MARS EXPRESS

PLANETARY FOURIER SPECTROMETER

FUM5

MEX-CNR-FUM5

PFS – FUM5

DOCUMENT CHANGE RECORD

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FUM 5 – OPERATING, NON-OPERATING CONDITIONS AND INTERFACES.

1- INSTRUMENT REQUIREMENTS

1.1 - MASS

The complete PFS Instrument consist of four modules

module "O" is the main double pendulum interferometer
dimensions (mm) : 260x350x430 and mass = 19.9 kg +0.4 kg for interface cups.+
1 kg for the mass increase of the balancing mass. = 21.5 kg
module "S" is the IR scanner module
dimensions (mm) :200x190x322 and mass = 3.0 kg+ 0.5 kg margin. = 3.7 kg.
module "E" is the Digital Processing Unit
dimensions (mm) : 200x146x180 and mass = 3.0 kg
module "P" is the power supply
dimensions (mm) : 60x230x180 and mass = 2.2 kg

Interconnecting Harness mass <= 0.8 kg

The total extimated weight will be = 31.2 kg.

1.2 - POWER and THERMAL

The experiment power consumption will be:

6 Watts in Cruise phase (ASTRA MODE) heating power.
10 Watts Power Stand-by (Sleeping mode, 5.5 hours along the orbit)
35 Watts Average Operational Power (Science mode 1.5 Hours along the obit)
44 Watts Peak Operational Power (when moving the scanner , for 1 minute).

These values are based on the Mars Express hardware . 10 % variation in either direction can be the possible fluctuations of the values. The peak power here should be considered an upper limit .

1.3.- ENERGY
We need to cool down the SW detector, therefore there is a need of a spacecraft passive cooler (thermal radiator) to dissipate 3 W in deep space.

Furthermore there may be a problem of thermal heat of Module O , in the sense that , presently O is considered covered with MLI , which means isolation from the spacecraft. The 15 watts dissipated inside O , then , can be a problem unless we find a way to dissipate that heat to space by means of thermal contact to the spacecraft.

1.4.- RF LINK

We give our data to the spacecraft mass memory for the downlink trasmission.

1.5.- TM/TC

Our nominal data rate allocation is 15 % of spacecraft data volume per day to be able to transmit all the observations and the calibrations and the housekeeping data. We can take more data and transmit more , depending on the orbit operation cyclogram. On the basis of our data compression schemes (with loss of information) we can go down OCCASIONALLY ONLY to 105 Mbits per day (corresponding to 35 Mbit per orbit).

1.6.- SYNCH AND DATE

We do not need any synch. However we need the information available on board about the pericenter. This info is the time dt after the last pericenter , or , better , after the last time the spacecraft has decreased altitude below 4000 Km from the planetary surface.

PFS also needs the on board time to be added to the data , and to be used later to reconstruct the footprint location on Martian surface.

1.7.- PYRO

Pfs has no pyro on board.

1.8.- SOFTWARE AND MEMORY

There are 3 on board software , therefore there are 3 RAM and 3 ROM , plus there is a Mass memory of 32 Mbit (redundant to 49 Mbit).

Module E	DAM	RAM	ROM
	ICM	RAM	ROM

Mass memory = 32 (49) Mbits

Module O	OBDM		RAM	ROM

1.9.- POINTING

PFS has a pointing device because needs to point nadir to measure Martian radiation, but in order to calibrate the measurements, we need to point also to a Blackbody of known temperature , and to deep space. Occasionally , also , we may use our scanner to point off nadir. The IFOV is 4 deg for the LW and 2 deg for the SW channel. The IFOV can be rotated by 110 deg in a plane across track , with respect to the orbit trace. We also request an unobstructed FOV of 10 x 120 deg .

