_Science_Min_Data_Rate	Closed / Open Loop	ON	H_Spectra_Slice + H_Spectrum	3.4	0.06
13	H_Science_Backup	Closed / Open Loop	ON	H_Image_Slice	270	0.6
14	H_User_Defined	ON any state (4)	ON	Any	270	3
19	H_Degraded	Closed / Open Loop	ON	H_Spectra_Slice + H_Spectrum	0.9	0.02
63	H_ME_TEST	OFF	OFF	H_Image_Slice	270	3

TABLE 3.4 V-H Operative Modes

NOTE

(1) **H_Image_Slice** : IR full frame adjusted in pixel size to a 432x256 pixels
(2) **H_Spectrum**: Composition of the 8 orders spread over the H-IR detector. The PEM-H uses the pixel map to extract 3456 pixels containing the spectral information from the full detector window of 432x256
(3) **H_Spectra_Slice**: Collection of 64 H_Spectrum, consequently acquired.
(4) Cooler states are: Closed Loop, Open Loop and Stand By.

3.3   Safe Mode

During normal operations this condition is reached after power-on; all the modules are powered-off except for ME, which shall perform the Primary Boot (run of the PROM S/W) thus initialising all the ME hardware (set watch-dogs, set S/C interface, etc.).
All commands relative to the management of the memory areas are possible exclusively from the Safe Mode (TC_Load_Memory, TC_Dump_Memory, TC_Check_Memory, VTC_Get_EEPROM_Status) as only the PROM S/W contains the routines to operate on memory areas.

This mode can be reached also
1. After reset from failure (event of category V and VI)
2. With an explicit VTC_Enter_Safe_Mode telecommand.

3.4   Idle Modes

Upon reception of the TC_Enter_Idle_Mode, the ME shall perform the Secondary Boot and will be able to accept commands for the PEMs and for the other internal subsystems
This mode group contains several Idle conditions as reported in table 3.5.

Mode	ME	PEM-M	PEM-H	Cooler-M	Cooler-H
Idle 1 (ME_Idle, H_Off, M_Off)	On	Off	Off	Off	Off
Idle 6(ME_Idle, H_PEM_On, M_Off)	On	Off	On	Off	Off
Idle 3(ME_Idle, H_Off, M_PEM_On)	On	On	Off	Off	Off
Idle 7(ME_Idle, H_PEM_On, M_PEM_On)	On	On	On	Off	Off
Idle 4(ME_Idle, H_Idle, M_Off)	On	Off	On	Off	On
Idle 2(ME_Idle, H_Off, M_Idle)	On	On	Off	On	Off
Idle 5(ME_Idle, H_Idle, M_Idle)	On	On	On	On	On

Table 3.5 Idle Modes Group description.

The Idle mode is the Stand-by mode of the instrument. Any sequence of TCs intended to bring VIRTIS in a stand-by condition must end in one of the above listed Idle Modes (see also chapter 3.3 for a graphical description).
When the ME is in Idle and one of the two PEMs or both are also in Idle we are ready to start the setting of the instrument to prepare it for the science acquisition.

3.5   Science Modes

Before starting the description of the scientific modes we need to define some nomenclature of the terms used in this framework:

H_Spectrum

A H_Spectrum is a composition of the 8 orders imaged on the H-IR detector, the H_Spectrum is extracted from the two-dimensional detector by using a map of the lighted pixels based on 8 spectral orders of 432 elements and a width of 5 pixel for each order. The 5 pixels are reduced to 1 pixel by averaging. The H_Spectrum is composed of 3456 pixels.

H_Spectra_Slice
A H_Spectra_Slice is 2-dimensional data array stored in the ME, and composed by 64 subsequent acquisitions of a H_Spectrum and has a total dimension of 3456 x 64 elements. The H_Spectra_Slice is then decomposed in sub-slices (compression units). The H_Spectra_Slice is a mathematical artifice adopted to built a correlation inside the H_Spectra_Slice and improve the performances of the compression algorithm.

H_Image_Slice
A H_Image_Slice is a H-IR full frame, adjusted to the common (with M-IR) dimension of 432x256. It is an instantaneous reading from the PEM-H without application of the Pixel Map.

Slice
A Slice is a 2-dimensional array of elements with a spectral (X) and spatial (Y) dimension. Is the instantaneous acquisition of M-VIS and M-IR detectors. A slice is window adjusted, reducing the M-VIS from a full acquired window of 438x256 elements and the M-IR window of 438x270 elements to a Slice of 432x256. A slice of 432x256 (spectral x spatial) can be decomposed to sub-slices of 144x64 (spectral x spatial). Sub-slices are needed for data compression.

Sub-slice
A Sub-slice is a portion of a Slice or of a H_Image_Slice and has a dimension of 144x64 elements. This sub-slice is generated as it is needed for the compression algorithm and is always a compression unit.
A Sub-slice is decomposed from a Slice or a 2-dimensional data array. This can be a M-VIS slice, M-IR slice or a H_Image_Slice, all with a dimension of 432x256 elements. The slice or 2-dimensional data array is decomposed to 12 sub-slices.

3.5.1   VIRTIS-M Science Modes

Before enabling the scientific acquisition, VIRTIS-M must be configured in a scientific operative mode. This is achieved by means of 5 different TCs (not all of them have to be necessarily uploaded each time a new Scientific Mode needs to be implemented, but all of them contain several parameters used for the scientific mode configuration):

MTC_Change_Data_Production_Param. This TC uses a single parameter (M_DATA_PRODUCT_PARAM or in short M_DPT) which select the acquisition type:
1. **M_Data_Science**. Normal selection for scientific acquisition.
2. **M_Data_Calibration**. Start of a calibration sequence.
3. **M_Data_Test**. Enter the test mode of the M channel, in which we can command directly the PEM-M (through the TC MTC_Command_Word) without any filter from the ME.

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MTC_Change_Operational_Param. This TC is used to select the ME data processing of the data acquired (spatial/spectral binning, data compression algorithm, frame summing) from the detectors and the repetition rate. The parameters of this TC define the value of the input for the algorithm for the calculation of the expected data rate.

Parameter	Function
M_ERT	External Repetition Time. Represents the interval between two slices delivery to the S/C. It can assume only4 values: 5, 20, 60 and 300 seconds
M_SS	Number of slices to be summed (SS = Slice Summing).
M_ACQ_MODE	Define the spatial/spectral binning performed by the ME. We can select 8 modes: **M_ACQ_MODE_NOMINAL_3x4_FULL_WIN** **M_ACQ_MODE_VIS_ONLY_1x4** **M_ACQ_MODE_IR_ONLY_1x4** **M_ACQ_MODE_HIGH_SPECTRAL_1x4_FULL_WIN** **M_ACQ_MODE_HIGH_SPATIAL_3x1_FULL_WIN** **M_ACQ_MODE_ALL_PIX_FULL_WIN** **M_ACQ_MODE_REDUCED_SLIT_3x1** **M_ACQ_MODE_ALTER_IR_ONLY_1x4**
M_COMP_MODE	Defines the on-line compression mode for the sub-slice (144x64). **M_NO_COMPRESSION:** no compression is done **M_LOSSLESS_COMPRESSION:** Mean compression factor is 3. **M_WAVELET_F1_COMPRESSION**: Compression factor is 8. **M_WAVELET_F2_COMPRESSION:** Compression factor is 10.67. **M_WAVELET_F3_COMPRESSION**: Compression factor is 16.

Table 3.6 Parameters of the MTC_Change_Operative_Param.

The 8 different values of the M_ACQ_MODE parameter shall correspond to the following window selections:

M_ACQ_MODE	PIXELS		BINNING		
	Spectral	Spatial	Spectral	Spatial	Detectors
NOMINAL_3X4_FULL_WIN	144	64	3	4	VIS + IR
VIS_ONLY_1X4	288	64	1	4	VIS
IR_ONLY1X4	288	64	1	4	IR
HIGH_SPECTRAL1X4_FULL_WIN	432	64	1	4	VIS+IR
HIGH_SPATIAL_3X1_FULL_WIN	144	256	3	1	VIS+IR
ALL_PIX_FULL_WIN	432	256	1	1	VIS+IR
REDUCED_SLIT_3X1	144	64	3	1	VIS+IR
ALTER_IR_ONLY_1X4	288	64	1	4	IR

Table 3.7 M_ACQ_MODE window definition

For the IR and VIS only modes the user has the freedom to define the spectral region, in fact only 288 spectral pixels are used out of 432 available.

MTC_Change_Functional_Param. With this TC we define the settings and values of parameters needed for the configuration of the PEM-M. Note that not all the parameters of this TC enter into the selection of the science mode.

Parameter	Function
M_IR_WIN_X1 M_IR_WIN_X2 M_IR_WIN_Y1 M_IR_WIN_Y2	Co-ordinates for window adjustment of the IR detector data. The PEM-M transfer to ME always the full 438x270 pixels window, which needs to be reduced to the window defined by M_ACQ_MODE.
M_IR_DELAY M_IR_EXPO	M_IR_DELAY represents an IR integration delay time to synchronise VIS and IR acquisitions. M_IR_EXPO is the IR exposition (integration) time.
M_CCD_WIN_X1 M_CCD_WIN_X2 M_CCD_WIN_Y1 M_CCD_WIN_Y2	Co-ordinates for window adjustment of the IR detector data. The PEM-M transfer to ME always the full VIS 876x512 pixels window, which needs to be reduced to the window defined by M_ACQ_MODE. **Note**: the M-PEM CCD channel is commanded internally by a window of 876x512 elements, but the PEM send a data set of 438x256 pixel to the ME which means the M-PEM performs a element binning of 2x2 (i.e. 4 detector elements are binned to 1 pixel).
M_CCD_DELAY M_CCD_EXPO	M_CCD_DELAY represents a CCD integration delay time to synchronise VIS and IR acquisitions. M_CCD_EXPO is the CCD exposition (integration) time.
M_SU_MODE M_SU_ANGLE_ FIRST M_SU_ANGLE_ LAST M_SU_ANGLE_ STEP_SIZE M_SU_NUM_IRT _ ANGLE	These parameter are needed for Scan Unit (SU). If M_SU_MODE = Off, the SU is <u>not</u> switched-on and <u>no</u> PEM commanding for SU control is done by the software independent from the -M mode. If M_SU_MODE = Point, the SU is switched-on and is commanded via M-PEM only once (if M_SU_NUM_IRT_ANGLE=1) i.e. the SU is placed on a fix point (boresight) given by parameter M_SU_ANGLE_FIRST. If M_SU_MODE = Scan the SU is switched-on and is commanded via M-PEM once per IRT i.e. the SU steps from the beginning of a start electrical angle (given by parameter M_SU_ANGLE_FIRST) to the end electrical angle (given by parameter M_SU_ANGLE_LAST) with a predefined step size (given by parameter M_SU_ANGLE_STEP_SIZE). M_SU_NUM_IRT_ANGLE defines the number of IRT (i.e. detector read-out cycles) and the SU is commanded one step. Scanning by Scan Unit is needed to expand the optical FOV to about –2°...+2° of the –M VIS and IR channel.
M_D_BCK_RATE	This parameter defines the frequency of dark acquisitions in science acquisition units.

Table 3.8 Parameters of the MTC_Change_Functional_Param (only those relative to the Scientific Mode selection).