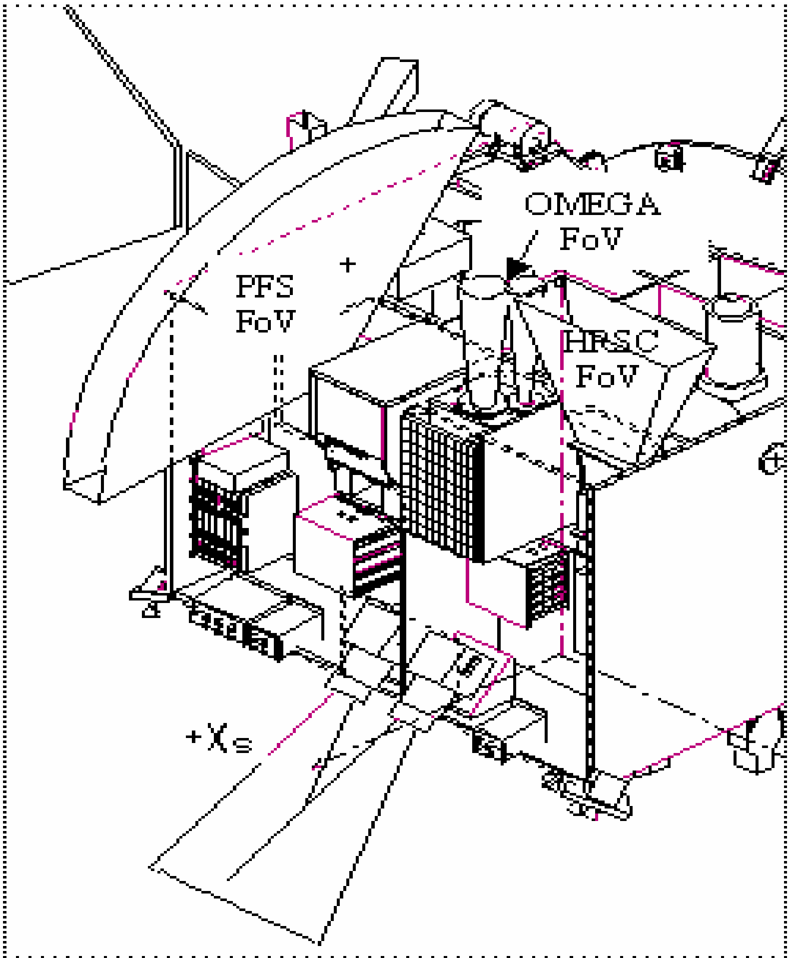


Image courtesy of MMS

1.12 SCANNER FOV REQUIREMENTS

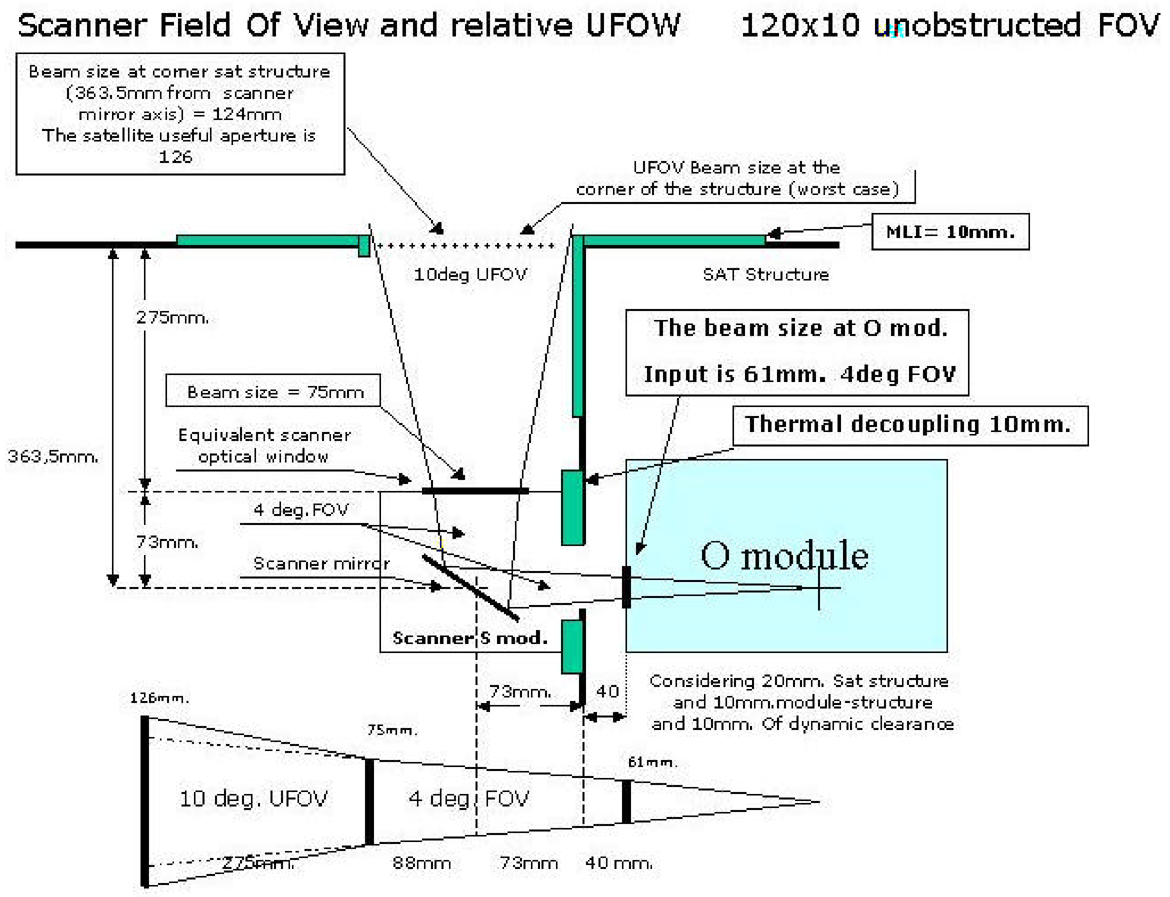


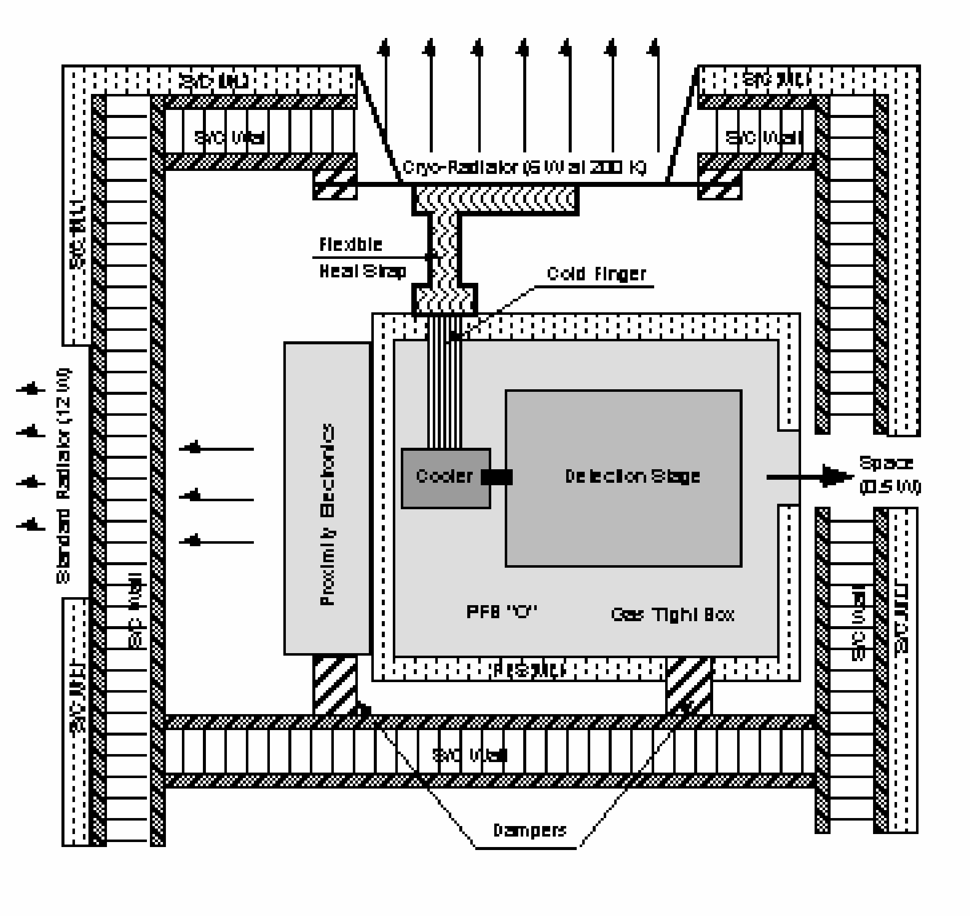
Fig. 1.13 NOTE: in the figure above the exit of O module should be 65 mm not 61 .

Diagram in fig 1.13 show the PFS FOW-UFOW requirements in details.

The beam size at O module input window is 65 mm. with a beam aperture of 4 deg.

The UFOV is 10deg. From the scanner main entrance and the beam size at the satellite structure (worst case) is 124mm.

2 . - THERMAL INTERFACES 2.1 - THERMAL ACCOMODATION



Thermal budget of the interferometer O Module .

The unit will be covered bt MLI (TBC)

The Power dissipated by external radiator will be of 6 Watts to keep the internal detector at temperature below 220K.

The thermal bonding strap need to be flexible enough avoiding mechanical stress and need to be long enough to compensate mechanical movement due to the launch or any vibration.

Image courtesy of MMS

2.2 - OPERATIONAL TEMPERATURES

Experiment Unit-location	Operating Temperature		Nonoperating Temperature		Switch-on Temperature		Temperature Stability
	Min [K]	max [K]	Min [K]	max [K]	min [K]	max [K]	[K/h]
Module “O” IB	280	290	<233	>310	280	290	5
Module “O” EB	250	310	<220	>360	250	310	NA
Module “O” SWS	200	200	NA	NA	NA	NA	5 (internally controlled)
Module “O” LWS	280	290	NA	NA	NA	NA	0.01 (internally controlled)
Module “E”	250	310	220	360	250	300	NA
Module “S”	250	310	220	360	250	300	NA
Module “P”	250	310	220	360	250	300	NA

2.3 - GROUND OPERATIONAL TEMPERATURES

Experiment Unit-location	Operating Temperature		Nonoperating Temperature		Switch-on Temperature		Temperature Stability
	Min [K]	max [K]	Min [K]	max [K]	min [K]	max [K]	[K/h]
Module "O"	230	300	<230	>310	230	300	5
Module "E"	250	310	220	360	250	310	NA
Module "S"	250	310	220	360	250	300	NA
Module "P"	250	310	220	360	250	310	NA

2.4 - CONDUCTIVE INTERFACE

Module "O"	Module "O" is conductively insulated from the mounting points. There is an additional conductive interface between the cold finger for SWS cooling and the S/C thermal pipe providing cooling.
Module "S"	The conductive interface is through the four mounting feet.
Module "E"	The conductive interface is through the four mounting feet.
Module "P"	The conductive interface is through the four mounting feet.

2.5 - RADIATIVE INTERFACE

Module "O" The "IB" is radiatively insulated from the environment by means of MLI blanket internal to the experiment. Moreover the entire Module "O" is radiatively insulated from the spacecraft by means of another external MLI blanket.

Module "E" The module is radiatively coupled with the spacecraft to improve the heat transfer towards the S/C during operation.

Module "P" The module is radiatively coupled with the spacecraft to improve the heat transfer towards the S/C during operation.

Module "S" The module is radiatively not coupled to the spacecraft.

2.6 - SPECIAL THERMAL REQUIREMENTS

The "O" Module needs a passive cooling system to keep the temperature of the SW detector at <=220K.The thermal power to be radiated is 6 Watts. On Mars 96 Spacecraft this was realized by using a radiator by 26 x 26 cm. exposed to outer space and located under the "O" module and thermally connected to the detector cold finger.

Solution to this point has been provided by the spacecraft manufacturer with external 6 Watts radiator .

2.7 - HEATERS

Module "O" Module "O" requires 5 W non-op heaters to prevent the IB temperature to go below 280 K. During operation a temperature control system powers a heaters net controlling critical points, the power is included in the power budget in operation.

This is needed also during cruise phase (at experiment off) and is called ASTRA mode.

2.8 - COATINGS and FINISHES

The outher surfaces of the "O" Module will be covered by MLI insulator, the emissivity will be 0.1 BOL, equivalent emissivity will be 0.03, solar absorptivity 0.2 BOL, 0.5 EOL (TBC).

The "E", "P" Modules will be black anodized, total hemisherical emissivity 0.8.

The "S" module will be golden kapton.