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MTC_Change_Alternate_Param. This TC is used only in the IR_Only_Mode (only the IR detector is used) and allows to define a subset of the functional parameters, namely the coordinates (M_IR_WIN_X1, M_IR_WIN_X2, M_IR_WIN_Y1, M_IR_WIN_Y2) the M_IR_DELAY and M_IR_EXPO.

MTC_Change_Calibration_Param. This TC is used only whenever M_DPT is set equal to "M_Data_Calibration". The parameters in this case define the integration times and the delay times for the CCD and IR detectors in each of the 7 phases of the calibration sequence, as well as the voltages and stabilisation times of the calibration lamps. See below for a description of the Calibration Mode.

Upon reception of a TC_Enable_Science , the ME shall transfer to the relevant PEM the table containing the parameters, defined above and required to set up the observation. A dump of the uploaded table is also issued to ground.
At this point the specific parameters selection define the operative mode and the PEM-M shall start the scientific acquisition and remain in this state until the ME receives the TC_Disable_Science from the Mission Time Line of the S/C.

3.5.2 VIRTIS-M Data Rate

We must distinguish between :

1. The scientific data rate (described in the first part of this chapter) which depends on the selected operative mode (binning, windowing, compression).
2. and the effective data rate from VIRTIS to the S/C which takes into account the fact that only 512 words packets are allowed and that in each packet the first 12 words are constituted by: a packet header (3 words), a data field header (5 words) and a specific data description header (4 words). This means that the ME shall format in each packet 500 scientific data words. As the number of words for each acquisition frame are in general not a multiple number of 500 the packets shall have a different length according to their total data size.

The calculation of the scientific data rate takes into account the window size, the compression factor and the repetition time, according to the following formula:

Average Data rate = $Det * 16 * \dfrac{Nspatial \ * Nspectral}{C * M\_ERT}$ [bps]

Where
- *Det* is either 1 if only one detector mode is used and 2 if both CCD and IR detectors are in use.
- *C* is the compression factor relative to the selected compression algorithm, given in table 3.6 .
- *M_ERT* is the selected repetition time
- *Nspatial* and *Nspectral* are the number of pixels in spatial and spectral directions, reported in table 3.7

The calculated value ranges from 0.06 kbps for a single detector reading with a repetition time of 300s and a maximum compression factor, to 707.79 kbps for an IR+VIS full window with minimum repetition time and no compression.

3.5.3 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 3.4 is reported a sketch of the detectors and their alignment with respect to the slit and spectrum direction. 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 have a physical size which is the half of the IR detector pixel, thus summation of 2x2 pixels shall be performed by the PEM to match spatial resolution of the IR channel. This action is performed directly by the PEM and is transparent to the final user.
The ME receives from the CCD 438 spectral and 256 spatial pixels and from the M-IR in full window mode receives 438 spectral and 270 spatial pixels. For compatibility with an integer binning value these format are further reduced to a common 432x256 by the ME.

For M-IR the ME can command the PEM to produce a reduced window (438 spectral and 90 spatial pixels) to be used in the *M_reduced_slit* mode. In this case 90 pixels in the central area of the slit are selected.
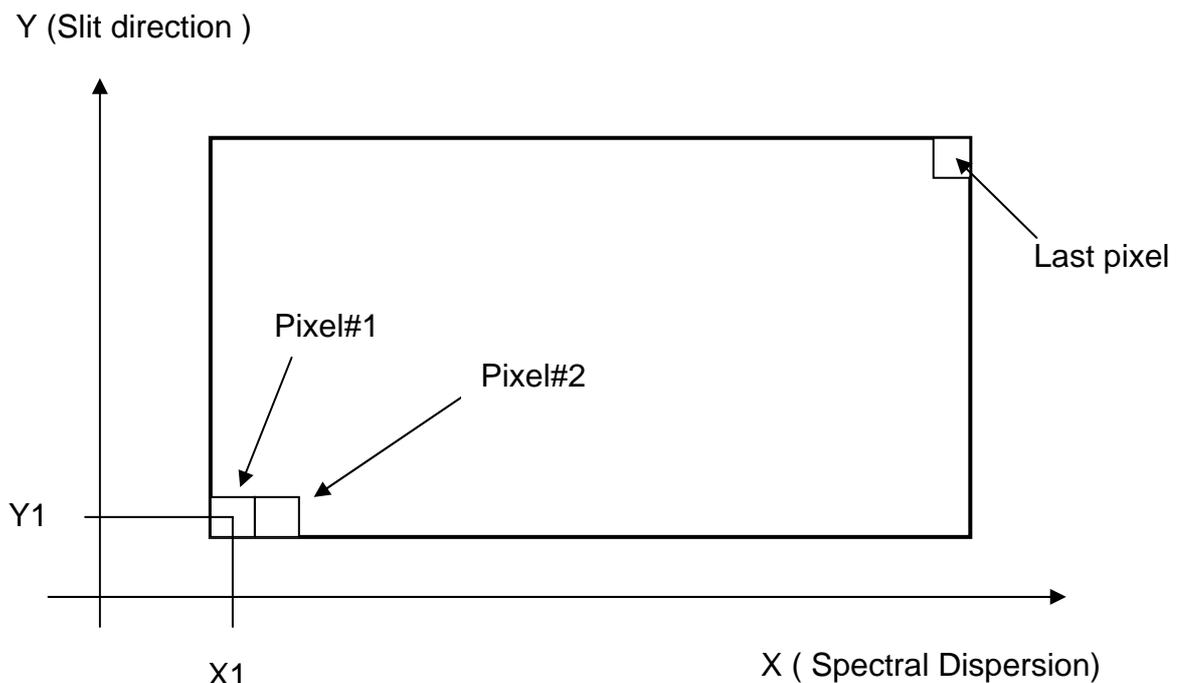
Figure 3.4

Data Organisation on the CCD and IR detectors of VIRTIS-M

3.5.4   VIRTIS-H Science Modes

As for VIRTIS-M we need to define the configuration of the H channel and the data processing to be applied by the ME. This is achieved by means of 4 TCs:

HTC_Change_Data_Production_Param. This TC uses a single parameter (H_DATA_PRODUCT_PARAM or in short H_DPT) which select the acquisition type and the data structure sent by the PEM-H to the ME after each single acquisition:

1. H_Nominal_Observation. The Pixel map is used to select region of the IR detector to be downloaded to ME.
2. H_Calibration. Start of a calibration sequence.
3. H_Nominal_Simulation. Data structure is as for H_Data_Nominal_Observation but the data content is simulated by the FPGA.
4. H_Science_Backup. Full window reading of the IR detector (270x438 pixels)
5. H_Spectral_Calibration_Simulation. An H_Image_Slice (same size as H_Science_Backup but only simulated data) is delivered to the ME
6. H_Test. Enter the test mode of the H channel, in which we can command directly the PEM-H (through the TC HTC_Command_Word) without any filter from the ME.

HTC_Change_Oper_Param. This TC is used to select the ME data processing of the data acquired (data compression algorithm, frame summing) from the detectors and the integration time and read-out frequency. The parameters of this TC define the value of the input for the algorithm for the calculation of the expected data rate.

Parameter	Function
H_INT_SCIENCE_NUM1 & H_INT_SCIENCE_NUM2	Two words (NUM1 = LSW and NUM2=MSW) used to define the integration time. The integration time t in sec is given by $t= (1024* NUM2+NUM1)*512x10^{-6}$
H_SUM	Determine if we perform on-board frame averaging (0=no sum; 1=sum)
H_N_FRAME **(see note)**	If H_SUM=0 the parameter represent the ME frame transfer frequency. e.g. if H_N_FRAME is 3, all frames are read by the PEM-H but only one every 3 is delivered to the ME If H_SUM=1 Don't care
H_N_SUM_FRAME **(see note)**	If H_SUM=0 Don't care If H_SUM=1 the parameter represent the number of frames to be averaged. In this case all the frames are read and delivered to the ME, but they are averaged before compression.
H_DARK_RATE	The number of frames between two consecutive dark acquisitions.
H_COMP_MODE	The selected compression mode

NB. The H detector is used in free run mode, in other words the PEM-H reads continuously the detector; however not all the frames are sent to the ME. The data transfer to ME is defined by the operational parameters H_N_FRAME, H_SUM and

H_N_SUM_FRAME. If no averaging is performed a frame is sent to the ME every H_N_FRAME acquisitions. If H_SUM is 1 (summing), H_N_SUM_FRAME are averaged and the averages frame is sent to the SSMM. This approach has been selected as it should ensure a good temperature stabilisation (for an example see appendix E.1 of AD10)

Table 3.9 Parameters of the HTC_Change_Operational_Param

There are limitations in the parameters selectable values. For instance:

o IF (H_INT_SCIENCE. Equal or less than. 700ms) AND (H_Data_Production_Mode=0) then H_SUM=0 and H_N_FRAME. equal or greater than. 2)
o IF (H_DATA_PRODUCTION_MODE=0 or 3) than H_DARK_RATE=2^K with K=0,1,2…

3.5.5   VIRTIS-H Data Rate

As for VIRTIS-M the specific selection of the operative parameters shall determine the average data rate for each mode. The data rate for H can be calculated as follows:

$$\text{Average Data rate} = 16 * \frac{Npixels \ * Ndark}{C * H\_IRT \ * N\_Frame} \ \text{[bps]}$$

where

♦ *Npixels* = 432x8 (Nominal_Observation); 432x256 (H_Science_Backup) see chapter 3.5.6
♦ *Ndark = H_Dark_Rate + 1*
♦ *C* is the compression factor relative to the selected compression algorithm:
   ▪ H_NO_COMPRESSION   C=1
   ▪ H_LOSSLESS COMPRESSION   C=2
   ▪ H_WAVELET_F1_COMPRESSION   C=8
   ▪ H_WAVELET_F2_COMPRESSION   C=10
   ▪ H_WAVELET_F3_COMPRESSION   C=16
♦ *H_IRT* = $\left(H\_INT\_Science + Science\_readout + HK\_readout + Idle\_time\right)$
♦ *Science_readout*   =0.18458 s in nominal mode
                             =1.1934 s in backup mode
♦ *HK_readout* = 2.304 ms
♦ *Idle_Time* = 79.872 ms#
♦ *N_Frame* =   H_Dark_Rate*H_N_SUM_FRAME + 1   if H_SUM=1
                      H_Dark_Rate*H_N_FRAME + 1   if H_SUM=0

The above formulas allows to define three different data rate ranges:
Minimum: < 3.4 Kbps
Nominal: 3.5 through 27 Kbps
Maximum: 28 through 87 Kbps

3.5.6   VIRTIS-H Science Data Format

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

VIRTIS-H is a high resolution spectrometer and does not perform imaging (for a complete description of VIRTIS-H optical head see chapter 1.2). The H-IR detector is used to acquire spectra spread over its surface, thus only a portion of the pixels contains useful scientific data, see figure 3.2. The 8 spectral orders are spread over the entire surface matrix. In each spectral order the spectrum covers 432x5 pixels (where 5 pixels represent the image of the slit size when imaged on the detector).