2.9 - UNITS MEAN HEAT CAPACITY

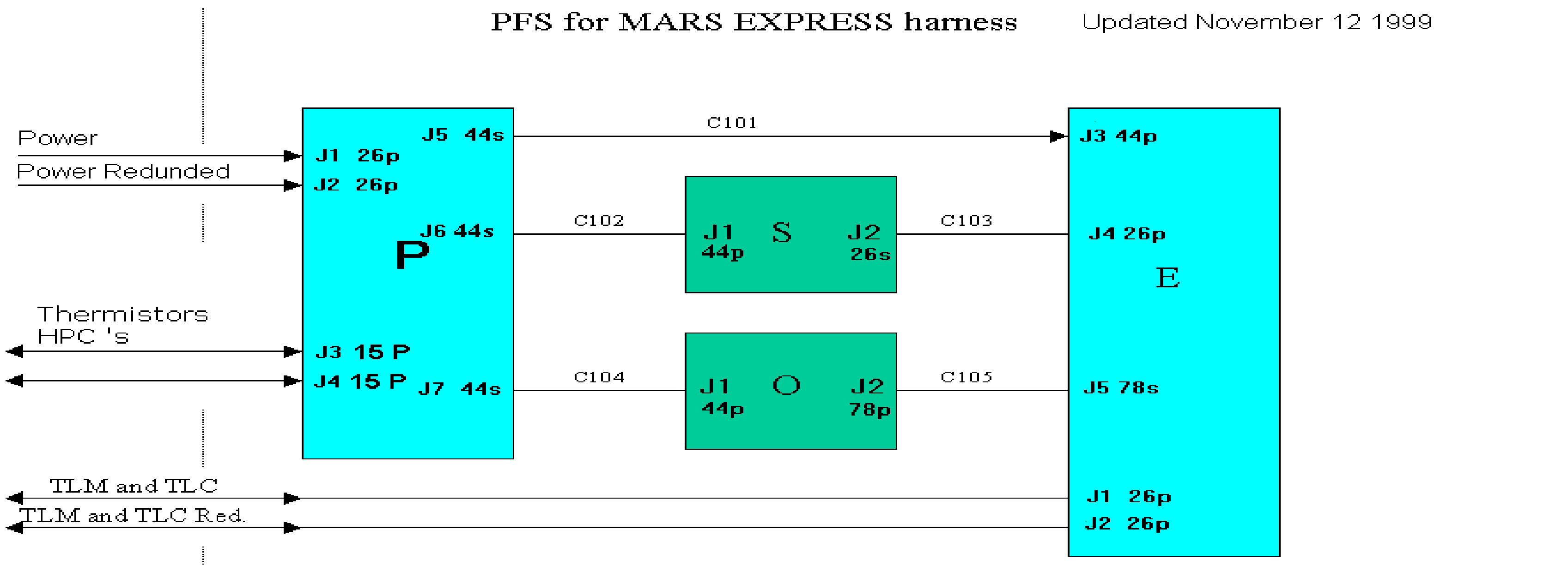
UNIT	HEAT CAPACITY J / kgK	NOTE
O	19400	
S	3600	
P	2070	
E	3150	

2.10 - UNITS HEAT DISSIPATION

MODULE	MEAN HEAT DISSIPATION Watts	PEAK POWER DISSIPATION Watts
O	2.5	15
S	1	10W. For 10Sec
P	6	
E	5	

3.1 ELECTRICAL ARCHITECTURE BLOCK DIAGRAM

ELECTRICAL ARCHITECTURE DIAGRAM	INSTRUMENT: PFS overall	MODEL: all



PFS for MARS EXPRESS Cabling

Connectors Items ending P are pins, S are sockets

C101 Power to E module , temp housekeeping E module, commands to S module and P module
C102 Power to S module , temp housekeeping of S module, Emergency Mirror Position
C103 Scanner commanding & housekeeping, Black Body temp mon. and lamp monitor.
C104 Power to O module & temp housekeeping
C105 O module commanding & data, calibration control and status

3.2 - PFS EXPERIMENT POWER REQUIREMENTS

POWER DEMAND	INSTRUMENT:	PFS	UNIT:	PFS-P	MODEL:	ALL
	ESTIMATED VALUES: X ■			MEASURED VALUES: ☐		

Power Lines Description	Average Power BOL [W]				Average Power EOL [W]				Long Peak Power		Short Peak Power	
	Modes				Modes				Peak [W]	Duration [s]	Peak [W]	Duration [s]
	ASTRA	SLEEP	NORMAL		ASTRA	SLEEP	NORMAL					
NOMINAL SET												
PFS Main, 28V Primary Power Con. J1, pins: 1(power) and 10(return)	**0**	**10**	**35**		**0**	**10**	**35**		**44**	**300**	**70**	**0.005**
ASTRA 28V Primary Power, Main line Con. J1, pins 2(power) and 11(return)	**6**	**0**	**0**		**6**	**0**	**0**		**-**	**-**	**-**	**-**
REDUNDANT SET												
PFS Redundant, 28V Primary Power Con. J2, pins: 1(power) and 10(return)	**0**	**10**	**35**		**0**	**10**	**35**		**44**	**300**	**70**	**0.005**

Notes:

1. **The data is estimated from PFS-Mars 96.**
2. **Only one set PFS Main/Redundant or ASTRA Main/Redundant is supplied at a time.**
3. **All PFS is supplied trough PFS-P and connectors J1 and J2. There are no other connections between PFS and Mars Express Power Supply System.**

3.3 - ELECTRICAL PFS/SAT REQUIREMENTS on POWER

VOLTAGE	LCL CLASS DEFINITION	Max nom.Power@Current	Trip-off /Limiting Point after 5uS
28 v.+- 1%	CLASS D	67.2W@2.3 Amp.	82W / 3.0 Amp.
28 v.+- 1%	CLASS B *	16.8W@0.6 Amp.	22W / 0.8 Amp.

*Not redunded (ASTRA heater power)

3.4 - ELECTRICAL PFS/SAT REQUIREMENTS on HIGH POWER COMMANDS

CMD NAME	MAIN CMD.	REDUNDED CMD.	NOTE
MAIN DC/DC ON	1	--	Intf. Fig. 3.1.3 in PID/URD annex RED.USER
MAIN DC/DC OFF	1	--	Intf. Fig. 3.1.3 in PID/URD annex RED.USER
REDUN. DC/DC ON	--	1	Intf. Fig. 3.1.3 in PID/URD annex RED.USER
REDUN. DC/DC OFF	--	1	Intf. Fig. 3.1.3 in PID/URD annex RED.USER
ASTRA ON	1	1	USED as NON REDUNDANT USER As in PID/URD ANNEX , Schematic 3.1.2
ASTRA OFF	1	1	USED as NON REDUNDANT USER As in PID/URD ANNEX , Schematic 3.1.2

3.5 - ELECTRICAL PFS/SAT REQUIREMENTS on THERMISTORS

FUNCTION NAME	MAIN	REDUNDED	NOTE
P MOD Temp.	1	1	USED as RED. USER
E MOD Temp.	1	1	USED as RED. USER
S MOD Temp.	1	1	USED as RED. USER
O MOD Eb Temp	1	1	USED as RED. USER
O MOD Ib Temp	1	1	USED as RED. USER

Thermistors are Yellowspring YSI-44907 model.

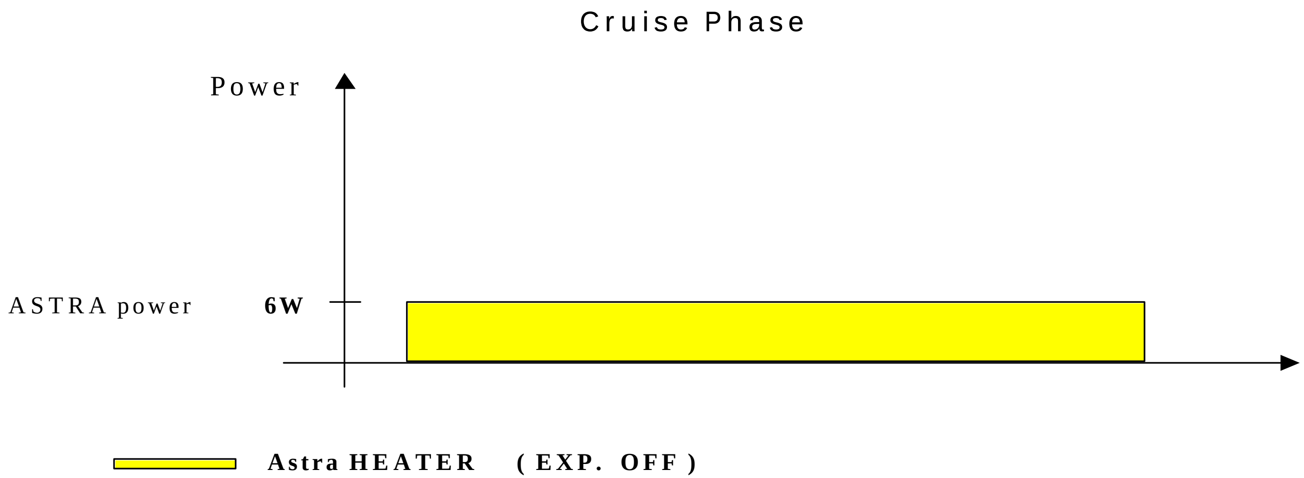
3.6 - ELECTRICAL PFS/SAT REQUIREMENTS on RELAY SWITCH STATUS