Thus overall only 15% of the 438x270 pixels matrix surface is used. To reduce the overall data rate and volume, H uses the so called Pixel Map which gives the exact location of the spectra over the H-IR detector. The ME calculates the location of the pixels to be downloaded and passes it to PEM-H which then download them accordingly. The downloaded data are the H_SPECTRUM, a set of 432x8x5. As H has no spatial resolution the 5 pixels are averaged together, thus the final end-product in the H_Nominal acquisition mode is a 3456 (or 432x8) pixels spectrum representing the full spectral range of the instrument from 1.88 through 5.03 micron.

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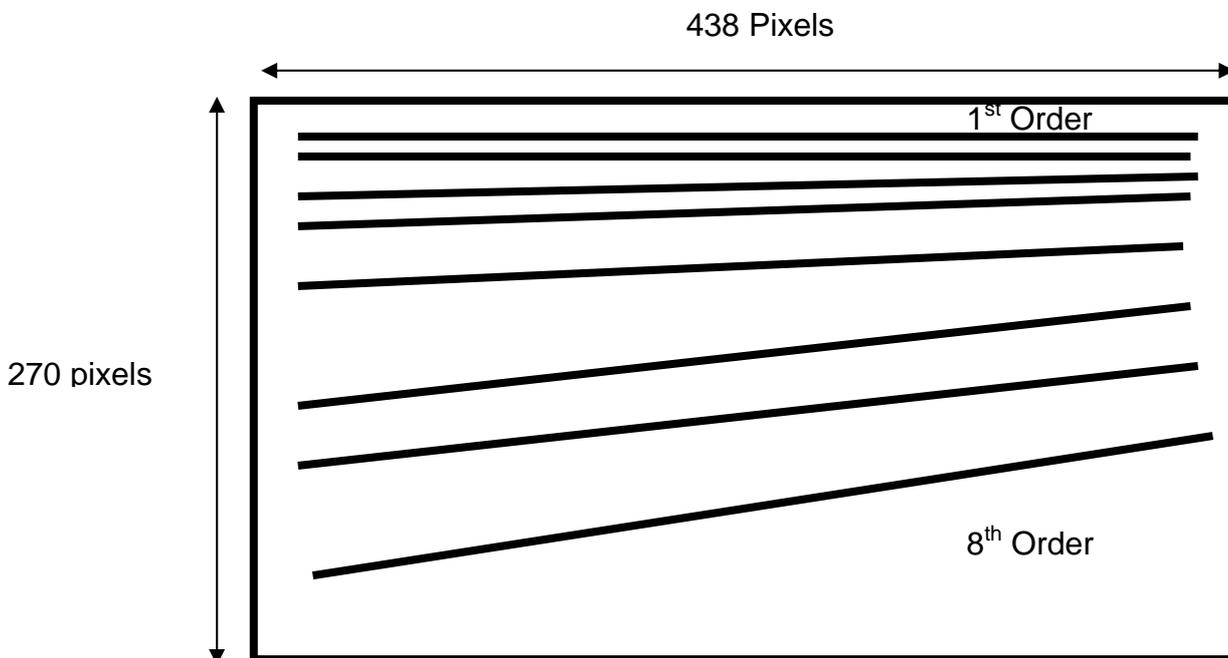

Figure 3.2 Spectral orders distributed over the IR FPA area. Only 15% of the matrix contains scientific data.

3.6   Test Modes

We can test independently the ME or the M or H channels, however the behaviour of the instrument in the two cases is profoundly different.
When ME test is selected we can test the DPU, PS, and the interfaces to M and H (M-IFE and H-IFE); in fact in ME_Test mode the two PEMs are switched off. In this case the default H/K will show for M and H the mode M_ME_Test and H_ME_Test.
On the contrary entering the test modes for M and H allows to command directly the PEMs (by means of telecommand MTC_PEM_Command_Word and HTC_PEM_Command_Word) without interference from the ME; thus we can test directly the two channels. In this case the default H/K will show for M and H the mode M_Test and H_Test.

3.6.1   ME Test Mode

VTC_Enter_Test_Mode is needed to enter the ME_Test_Mode. It is used for testing the main parts of the ME (DPU, M/H-IFE, PS). Only simulated Science data are produced.

ME test mode means:
o   entering the test mode can only be done in ME_IDLE mode.
o   only the DHSU power converter and the H-IFE and M-IFE are switched-ON.
o   the –M and –H converters are OFF.
o   after VTC_Enter_Test_Mode(ME) and after TC_Enable_Science, the M-IFE and/or H-IFE produces periodically pseudo random test pattern
o   the test pattern are compared (completely word by word) on-line by software, if there is an error in the pattern, an event is issued to the S/C, so IFE/DPU hardware problems can be detected
o   the pattern are processed (as defined by the –M/-H data processing parameter), packed in TM packets (as for science data coming from the PEMs) and are sent to the S/C via HS link or SDT interface
o   the data volume to be generated by the M-IFE or/and H-IFE and the repetition rate for each channel are selected by the parameter in VTC_Enter_Test_Mode

3.6.1.1 Entering a ME test mode with max. data volume and high repetition rate

o   Preconditions: ME IDLE mode; H-PEM Off, M-PEM Off, HSLink Active
o   MTC_Change_Operat_Param_RAM(ALL_PIX_FULL_WIN, NO_COMP)
o   HTC_Change_Operat_Param_RAM(NO_COMPRESSION)
o   VTC_Enter_Test_Mode
   ♦   Unit_ID = 1 (ME)
   ♦   M Repetition rate = 5sec
   ♦   Number of M-VIS words = 112153 (438x256 science words + 25 H/K words)
   ♦   Number of M_IR words = 118280 (438x270 science words + 20 H/K words)
   ♦   H Repetition Rate = 5 s
   ♦   Number of H_IR words = 118296 (438x270 science words + 36 H/K words)
o   Default HK will show ME =**ME_Test**, H = **Off**, M = **Off**
o   TC_Enable_M_Science_SSMM ; start of M-IFE pattern generation

o Default HK will show ME =**ME_Science**, H = **Off**, M = **M_ME_TEST**
o TC_Enable_H_Science_SSMM ; start of H-IFE pattern generation
o Default HK will show ME =**ME_Science**, H = **H_ME_TEST**, M = **M_ME_TEST**
o Each 5 seconds 684 (3 x 228) Science TM packets and 3 PEM-HK TM packets are produced.
o TC_Disable_M_science_SSMM ; stop of M-IFE pattern generation
o TC_Disable_H_science_SSMM ; stop of H-IFE pattern generation

In this particular case science data are produced with an average rate of about 1.1 Mbit/s. In ME test mode data rate and volume to be simulated from the IFEs is defined only by the VTC_Enter_Test_Mode (not by –M or –H specific parameter, e.g. the M_ERT)

3.6.2 M Test Mode

The M_Test mode can be entered by selecting M_DPT= 2 (M_Data_Test) in the TC_Change_Data_Product telecommand. The M channel shall enter the M_Test Mode (mode number 6 in table 3.1) when an MTC_Enable_Science_HSLink telecommand is sent.
Moreover, when in M_Test mode the PEM can be commanded directly by means of the MTC_PEM_Command_Word without any control by the ME. Thus such a mode is extremely useful if we need to overcome the ME controls or if we need to check some specific behaviour of the M channel.

During M_Test the M-cooler could be in any state.
The M science telemetry data format can be anyone as the science data are downloaded from M in the same way as a normal science mode (full frame for Vis and IR).

3.6.3 H Test Mode

The description given above for the M_Test mode is essentially valid also for the H_Test mode. However there is a limitation in the H science telemetry data format. In fact, as the Pixel Map is not used, the full IR frame is transferred to the ME and thus H shall always produce an H_Image_Slice.

3.7   Annealing Mode

Both IR detectors, for M and H, can be annealed however the specific procedure adopted is different for the two channels.

3.7.1 M_Annealing

The MTC_Annealing command is used to start or stop annealing of the M-IR detector. The M cooler must be off while the PEM-M must be powered on before commanding the annealing.

 If annealing is started, the following procedure is performed:

1. the M-PEM is commanded by M_IR_DETECTOR_OFF
2. the M-PEM is commanded by M_IR_ANNEALING_ON
3. the M-Mode is changed to M_ANNEALING
4. the M_IR_TEMP PEM-HK are monitored every 10seconds and the M_IR_TEMP is checked against the M_ANNEAL_LIMITS (given by the ACTUAL functional parameter). If the M_IR_TEMP is 5K over M_ANNEAL_LIMITS the PEM is commanded by M_IR_ANNEALING_OFF and the annealing sequence is stopped.
5. Otherwise the PEM-M shall perform autonomous temperature control regulating the heater power to achieve the M_ANNEAL_LIMITS temperature.
6. The ME shall remain in the annealing mode until one of the following cases is verified
   - a MTC_Annealing(Stop) command is received
   - a time-out (given by M_ANNEAL_TIME_OUT in ACTUAL functional parameter) is reached.
7. The PEM is then commanded by M_IR_ANNEALING_OFF and the M-Mode M_ANNEALING is left.

Before issuing the MTC_Annealing command we must specify in the MTC_Change_Functional_Parameters, the temperature set point (parameter M_ANNEAL_LIMITS) and the maximum time for the annealing heater to be powered (M_ANNEAL_TIME_OUT).

3.7.1.1 M_Annealing sequence example

Starting from the condition (ME=idle, M=On, H=Off), to activate the annealing of M we shall issue the following commands:
- MTC_Change_Func_Param_RAM all default parameter values except:
  - M_ANNEAL_LIMITS   = required temperature set-point (max 38C)
  - M_ANNEAL_TIME_OUT   = required time out (max 255 minutes)
- MTC_ANNEALING with parameter = 1 (START)

The instrument shall go in the condition (ME=idle, M=Annealing, H=Off),
- Wait for the required time
- MTC_ANNEALING with parameter = 2 (STOP)
- The instrument shall return to the condition (ME=idle, M=On, H=Off).

3.7.2   H Annealing

For H the sequence is rather similar to the H, however there is an essential change as the heater control is performed by the ME and not by the PEM-H.

The HTC_Annealing command is used to start or stop annealing of the H-IR detector. The H cooler must be off while the PEM-H must be powered on before commanding the annealing.

 If annealing is started, the following procedure is performed:

1. the H-detector is commanded OFF
2. the H-Mode is changed to H_ANNEALING
3. The detector temperature is checked every H_ANNEAL_CHECK_PERIOD seconds, if the Detector temperature is lower than H_ANNEAL_TEMP (the temperature to be reached during annealing), the annealing heater is powered.
4. The ME shall remain in the annealing mode until one of the following cases is verified
    o a HTC_Annealing(Stop) command is received
    o a time-out (given by H_ANNEAL_TIME in ACTUAL functional parameter) is reached.
5. The M-Mode M_ANNEALING is then left.

Before issuing the HTC_Annealing command we must specify in the HTC_Change_Functional_Parameters, the temperature set point (parameter H_ANNEAL_TEMP), the maximum time for the annealing heater to be powered (M_ANNEAL_TIME) and the detector temperature monitor interval H_ANNEAL_CHECK_PERIOD.