FUNCTION NAME	MAIN	REDUNDED	NOTE
MAIN DC/DC ON RSS	1	--	
RESE. DC/DC ON RSS	--	1	
ASTRA ON RSS	1	1	

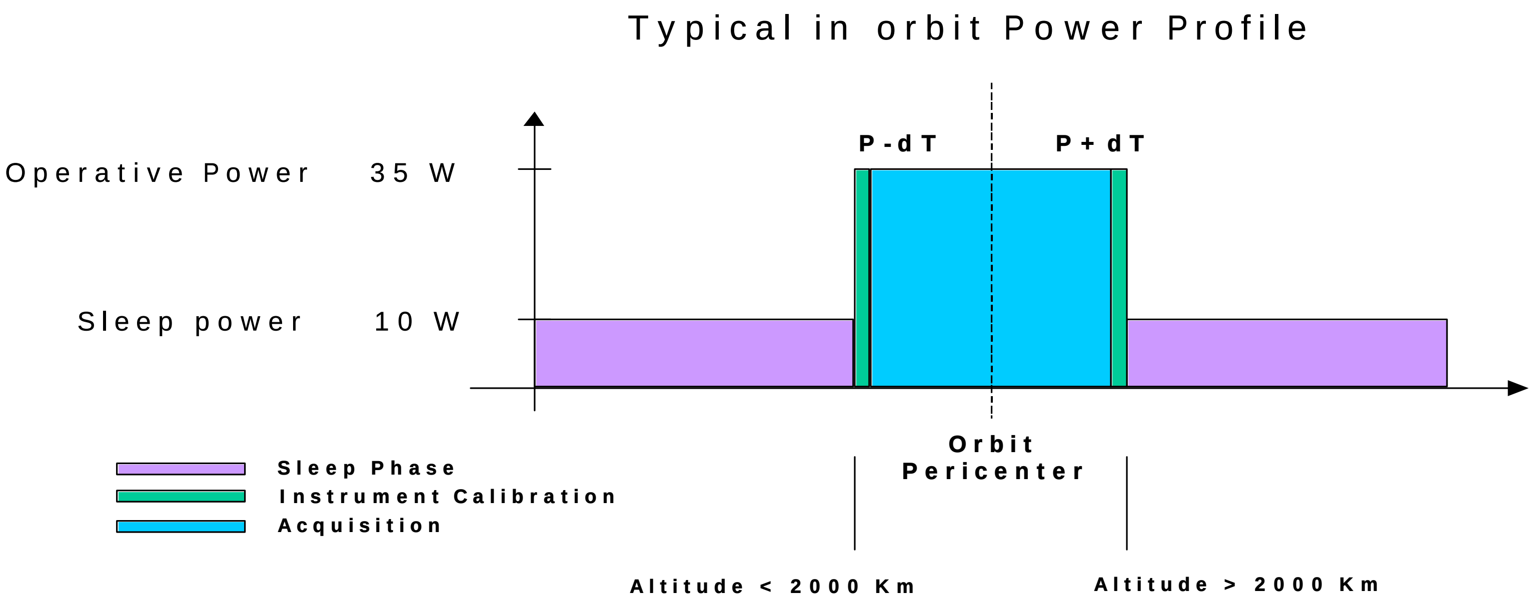
3.7 - ELECTRICAL SAT/PFS REQUIREMENTS on TTC01-B TLM/TC

FUNCTION NAME	MAIN	REDUNDED	NOTE
MLC	1	1	
TSY	1	1	
SDT	1	1	USED as NON REDUNDANT USER As in PID/URD ANNEX , Schematic 3.1.2
SDC	1	1	USED as NON REDUNDANT USER As in PID/URD ANNEX , Schematic 3.1.2