3.7.2.1 H_Annealing sequence example

Starting from the condition (ME=idle, M=Off, H=On), to activate the annealing of H we shall issue the following commands:
- HTC_Change_Func_Param_RAM all default parameter values except:
    o H_ANNEAL_CHECK_PERIOD   = required monitor interval (max 255 s)
    o H_ANNEAL_TEMP   = required temperature set-point (max 80C)
    o M_ANNEAL_TIME   = required time out (max 255 minutes)
- HTC_ANNEALING with parameter = 1 (START)
The instrument shall go in the condition (ME=idle, M=Off, H= Annealing),
- Wait for the required time
- HTC_ANNEALING with parameter = 2 (STOP)
- The instrument shall return to the condition (ME=idle, M=Off, H= Annealing).

3.8   Cool-Down Modes

M and H Coolers can be operated together or separately. Moreover, for each cooler we can power either only the CCE (Cooler Control Electronics) or the CCE plus the Motor itself. The following conditions apply:

Mode	CCE	Motor
Off	OFF	OFF
Stand-by	ON	OFF
Closed Loop	ON	ON
Open Loop	ON	ON

The Stand-by mode is used to check the CCE electronics, no actual cooling is performed as the motor is powered off.

The <u>Closed Loop mode</u> is the selection when working in nominal conditions. In this case the parameter passed to the ME is the temperature set point. Every 10 sec the ME shall check the cold tip temperature of the cooler against the set point temperature to verify reaching of steady state conditions.

The <u>Open Loop mode</u> is used in case of failure of the Closed Loop mode. In this case the parameter passed to the ME is the motor rotation speed. While in Closed Loop the speed of the motor is varied according to the temperature conditions reached, in Open Loop the motor speed is kept constant throughout the operation sequence.

When Closed Loop or Open Loop modes are selected, the VIRTIS SW shall control the mode progress as follows :

1. At each H/K acquisition, the VIRTIS SW shall check the H/K of the coolers which are On

2. If a cooler is in Close Loop and the measured temperature matches the commanded one within 1.5°C, the "Cool_Down_End_Success" Normal Progress Event (service 5,subtype 1) shall be reported to the S/C and the cooler is said to be in Steady State.

3. If after a predefined time of 2 hours the target temperature (i.e. the commanded temperature for Closed Loop cool-down or the 80K temperature for Open Loop cool-down) has not been reached (within 1.5°C), the "Cool_Down_End_Failure" Warning Event Report (service 5, subtype 2) shall be reported to the S/C.

4. When the cooler Steady State is reached, the VIRTIS SW shall monitor the measured temperature to verify that it is equal (within 1.5°C) to the target temperature (i.e. the commanded temperature for Closed Loop cool-down or the 80K temperature for Open Loop cool-down); if this check fails, the "Cooler Steady State failure" Warning Event Report (service 5, subtype 2) shall be reported to the S/C.

When the Cooler operations are started the corresponding channel mode shall be reported "Cool-Down" in the Default H/K.

Moreover, if a PEM is powered on when the respective Cooler has not yet reached the operative temperature, the instrument mode shall remain "Cool-Down". On the contrary, if the Steady State condition has been reached the powering of the PEM shall cause the instrument to perform a transition to the "Idle" mode.

This is summarised in the next table:

PEM (M or H)	Cooler (M or H)	Resulting (M or H) Mode
Off	Off	Off
Off	Cool Down	Cool Down
Off	Steady State	Cool Down
On	Cool Down	Cool Down
On	Steady State	Idle
On	Off	On

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/operation of the instrument. Also some disposition from closed NCR have been added

4.1.1   Thermal limitation on ME usage.

According to the latest TV qualification test performed on the ME PFM (refer to VIR-KAY-RP-079), the FM can be operated at 50°C TV environmental conditions in nominal power mode with both VIRTIS M and H modules running simultaneously. The ME FM can be operated at 60°C TV conditions only in the so-called 70% power mode, i.e. either VIRTIS-M or VIRTIS-H is running.

In reduced power mode, to minimise the thermal stress to the ME PS, VIRTIS-H should be operated only with the Main DHSU (main power) and VIRTIS-M should only be operated with the Redundant DHSU (redundant power). The rationale for this lies in the fact that VIRTIS-H DC/DC transformer is farther away from the H-CCE and viceversa for the M DC/DC, thus we can avoid hot spots.

However, we must also take into considerations that the overall VIRTIS qualification was performed in Officine Galileo with VIRTIS-M and VIRTIS-H PFM and with the ME QM. This has caused several failures summarised in the NCRs; RO-VIR-NCR-43/45/48/49/54. The disposition for these NCR is the following:
VIRTIS has been qualified only up to 45°C, for both Full Power and Reduced Power conditions; thus the maximum operational temperature for VIRTIS shall be considered 35°C. At any rate being all these NCRs caused by PS malfunctions the first paragraph statement should apply and operations should not be affected by these NCRs.

4.1.2   High Speed Link Disconnection

Due to a bug in the IEEE1355 chip, when the link is disconnected by SSMM we have to go through a full VIRTIS reset operation. That is:
- VIRTIS is sent to Safe Mode (TC_Enter_Safe_Mode command)
- Secondary boot is performed (TC_Enter_Idle_Mode command)
- The HSL is started again (TC_Reset_And_Start_HSLink)

4.1.3   Incorrect House Keeping reading (NCR RO-VIR-NCR-0038)

As specified in the mentioned Non Conformance Report, the reading of the H/K value of the M_Grating_Temperature parameter in the MTM_PEM_IR_HK_Report (3,25) telemetry is wrong due to a malfunction of the relevant thermistors inside the Optics Module. The value must not be considered valid.

4.1.4   No event report of successful Primary Boot

Upon power-on VIRTIS shall perform the download of the PROM S/W to RAM, and shall initialise the ME (Primary Boot). At the end of the primary boot the ME shall be in Safe_Mode. However, no event report has been anticipated to signal the end of execution of this command. Moreover, no H/K is sent until completion of the synchronisation to the S/C SCET, by means of TC_Accept_Time_Update. If not synchronised within 60s the instrument shall start with a SCET of 0x8000000000.

4.1.5   Event RUNS Unsynchronised

This event is issued only when a accept_time_update is issued after 60s. Is sent as an answer to an improper time update. ruivedere

4.1.6   Offset in PS/DPU temperature readings (RO-VIR-NCR-0049).

For unknown reasons, on the Redundant Power line, when the H cryocooler is powered on an offset in the temperatures reading of the PS and DPU temperatures is added. See table

	PS Temp (°C)	DPU Temp(°C)
H Cryocooler OFF	T=T0	T=T1
H Cryocooler ON	T=T0+4	T=T1+3

4.1.7   Software versions

The EEPROM Software has been updated throughout the life of the instrument to cope with malfunctions (NCRs) and new requirements arisen during the instrument usage. On the contrary the PROM S/W version has been fixed very early in the program and we were able to keep the same version.

Throughout all the calibrations, before instrument delivery to ESTEC, the following S/W versions have been used:
- PROM   version V2.0-1
- EEPROM   version V3.4
- EGSE software   version V6.2

The EQM S/C hosts the EQM instrument which carries the following S/W versions
- PROM   version   V1.1-1
- EEPROM   versions: V3.6 (address 0x20078000) and V3.5.4 (address 0x20000000) on both Main and Redundant

The PFM S/C hosts the PFM instruments which had the following versions
      November 2001 – May 2002
- PROM   version   V2.0-1

- EEPROM   versions: V3.5.4 (address 0x20000000) on both Main and Redundant

This has been used throughout the TB/TV tests on the S/C.

    June 2002 – August 2002
- PROM   version V2.0-1
- EEPROM   versions: V3.5.4 (address 0x20000000) and V3.6 (address 0x20078000) on both Main and Redundant

This has been used during SFT and SVT1

    August 2002 - Launch
- PROM   version   V2.0-1
- EEPROM   versions: V3.6.1 (address 0x20000000) and V3.6 (address 0x20078000) on both Main and Redundant

Used during SVT2, and also during the new launch campaign.

4.2 Ground Operation Plan

The ground test plan along with the specific procedures is given in the PFM System Level Test Specifications and Procedures (RO-VIR-TS-002 issue 1)

In the present document we need to 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. Typical operating temperatures are in the region of 130K. 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:

1. 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.
2. Test carried out inside the TV chamber (Thermal Vacuum and Thermal Balance tests). Under proper environmental conditions also performance measurements can be executed. We propose to run the internal calibration procedure as well as a test routine for the Scan Mirror Unit.

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4.3 Flight Operation Plan TO BE REVISED ACCORDING TO THE NEW LAUNCH.

The Rosetta mission is characterised by different mission phases identified and described in some details in AD1 volume VI and in AD3. In what follows we have summarised the scientific objectives in each phase, giving an indication of the activities to be carried out and of the operative modes, of the data volume produced and of the expected power consumption. We took into consideration the latest information from ESOC contained in AD4 through AD7 regarding the first mission phases (commissioning, cruise, planets swing-bys and asteroids fly-bys), while for the comet phases a revision shall be performed later on.

The instrument power dissipation, see chapter 2.3, by the Main Electronics Module is such that full operation (both channels M and H working at the same time) of the instrument cannot be guaranteed for heliocentric distances below 1.4 AU. Thus it has been agreed to reduce the power dissipation of the Main Electronic Module by a 30% allowing only single channel acquisition. It has been also agreed with the ROSETTA Project Office that in case of over-temperature conditions shall be VIRTIS responsibility to take actions to prevent damages to the S/C and to the instrument.

A word of caution must be added regarding the description (activities, data volume and data rates) of the phases after the Commissioning and Cruise, as a thorough reanalysis of them is being carried out by the team.

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 (ALICE, MIRO, OSIRIS and NAVCAM). In the present ESOC plan (see AD 4) 5 full days are allocated for Functional Test, 5 days for Interference Test and 2.5 weeks for the instruments co-alignment.

Critical operations are conducted during ground station passes (about 7 hours duration) with an immediate feedback to ground; less critical activities can be carried out outside these periods uploading a sequence of TC to be executed autonomously by the DMS (using Mission Time Line).

The overall data volume of the commissioning activity is given by summing the VIRTIS functional tests, plus calibration sequence plus the VIRTIS co-alignment procedures (described in the following). The overall result is **699.5 Mbit plus about 250 Mbit for functional tests (TBC).**

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 (see chapter 3.4) 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

During the VIRTIS Functional Tests campaign we shall exercise all the instrument functions, all the mechanisms and we shall check the instrument performances variation as a function of various internal conditions (change in calibration lamps voltages, change of IR detector temperatures) to demonstrate that after launch all the instrument functions have not been degraded. We shall have to:

❖ <u>Verify all Services</u>. All services must be checked, however, the following distinction is valid:

- Service 9   Time Management
- Service 17   Connection Tests

Are executed during the POWER-ON OBCP. No need to be repeated.

- Service 255   Common Payload Private TCs

One TC belonging to this service is executed, and hence verified, at POWER-ON (TC_Reset_And_Start_HSLink). The rest needs to be checked.

- Service 1   TC Acknowledge
- Service 3   H/K Reporting
- Service 5   Event Reporting
- Service 20   Science Reporting
- Service 192   Common Private TCs
- Service 193   VIRTIS-M Private TCs
- Service 194   VIRTIS-H Private TCs

These service shall be verified when performing Science Acquisition and Calibration, moreover they have been extensively tested on ground (IST and S/C TV) so there is no need to re-test them here.

- Service 6   Memory Manag. + Service (192,13) GET_EEPROM_STATUS

This service must be verified explicitly in this procedure as it is a PROM S/W only activity and also is an essential capability of the instrument for S/W Patch upload.

The above considerations are summarised in the procedure VIR-CVP-001: Services Verification.

❖ <u>Exercise Acquisition modes</u>. We need to test acquisition in several M and H modes plus check the instrument/SSMM behaviour under limiting conditions.

- Maximum Data Rate: full detectors (M-VIS + M-IR + H), minimum repetition time, no compression, no scan.

- Maximum Data Processing: M+H max binning modes, minimum repetition time, lossy compression, scan on.

- Nominal M+H mode with default parameters

- Nominal M Science with default parameters

- Nominal H Science with Default Parameters

❖ VIRTIS-M/H additional Modes Test. It is required to test several additional operative modes. A procedure is listed in the commissioning phase plan but the detailed procedure description and the parameter values are still TBD.

❖ Scan Unit Test. While covers and cryocoolers shall be tested in the framework of the internal calibration, the scan unit must be tested independently. Commanded angle Vs measured angle, operation with various starting/ending points and various step sizes, etc.

❖ VIRTIS-H Pixel Map. As part of the VIRTIS-H testing we require to upload a new pixel map (the list of coefficient used to calculate the coordinates of those pixels to be analysed by the ME) and a bad pixel map.

❖ Cryocooler temperature calibration . We shall select three temperatures in Closed Loop mode (70-80-90K) and 3 cooler motor speeds (1500,2200,2800 rpm) for each detector and monitor the detector and cold finger temperatures

❖ Science Data Transfer via RTU. Check IST for a template of mode implementation

❖ M Internal Calibration. This shall be carried out under various conditions of lamp current. For M every internal calibration cycle takes about 30min. The values shall be

	Minimum (mA)	Nominal (mA)	Maximum (mA)
IR Lamp	94	100	109
VIS Lamp	240	250	254

❖ H Internal Calibration. Also in this case we shall perform several calibration run with different values of the parameters. At present we are not able to define the details of this procedure but it shall be very similar to the one for M. It is listed in the commissioning phase plan and a template is reported in the detailed procedure description but the parameter value are still TBD.

❖ MAIN / REDUNDANT power channel. All the above procedures are performed on the MAIN Power Channel. A limited number of tests shall be performed on the redundant channel:
   o In-Flight Calibration with nominal parameters.
   o Science data transfer via HSL
      ▪ Maximum Data Rate
      ▪ Maximum Data Processing

- o Science Data transfer via RTU
- o Cryocooler temperature calibration

4.3.1.2 Interference Tests

The interference Test detailed modalities shall be agreed with SOC.

However, as a preliminary input we anticipate to induce disturbances on other instruments due to:

1. Mechanical vibrations   >> Cryocooler on MIDAS
2. EMC due to intensive operations >> max data rate/ max data processing.

In principle we could be also subjected to EMC noise from other instruments to check this VIRTIS shall be placed in nominal acquisition mode while other instruments perform their "noisy" activities.

4.3.1.3 Internal Calibration Sequence

The VIRTIS-M calibration procedure is divided in 7 phases which are summarised in table 4.1. 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 4.2) 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	Duration (s)
0	Close	Open	OFF/OFF	0.0 / 0.0	Read-Out Noise	151
1	Close	Open	OFF/OFF	0.5 / 1.0	Background VIS+IR	120
2	Close	Close	OFF/OFF	0.5 / 1.0	Dark VIS+IR	60
3	Close	Open	ON/OFF	0.5 / 20.0	IR acquisition +VIS	180
4	Close	Open	OFF/ON	0.1 / 1.0	VIS Acquisition + IR	84
5	Close	Close	OFF/OFF	0.5 / 1.0	Dark VIS+IR	60
6	Close	Open	OFF/OFF	0.5 / 1.0	Background VIS+IR	120

Table 4.1 VIRTIS-M calibration phases sequence. **Total duration 775 sec on HSLink; 2134 on RTU.**

Phase	Cover	Shutter	Slit	Telescope	Radiometric	Mode

#			Lamp	Lamp	Lamp	
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 4.2 VIRTIS-H calibration phases sequence. **Total Time 274s on the HSLink; 448 on RTU**

Additionally, we shall also perform measurements of external dark opening the cover. For VIRTIS-M one 64x64 image acquisition in nominal mode requires 18.9 Mbit uncompressed (including one dark every ten slices). 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**.

Thus, the presently envisaged full calibration plan is given in table 4.3

A full calibration sequence lasts up to 3 hours depending on the environmental conditions.

OPERATION	TIME (*) Minutes	DATA VOLUME Mbit	AVERAGE POWER Watts	COMMENTS
Power ON	-	-	9.8	
Instrument Settings	5	0.1	9.8	Only housekeeping
Instrument Checkout	5	0.1	49.2	Only housekeeping
Cool Down M+H	130	0.1	57.9	Only housekeeping
Calibration M+H	5	28.2	65.8	
Cover open	1	0.1	65.8	Only housekeeping
(M+H) Science	30	112.1	65.8	10 x (Dark + Space)
Cover close	1	0.1	65.8	Only housekeeping
Instrument Checkout	5	0.1	49.2	Only housekeeping
Power OFF	-	-	-	
TOTALS	180	140.5		

(*) Timing is still an approximation. Proper timing shall be measured on the PFM.

Table 4.3 Full calibration plan

4.3.1.4 VIRTIS-M / Spacecraft alignment

Based upon the orbital position and the solar angles, a standard star is chosen and the spacecraft positioned within its APE to view the star. Therefore, we shall need to perform

a scan of about 0.6 degrees (twice the APE) around the –M boresight in order to find the reference star; if we work in the high spatial resolution mode each step shall be of 0.250 mrad and thus 64 steps shall be needed and hence 64 slices. Translating this in data volume we get (64+6)x256x144x2x16 = 83 Mbit.

However, as we expect to image regions with multiple stars in the full FOV of the instrument we shall take several full FOV images of selected sky regions to co-align also with the other remote sensing instrument and to define our geometric distortions if any. A single slice is composed of 256x144 pixels for each detector, and a full FOV is made of 256 slices. We must then add a dark acquisition every 10 science acquisitions (on average) for both detectors. Thus, each full acquisition shall be composed of (256+25)x256x144x2x16=330 Mbit. We shall multiply by three this data volume as at least three different acquisitions shall be needed. We shall then produce 990 Mbit

When compressed by a factor of 2 the overall VIRTIS-M alignment procedure shall produce **537 Mbit.**

4.3.1.5 VIRTIS-H / Spacecraft alignment.

VIRTIS stability shall be such that the two channels shall be aligned within ½ -M high resolution pixel (125 μrad), and will remain aligned after launch vibrations. However, as the in flight co-alignment procedure is autonomously performed we cannot use the previous knowledge on the star location to have the S/C drifting (with an error in pointing proportional to RPE) to the real star position. Thus, we shall need a S/C scan over a square of 0.6 x 0.6 degrees (twice the APE) in steps of one -H FOV (0.450 mrad). This translate in 576 -H slices, in the **-H Only Science Mode** (approx. 55kbit each slice). The total data volume shall be **22.0 Mbits**.

4.3.1.6 VIRTIS / Other remote sensing instruments co-alignment

As before the launch the imaging experiments will be co-aligned with an accuracy of 7' (2.1 mrad or 4 -H pixels) for instrument mounted on the same panel (VIRTIS Vs OSIRIS) or 11' (3.3 mrad or 8 -H pixels) for instruments on different panels (VIRTIS Vs NAV, ALICE, MIRO), and as the combined VIRTIS IFOVs are the smallest of all the above instruments, when aligning VIRTIS Vs S/C with a known star, the same star will fall inside the FOV of the other instruments; thus, VIRTIS -H and -M will be simultaneously co-aligned with the other imaging instruments.

4.3.2 Cruise Phases

During the six cruise phases VIRTIS is generally switched off, as other experiments, with the exclusion of periodical testing of VIRTIS which include the calibration sessions.
ROSETTA Project Office has anticipated a sequence of 12 check-out sessions (see AD6), two for each asteroid fly-by one for each planet gravity assist and the remaining 5 to be performed during Cruise Phases 1 (three check-out sessions), 4 and 6.
When activated during the Cruise Phases check-outs VIRTIS shall perform the full calibration sequence described in paragraph 3.3.1.1 above.

4.3.3   Mars Gravity Assist

The main purpose of the activity in this phase shall be to test the performances of the two channels of the instrument and to perform an extended calibration section. Interesting science can also be performed if the encounter configuration is favourable. A test of the several implemented compression algorithms shall be also performed.
The planet encounter sequence is defined in AD5. Close encounter speed is 7.3km/s while the minimum distance shall be of 200km.
P/L scientific activity is limited to the post swing-by phase starting from closest approach t_0 up to t_0 + 1day. Moreover,
Full calibration, see paragraph 3.3.1.1, shall be performed before and after scientific observations.

For the –M Mapper channel, the high ground relative speed at close encounter will impose the use of the scan mirror to avoid image smearing during integration. The minimum selectable repetition rate is 5s, which implies that at minimum distance from the planet the Mapper will acquire unconnected slices rather than images. This will be true up to around t_0 + 30min. For the next 15 minutes the repetition rate of 5s shall allow acquisition of 3 images in the nominal mode (se figure 3.1). For later times repetition rate must be decreased to avoid over-sampling. Changing the repetition rate to 20s, will allow to continue acquisition of connected images (in pushbroom mode) up to 100m after close encounter. Planet rotation has not been considered in view of the short overall time.

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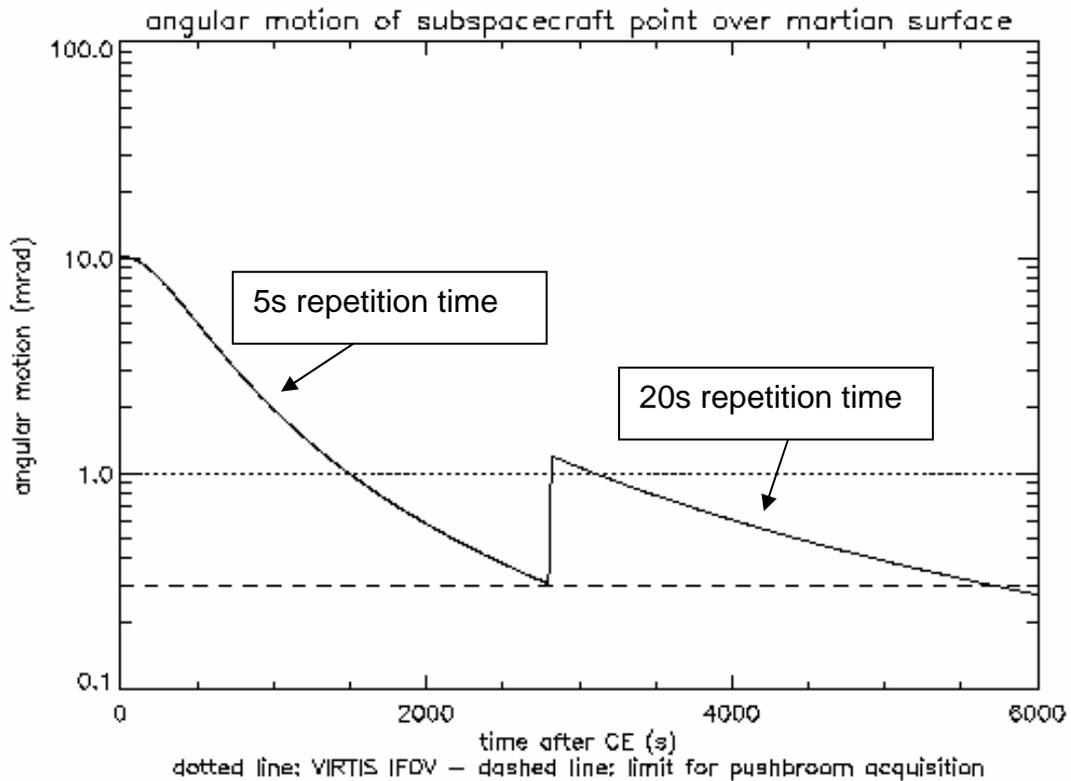
Figure 4.1. Variation of the angular motion of the surface track as a function of the time after Close Encounter. The dotted line represent the size of the VIRTIS IVOF in nominal mode, while the dashed line is the selected limit for pushbroom acquisition. A ground track angular motion larger than 1 mrad produces unconnected slices, while an angular motion below the inferior limit produces over-sampling.

As far as –H is concerned we can assume for the moment a run-along activity with one spectrum every –M repetition. Thus, during the pushbroom phase VIRTIS shall be working in **(M+H) Nominal Mode**.
At increasing distances the –M mirror shall be used to produce images at High spatial and spectral resolution; we shall collect 256 slices in the **(M+H) high spatial operative mode**, followed by 64 slices in the **(M+H) high spectral operative mode**. This will produce two -M data cubes, while for -H the large redundancy will increase the SNR*.*

Start time	End time	Instrument mode	Total slices (#)	Data volume (Mbit)
CE - TBD	CE - TBD+3h	Full calibration		150.7
CE	CE	Set repetition rate to 5s		
CE	CE + 47m	M Nominal (144kbit)	560	80
		H Nominal (14kbit)	560	8
CE+47m	CE+47m	Switch to repetition rate 20s		
CE+47m	CE+100m	M Nominal (144kbit)	160	23
		H Nominal (14kbit)	160	2
CE+100m	CE+1d	M High Spatial Res (600 kbit)	256	154
		H Nominal data rate (14kbit)	256	4
		M High Spectral Res (430 kbit)	64	28
		H Nominal data rate	64	1
CE+TBD	CE+TBD+3h	Full Calibration		150.7
			TOTAL	**601.4**

Table 4.4 MARS swing by operations after Close Encounter (CE)

4.3.4   Earth Gravity Assists

Characteristics of the Earth swing-bys are given in AD5 and summarised as follows:

EARTH SWING_BY DATA				
	Swing-by date	Speed Km/s	Distance (km)	Data Rate (kbps)
Earth1	28/11/2005	9.2	4511	20.57
Earth2	28/11/2007	9.6	1374	20.57

Table 4.5 Swing By data

The first Earth swing-by shall allow scientific measurements to be started 1h45m before CE lasting until 1d after CE (TBC from ESA), while the second is more favourable with a operational activity starting 6h before CE and lasting until CE plus 1d (see AD5).
As a first approximation we can assume to perform the same operations performed during the Mars swing-by. However the integration time will be much shorter due to the high albedo of the oceans and of the clouds. Observation of the Earth's atmosphere will allow accurate spectral calibration of both channels.
Capability of operating before the CE will allow us to add a pre-encounter session where the –M mirror shall be used to produce images at High spatial and spectral resolution; we shall collect 256 slices in the **(M+H) high spatial operative mode**, followed by 64 slices in the **(M+H) high spectral operative mode**. This will produce two -M data cubes, while for -H the large redundancy will increase the SNR. Moreover, we could follow in pushbroom mode using **(M+H) Nominal Mode** and a repetition rate of 5s. The new preliminary observation sequence for the two Earth swing-bys is given in table 3.6

Start time	End time	Instrument mode	Total slices	Data volume

			(#)	(Mbit)
CE – TBD	CE - TBD+3h	Full calibration		150.7
CE - 1h45m	CE-1h15m	M High Spatial Res (600 kbit)	256	154
		H Nominal data rate (14kbit)	256	4
		M High Spectral Res (430 kbit)	64	28
		H Nominal data rate	64	1
CE - 40m	CE + 40m	M Nominal (144kbit)	960	140
		H Nominal (14kbit)	960	14
CE+40m	CE+40m	Switch to repetition rate 20s		
CE+40m	CE+100m	M Nominal (144kbit)	180	26
		H Nominal (14kbit)	180	2.5
CE+100m	CE+1d	M High Spatial Res (600 kbit)	256	154
		H Nominal data rate (14kbit)	256	4
		M High Spectral Res (430 kbit)	64	28
		H Nominal data rate	64	1
CE+TBD	CE+TBD+3h	Full Calibration		150.7
			TOTAL	**857.9**

Table 4.6 Earth1 and 2 swing by operations.

4.3.5   Asteroids Flybys

The flyby data for the two asteroids are given in table 4.7. The source of information for the present asteroid fly-by strategy is given in AD7.
The present observation strategy identifies three S/C phases
- Approach phase   from 5months (3 for Siwa) to 6hours from CE
- Asteroid into Fly By mode   from 6h before CE to 20minutes after CE
- Post flyby phase   from 20minutes to 2months after CE

FLYBY DATA						
Asteroid	**Flyby Date**	**Sun distance (AU)**	**Earth distance (AU)**	**Relative speed (km/s)**	**CE distance (km)**	**Science DL rate (Kbps)**
Otawara D = 5.5km P = 2.7h	11/07/2006	1.90	1.30	10.6	2183	20.57
Siwa D = 110km P = 20h	24/07/2008	2.75	3.11	17	3500	ASTA 20.57 ASTP 12.85

Table 4.7 Asteroids Fly-By data

when the asteroids are first detected (we shall need to scan around the bore-sight direction to identify the asteroid) and are point-like sources VIRTIS shall perform measurements of: a) light curve (geometrical properties); b) phase curve (physical properties); c) integrated spectrum (composition).
Full view of the asteroid will allow multispectral imaging of the surface in order to identify their mineralogical composition. At closest approach when the ground speed is higher

VIRTIS shall perform a motion compensation, by means of the –M scanning mirror, either to observe the same point on ground and to provide connected slices (images).

In the fly-by description which follows we shall suggest few modifications to the proposed Operations timeline as given in AD7.
Common S/C requirements for both fly-bys are that:
- co-alignment among S/C-VIRTIS-NAV has already been performed.
- the S/C should guarantee the pointing stability (according to AD1)
- The S/C must be capable of performing Nadir pointing during all fly-by phases.

4.3.5.1   AST1A - Otawara Approach Phase and Close Encounter

The present Operations timeline (AD7) anticipates a full calibration few months before encounter.
We shall divide the overall approach and close encounter phases in three parts:

1. This asteroid will be visible with VIRTIS-M in the IR range at about 0.15 millions of km (about 3 hours before encounter with linear approximation). Before 0.15 millions of km we 'll start the VIRTIS initialization, at about 7 hours before the C.E. VIRTIS will perform a full calibration sequence. This procedure will take about 3 h.

2. The asteroid will fill up the VIRTIS IFOV at a distance of about 22000km (diameter about 5.5km). Between about 150000 km and 22000 km the asteroid is subpixel. In this range of distance only VIRTIS-M (both channels) will operate. We intent to use the mode reduced slit (64x144) with 10 scan (10 slices:+/-5 scan around boresight), to be quite sure that the asteroid is in the VIRTIS image (APE S/C). According to the signal that we expect, any images should be acquired with different integration time (VIS and IR) and repetition time. We foresee the following sequence until the asteroid is sub-pixel (about 22000 km or 30 min before C.E.)

3. At about 22000 km, Otawara will fill the VIRTIS M IFOV. The asteroid will grown to fill about 10 pixel at C.E. Due to the small asteroid size and the large distance of the C.E., VIRTIS will acquire contiguous slices. VIRTIS will use the scanning mirror to acquire the full disk of the asteroid. From 22000 km before C.E. also VIRTIS H will be used to acquire spectra of Otawara. From about 30 min before C.E. to 10 min before C.E. VIRTIS M will acquire images in mode reduced slit with 10 scan (10 slices:+/-5 scan around boresight). About 10 min before C.E., the asteroid will fill 5 pixels. From 10 min before C.E. and the end of asteroid fly by, about 16 min after C.E., VIRTIS M will acquire images in mode reduced slit with 20 scan (10 slices:+/-10 scan around boresight).

Start time	End time	Instrument mode	Total slices (#)	Data volume (Mbit)
CE – TBD Months	CE – TBD months+3h	Full Calibration		150.7
CE - 4h	CE-30m	M Reduced Slit - Repetition rate 20s	2460	88.6
CE – 30m	CE + 16m	M Reduced Slit H Nominal	300 540	44.0 7.8
CE+TBD weeks	CE+TBD weeks +3h	Full Calibration		150.7
			TOTAL	**441.8**

Table 4.8 Otawara Operations.

4.3.5.2 AST2A - Siwa Approach Phase and Close Encounter.

Siwa could be detected at about 70 millions of km, at 1.68 μm with an integration time of 10 sec. The rotation period of the asteroid is 20h, to study its light curve and hence its rotational properties, we shall need to observe it for at least several rotational periods. Moreover, for the study of the phase curve, these measurements shall be repeated, several times (of the order of 10) after a significant amount of time from each other, to allow for observations under different phase angles
For the measurement of the asteroid light curve, a measurement frequency of a cube in (M+H) Low Data Mode every 15 minutes approx. with an integration time of few seconds, shall be required. Being the period of Siwa of about 20hr, a total of 80 cube shall be needed to cover a full asteroid rotation. If we include the observations for the Phase Curve we end up with a total of 800 cubes during the pre S/C Fly-By Mode. We need to remind here that each cube will contain only few lighted pixels, thus the compression factor could be twice the factor assumed here.

 The asteroid will fill up the VIRTIS high spatial resolution IFOV at a distance of 450.000 Km (about 7h before CE). However, until a distance of 35000 km the slow angular speed of the S/C shall prevent the use of pushbroom mode. We shall keep acquiring data cubes in the M_Science_Slit_Reduced mode, with a frequency of one cube every 15 minutes. This will yield about 20cubes, or 320slices.

From the 35000km, or 35m before CE, we shall start acquisition in pushbroom mode, for the first 15 minutes the S/C motion doesn't need mirror compensation while from –15m to +10m we shall need to use the internal mirror to compensate for the high relative ground speed. However for the data volume calculation we can assume continuous operations with a repetition rate of 5s.

Start time	End time	Instrument mode	Total slices (#)	Data volume (Mbit)
CE – TBD months	CE – TBD months +3h	Full calibration		150.7

CE - 50d	CE- 6h	M Slit Reduced mode (36 kbit)	12800	460.8
		H Nominal data rate (14 kbit)	12800	179.2
CE – 6h	CE – 35m	M Slit Reduced mode (36 kbit)	320	11.5
		H Nominal (14 kbit)	320	4.5
CE - 35m	CE + 10m	M Nominal (144kbit)	540	77.8
		H Nominal (14kbit)	540	7.6
CE+TBD	CE+TBD+3h	Full Calibration		150.7
			TOTAL	**1042.8**

Table 4.9 Siwa Operations

4.3.5.3   AST2P - Siwa post fly-by Phase.

Contrarily to Otawara AD7 doesn't include direct asteroid observations after CE + 10m. For this reason we have included only the full calibration as activity to be performed in the post fly-by phase, see table 3.9.

4.3.6   Comet Far Approach Phase.

In this phase we expect to acquire the comet for the first time at a distance which depends on the albedo and the temperature of the object itself. For the typical Wirtanen parameters, given in table 4.9, and assuming a 10 s integration time the comet can be detected from 70000 km to 40000 km depending on the wavelength selected for the observation. As soon as the comet is acquired, the spectral phase curve can be performed. This will be important in order to create a reference case to be compared with the ground based observations. As far as -H is concerned we foresee one observation per day using a long integration time in order to search for early cometary emissions (CO and H_2O).
In this phase the comet fills only one pixel of -M and with the given S/C APE we should use the mirror to acquire a cube and thus to have the certainty of having the comet inside the VIRTIS FOV (only -M). The two channels will be used separately in order to optimise the observation strategy and reduce the S/C resources usage.

A measurement frequency of a cube in **M only Low Data Mode** every 5 minutes approx. with an integration time of several seconds for each slice and 16 slices for each cube, shall be required. Being the rotation period of about 7hr, a total of 84 cubes shall be needed to cover a full comet rotation. For the phase curve, these measurements shall be repeated, several times (of the order of 5) after a significant amount of time, to allow for observations under different phase angles. With these parameter selection we will get a total of about **248.0 Mbytes.** It must be remembered that a very large data compression factor shall be obtained in this case as there will be only few illuminated pixels.
During the last part of this phase, that is when we will be closer to the comet, we intend to perform **-H Only Science Mode** measurements, for the early coma detection 1 hour integration once a comet rotation period. This should be repeated 10 times, and should begin at distances below 100 R_c. This will produce **0.3 Mbytes**.

4.3.7   Comet Close-Approach & Transition to Global Mapping Phases

During the close approach the VIRTIS scientific objectives are the early mapping of the nucleus surface and the observation of the nucleus surface under different illuminations and phase angle conditions with –M and the possible detection of a weak activity, performed with –H. The two channels will be used separately in order to optimise the observation strategy and reduce the S/C resources usage.

For –M we expect to make observations in **M only science High Spatial Mode** in order to achieve a resolution, at about 180 comet radii, of about 45 m. The field of view of –M, however is not completely filled: at the beginning of this phase the comet will fill only 30 pixel, while at the end it will be contained in about 160 pixels. We can then acquire a series of slices up to cover the comet. We shall acquire one cube of 32 slices average per day: this corresponds to **18.9 Mbytes per day (a total of 302.4 Mbytes will be produced).**
Additionally, for -H only we will continue for the early coma detection 1 hour integration once a comet rotation period. This should be repeated 10 times, and should begin at distances below 100 R_c. This will produce **0.3 Mbytes**.

4.3.8   Comet Nucleus Mapping and Close-Encounter

This phase begins when the spacecraft starts the approach to the close orbiting phase around the comet. According to the last EID-C, these phases will last about 32 days altogether. We have developed an orbital simulator to choose the optimal orbits for mapping purposes. The observation strategy for VIRTIS has been developed assuming the values for the P/Wirtanen nucleus and for the Rosetta spacecraft orbit as reported in Table 3.10
For the simulations is used as standard model of the nucleus a triaxial ellipsoid of mean radius R_mean= 0.78 km, as it has been recently suggested, and axes in the relative proportions a:b:c = 1:0.7:0.5. The rotation period has been assumed to be 7 hours. In the numerical simulation the nucleus has been approximated by 350 mass points with random deformations in density and surface shape. We have chosen a typical elliptical quasi polar orbit with periaster at 10 r_c and apoaster at 25 r_c, tilted in such a way to guarantee that the instrument axes will not look in the Sun direction, and with an inclination of the comet rotation axis of 30°. A delay time has been also considered in order to avoid oversampling. Few words of explanation are required here. In fact, in the previous versions (draft1 through draft5) of this document, we have computed the typical *data volume collected and the associated redundancy* without taking into account the VIRTIS -M and -H repetition times, because they were still to be defined. Now the minimum repetition time has been fixed to about 5 sec for –M. Moreover, we have imposed to acquire a new slice only when the sum of the repetition time and the integration time is smaller then the dwell time, but comparable to it. If the dwell time is much longer than the previous sum, then we have introduced a delay time, in order to acquire only when a new scene enters in the VIRTIS FOV.

PARAMETER	Typical value
SIZE (m) (average)	780
DENSITY (Kg/m^3)	500
MASS (Kg)	1.1 E 12
ROTATION PERIOD (h)	7.0

ALBEDO	0.04
a:b:c	1:0.7:0.5
Orbit apocenter	25 R_c
Orbit pericenter	10 R_c
Orbit Period (Days)	14.1
Node Line Angle	30.0
Inclination (deg)	30.0
Polar deviation(*) (deg)	12.0
Tilt (deg)[**]	45
Eccentricity	0.43

(*)   Polar deviation is the angle between the pole line and plane of the S/C orbit.
(**) Tilt is the angle between the comet-Sun direction and the S/C orbital plane.

Table 4.10 P/Wirtanen characteristics data

Under the above orbital and instrumental conditions in 32 days we cover about 85% of the nucleus surface, with a typical spatial resolution of 14 m for -M in the nominal mode and an average dwell time of about 80 s (by dwell time we mean the residence time of a spot on the nucleus in the IFOV of the two channels). However, 80% of the nucleus surface is covered in only 11.6 days, while we need additional 21 days to cover an additional 5%. This implies that to increase the coverage from 80% to 85% we introduce a large data redundancy; in fact, the average number of times we observe the same region of the surface is 4.97 in the first 11.6 days and increase up to 11.9 in the following 21 days. This holds true in both Nominal and High Spatial Resolution Modes. Thus, to optimise the observation strategy, we have performed a trade-off between surface coverage and data redundancy,   subdividing the total observing time into 3 periods of about the same length, in which we perform continuous observations in different operating modes, see also Table 3.11 with the detailed results:

M + H Science Nominal Mode. We shall devote the first part of the mapping phase to the maximum coverage of the nucleus surface in the nominal spatial resolution mode. From the modelling performed we cover 80% of the nucleus surface in 11.6 days with an average spatial resolution (with –M) of 14.25 m. Of course, the full coverage is obtained only with -M; for -H we expect to cover about 12.5% of the surface. The anticipated data volume shall be of **66.38 Mbytes uncompressed (about 5.72 Mbytes per day uncompressed).**

M + H Science High Spatial Mode. The 80% coverage is obtained in 11.72 days, with an average spatial resolution of 3.5 m and a data volume of **723.38 bytes (about 61.72 Mbytes per day uncompressed).**

M + H Science High Spectral Mode. We select a number of regions, among which the potential landing sites should be included, of the nucleus surface to be studied with higher spectral resolution in the remaining 9 days. We plan to study about 15 regions acquiring image cubes of 64 slices each, for a total data volume of **449.3 Mbytes (49.92 Mbytes per day uncompressed).**

Thus, over the 32 days of duration of this phase, we shall acquire a total of **1239.06 Mbytes (or 38.72 Mbytes per day uncompressed).**

MODE	Duration	Data Volume	Mean Dwell Time	Mean Spatial Resolution	Redundancy
	(Days)	(Mbytes)	(s)	(m)	
-M Nominal	11.60	46.38	77.4	14.25	0.50
-H Nominal	11.60	20.00	9.0	3.30	0.12
-M High Spatial	11.72	703.38	19.8	3.52	5.00

Table 4.11 Results of the Nucleus Mapping Phase simulation. 80% Surface covered

4.3.9   Coma Observation

Throughout the escort to perihelion phase, subdivided in many subphases in the EID-C, we will perform integrated and systematic observations of the cometary coma. A minimum distance to the nucleus of the order of 100 km is required. For the cartography of the coma, observations at several phase angles are needed to retrieve the spatial   distribution and the morphology of the coma. Long integration times also are needed to obtain spectra of minor constituents. The full escort phase will last 367 days, during which we will perform high spectral resolution observations with -H and observations combined of -H and -M for coma mapping. Coma mapping is also of interest for MIRO experiment, and a common observing strategy will be fruitful. A requirement for VIRTIS coma mapping will be to scan in two orthogonal directions, one axis being in the ecliptic plane, with 10 points in each direction (20 points total). This is a requirement to the S/C as -H does not have a the spatial scanning capability.

In what follows we give a description of the activities to be carried out, and an estimate of the data volume:

Limited Coma Mapping. VIRTIS shall require a cross of at least 10 points in each orthogonal directions, for a total of 20 points. It shall work in the **M+H Science High Spectral Resolution Mode.** It follows, that each scan shall be the collection of 20 slices (with 60 s integration time average), for a total of 9.36 Mbytes. The previous sequence should be repeated for 6 different distances from the nucleus, at same phase angle, and for 6 different phase angles at the same distance, to explore different shells within the coma and different phase angles. Thus, we shall acquire about 240 slices **a total of 112.32 Mbytes per map.** The map production shall take about 4 hours. A new map every four weeks (TBC) shall be needed.

Full Coma Mapping. If possible, a complete 2D mapping of the coma is foreseen as a design goal, with a square unit field of view of 10° x 10°, resulting in about 300 points on the sky. We will perform observations in the **M+H Science High Spectral Resolution Mode**. Thus, this strategy shall recquire **a total data volume of 140.4 Mbytes** and would be interesting also for MIRO observations. We are aware that this can be achieved only with complicated spacecraft operation, and it is not considered as a requirement.

Jets Observations. We shall map the molecular composition of the jets as it expands from the nucleus surface. To do so we shall require a scan, performed by the S/C, at increasing distances from the nucleus surface. If we assume as before 20 scan point, and observations in the **-H Only Science Mode**, we shall get 0.56 Mbytes per jet in about 20 minutes; additionally, if we perform 10 such scan per week we shall sum up a total of **5.6 Mbytes per week**.

Search for minor constituents. To do so we shall operate in **-H Only Science Mode** with very long observation times (i.e., 1 hour equivalent integration time for each slice). The observations shall be performed inside and outside the jets and shall be repeated once per week. The best observation location for this measurements is close to the limb of the nucleus. Assuming 10 observations inside the jets and 10 observations outside, we get a total of **0.56 Mbytes per week** in about 20 hours cycles.

Nucleus Observations. The goal of these observations is to search for variations of the nucleus after onset of gaseous activity. In particular, we shall perform a low resolution mapping of active and inactive regions in the **M+H High Spectral Resolution Mode**. We shall need a full cube (64 slices) once a week, thus producing a **data volume of 30 Mbytes per week uncompressed** in about 10 minutes operations.

In conclusion during the overall coma observation phases we shall acquire an average of **64.24 Mbytes per week** (the accumulated figure shall be of **3340 Mbytes**) working an average of 24.5 hours per week.

4.3.10 Mission Timeline

In Table 3.12 are summarised the major information relative to the present operating strategy, as detailed in the previous paragraph. In table are reported all the mission phases as identified in the EID-C, along with their expected durations. The third column represent the effective length of time in which the instrument is switched on, and the next 5 columns report the amount of time spent in each operative mode, in percent of the effective observing time duration. The other columns reports the average power, data rate (calculated over the total phase duration) and data volume expected in each phase.

Phase Name	Phase durat.	Effect. Obs. time	Operative Modes (% time in each)					Avg. P	Avg. Data Rate	Data Vol.	Acc. Data	Com- ments
	days	hours	Test & Calib.	M+H	M only	H only	Low Data	W	Kbit /sec	Mbytes	Mbytes	
Launch	2		-	-	-	-	-	0	0.00	0.00	0.00	
Commis-sioning	90	12.0	25.0	-	37.5	37.5	-	43.4	0.07	89	89	Test+Full Calibr.+ Alignement
Cruise 1	767	12.0	100.0					65.8	0.001	76	165	Full Calib. every 6 months (4)
Mars flyby	121	11.0	27.3	72.7	--	-	-	65.8	0.29	376.96	541.96	
Cruise 2	30	0.0	-	-	-	-	-	0	0.00	0.00		
Earth flyby 1	61	0.0	-	-	-	-	-	0	0.00	0.00		
Cruise 3	105	3.0	100.0	-	-	-	-	65.8	0.01	19	560.96	Full Calibration (1)
Otawara approach	92	7.8	38.5	16.0	-	-	45.5	65.8	0.17	167.9	728.86	
Otawara p. flyby	61	3.5	-	-	-	-	100.0	65.8	0.03	20.6	749.46	
Cruise 4	412	6.0	100.0	-	-	-	-	65.8	0.009	38	787.46	Full Calib. every 6 months (2)
Earth flyby 2	61	11.0	27.3	72.7	-	-	-	65.8	0.57	376.96	1164.42	
Cruise 5	118	0.0	-	-	-	-	-	0	0.00	0.00		
Siwa approach	92	1132.5	0.3	-	-	-	99.7	65.8	0.97	964.40	2128.8	
Siwa post flyby	61	6.5	-	-	-	-	100.0	65.8	0.46	301.0	2429.8	
Cruise 6	1160	18.0	100	-	-	-	-	65.8	0.04	114	2543.8	Full Calib. every 6 months (6)
Comet drift	98		-	-	-	-	-	0	0.00	0.00		
Far Approach	77	48.0	6.3			20.8	72.9	59.2	0.30	248.30	2792.1	
Close Approach	8	192.0	-	-	97.40	2.60	-	37.5	1.75	151.35	2943.5	
Trans. Global Map.	8	192.0	-	-	97.40	2.60	-	37.5	1.75	151.35	3095	
map./close obs.	32	768.0	-	100.0	-	-	-	65.8	3.58	1239.06	4333.9	
Comet low activity	150	528.0	0.6	4.70	-	94.70	-	35.5	0.91	1468.27	5802	
Moderate activity	87	304.5	-	4.80	-	95.20	-	35.7	0.85	798.41	6600	
Sharp increase	35	122.5	-	4.80	-	95.20	-	35.7	0.85	321.20	6921	
High activity	52	185.0	1.6	4.70	-	93.70	-	36.2	1.01	568.91	7490	
Near perihelion	43	150.5	-	4.80	-	95.20	-	35.7	0.85	394.62	7885	

Table 4.12 Summary of operational modes and resources usage during the various mission phases. **TO BE REVISED**

4.4   Failure Detection and Recovery Strategy

VIRTIS fault tolerance design has been oriented towards the maximum simplicity of redundancy design taking advantage of the fact that being a two channels instrument, any failure along one channel chain still allows for the operation of the other channel. From this point of view VIRTIS does not contains any single point failure. However, being both channels necessary for the fulfilment of the scientific objectives, the reliability concept of each channel has been optimised by means of fail open mechanisms (shutters and covers). Thus, cold redundancy has been implemented only inside the ME in the boards PS and DPU which have identical replicas, which can be powered by means of the redundancy power line whenever a failure event is issued.

From an operational point of view VIRTIS shall be capable of autonomous failure detection. To monitor the instrument status VIRTIS shall provide to ground and to DMS unambiguous operational information contained in:

1. TC verification reports (Acceptance and/or Execution).
2. H/K data reporting.
3. TM Events reporting. A service used to provide information on failures, anomalies and normal progress of sequences.

The DMS shall control VIRTIS behaviour by means of the TM Events Reports, and during the power on OBCP also using the Default H/K parameter information.
Events are classified according to their subtype:

Sub Type 1   Normal Progress Event Report
Sub Type 2   Warning Anomalous Event Report
Sub Type 3   Ground Action Anomalous Event Report
Sub Type 4   On-Board Action Anomalous Event Report

A full list of VIRTIS TM event is given in table 6.1. The events can be generated anytime during operations, but for the sake of the autonomous on-board activities we can split them in three parts:

♦ anomalies detected during Primary Boot
♦ anomalies detected during Secondary Boot
♦ anomalies during normal operations

VIRTIS is fully autonomous from the S/C in terms of emergency recovery from any type of S/W and H/W failure. If a major malfunction is found, the ME issue a subtype 3 or 4 event and perform a full instrument reset:

1. Power off all subsystems (PEMs, cryocoolers, etc.)
2. Perform a Primary Boot: upload of primary level software
3. Enter the Safe Mode of the instrument.

This is the safest condition for VIRTIS. If the failure is detected during Power On OBCP procedure, the OBCP itself shall be aborted and VIRTIS powered off, if the failure is detected during normal operations, VIRTIS in Safe Mode shall guarantee that no additional damage is done to the instrument itself, prior to the on-ground analysis.

4.5   Contingency Recovery Procedures

As explained in chapter 4.4 VIRTIS ME S/W is capable of detecting internal failures and act accordingly. However, if a failure is detected during scientific operations, the instrument shall reset itself and the scientific session from that moment until a subsequent reset of the instrument is lost.
To minimise scientific data loss, the team has proposed a recovery procedure in case a malfunction was to be detected during scientific operations. The Recovery OBCP was supposed to do the following:

1. DMS detect a subtype 4 event. This trigger the issue of a "start VIRTIS Recovery OBCP" command
2. DMS is commanded to interrupt VIRTIS TimeLine
3. VIRTIS is power cycled (power off main power line, power on redundant power line)
4. Upload SCET time update
5. Issue VTC_Enter_Idle_Mode
6. Restart HSLink connection to SSMM
7. Start cool-down both channels (wait for temperature steady state to be reached)
8. Power On both PEMs
9. Restore VIRTIS TimeLine
10. Return

An OBCP based on the above activities has been proposed as an ECR (Engineering Change Request) RO-VIR-ER-058, which has been rejected by ESOC with the following comment:

The OBCP is not operationally acceptable since it would put the instrument in a state which might be different from what has gone through the mission planning done at RMOC. This is deemed to be unnecessary and complex.

5   Data Operations Handbook

5.1   Telecommand Function Definitions

See the EID-B section 2.8.3.2.2 given in attachment 2.

5.2   Telecommand Parameters Definitions

See the EID-B section 2.8.3.2.2 and appendixes B,C given in attachment 2.

5.3   Telemetry Packet Definitions

See the EID-B section 2.8.3.2.1 given in attachment 2 and the database printouts.

5.4   Telemetry Parameters Definitions

See the EID-B section 2.8.3.2.1 and appendixes B,C given in attachment 2 and the database printouts.

5.5   Event Packet Definitions

See the EID-B section 2.8.3.2.1 given in attachment 2 and the database printouts

5.6   Anomaly Report Definition

See the EID-B section 2.8.3.2.1 given in attachment 2 and the database printouts
A full list of the presently defined events reports is given in table 6.1. It contains not only the anomalous conditions but also the normal progress event of subtype 1.

5.7   Context File Definition

No context files are used by VIRTIS

5.8   Data and Dump File Definitions

See the EID-B section 2.8.3.2.1 given in attachment 2 and the database printouts

5.9   On ground Monitoring of H/K and Events

The CCS is required to monitor VIRTIS behaviour using all three different modes of reporting available to the experiments during on ground and in flight activities; namely:

♦ TC verification reports (Acceptance and/or Execution). The S/C controls that the previous TC has been accepted and is executed. This feature is avalable only for a limited number of TCs. Lack of response from the experiment is either due to malfunction or bad TC structure (wrong parameter values, invalid mode transition, etc.)
♦ H/K data reporting. Health state of VIRTIS is monitored by means of H/K TMs; a list of parameters which are to be monitored is given in the following of this document.
♦ TM Events reporting. A service used to provide information on failures, anomalies and normal progress of sequences.

For a complete list of TC and TM, and for more details the reader is referred to attachment 2.

5.9.1   TC verification reports

If an Acceptance Report is required by TC, the user generates it, indicating either success or failure of the checks performed prior to execute the TC, including verification of check of packet correctness (header, checksum, etc.) and consistency of the TC with the actual VIRTIS mode. The acknowledge is generated within 4 sec of receipt of the TC.

The TM acknowledge packet always includes both the TC Packet ID and the SEQUENCE CONTROL fields as identifier of the TC packet being acknowledged

The TC Acceptance is applicable to all TCs, while the Execution Success is applicable only to:

1. Disable_Science_HSLink   (TC20,11)
2. Disable_Science_RTU_Link   (TC20,2)
3. MTC_Cover   (TC193,3)
4. HTC_Cover   (TC194,3)
5. MTC_ECA   (TC193,4)
6. HTC_ECA   (TC194,4)

While the Execution failure is applicable only to:

1. MTC_Cover   (TC193,3)
2. HTC_Cover   (TC194,3)
3. MTC_ECA   (TC193,4)
4. HTC_ECA   (TC194,4)

5.9.2   H/K Reporting

This service is used to transmit H/K data required both for monitoring the operational aspects of the instrument and for interpreting science data. The ME collects H/K data from

the powered modules and generates HK Report TM packets at the rates and conditions given in table 2.9 (see section 2.3.4.4)

It is evident from the table that H/K with SID 2 and 3 cannot be received when performing test in air as the coolers and ECA (Emergency Cover Actuator) shall not be operated. Monitoring of this H/K must then be disabled on CCS.

We must also point out that during scientific acquisition TM with SID 4,5,6 are sent not only with each science data (as separate H/K packets) but also every 10s.

The S/C DMS shall not perform any check on the H/K values

5.9.3 Events Reporting

This service provides for the reporting to ground or DMS of unambiguous operational significative information such as:
- failures and/or anomalies detected on-board
- autonomous on-board actions
- normal progress of payload operation/activities

Event reports:
- identifies uniquely the event, its occurrence time and related data
- are generated only once per event occurrence and are concise
- includes the nature/severity of the event
- are self standing (i.e. not require data from other packets or TC history to be interpreted)

Events are classified according to their subtype:

Sub Type 1   Normal Progress Event Report
Sub Type 2   Warning Anomalous Event Report
Sub Type 3   Ground Action Anomalous Event Report
Sub Type 4   On-Board Action Anomalous Event Report

The following table 6.2 shows the different Event Report types as defined for the VIRTIS instrument according to attachment 3. This list shall be updated according to the last Flight S/W version.

The DMS/CCS is requested to monitor **all** the subtype 3,4 to point out anomalies in the instrument behaviour