3.8 POWER PROFILE in CRUISE PHASE (ASTRA HEATER)



3.9 POWER PROFILE of TYPICAL INSTRUMENT OPERATION AROUND MARS PERICENTER



4 – EXPERIMENT DATA AND COMMANDING

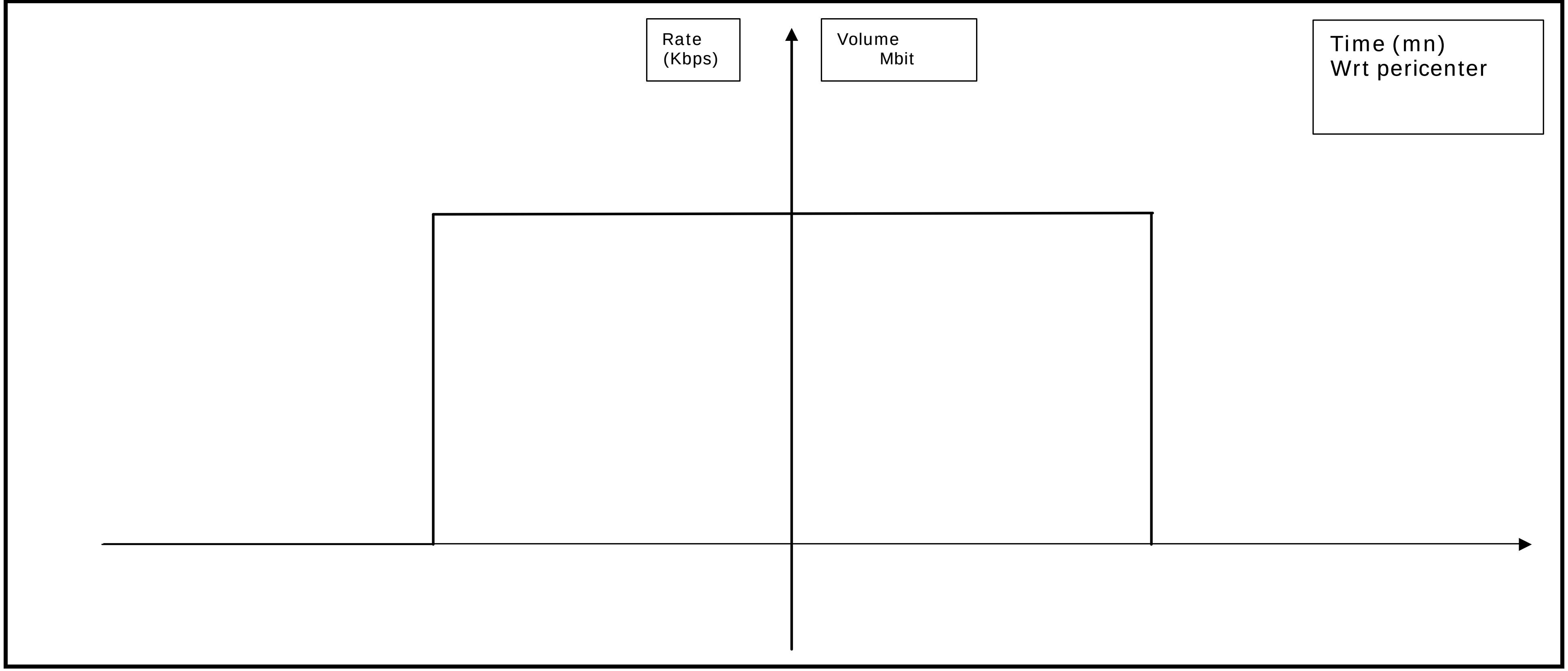
4.1 DATA RATE and VOLUME

DATA RATE AND VOLUME										INSTRUMENT: PFS	MODEL: ALL
DATA	OPERATIONAL PHASE/MODE									Maximum length	
	1: Experiment in Mode 17			2: Experiment in Mode 9 extended			3: Experiment in Mode 12 extended				
	Rate (kbps)	Duration (s/orbit)	Volume (Mbit)	Rate (kbps)	Duration (s/orbit)	Volume (Mbit)	Rate (kbps)	Duration (s/orbit)	Volume (Mbit)	Block	Packet
SDT HK	32										
SDT SCIENCE	32	5400	120		5400			5400		8k Words	
TOTAL SDT			120								
IEEE 1355											

Note: 1) Values shown are acquired PER ORBIT at Pericenter pass.
2) PFS Experiment Modes shown here are some operational modes selected as the most suitable for Mars Express in orbit operations.

4.2 DATA PROFILE

DATA PROFILE	INSTRUMENT: PFS	MODEL: ALL
	DATA LINE:	SDT



Data Rate is assumed fixed at 32Kbit/s.
For Data Volume and timings around Pericenter please refer to Data Rate and Volume Table

4.3 TIPYCAL INSTRUMENT TIMELINE

INSTRUMENT TIMELINE		INSTRUMENT: PFS	MODEL: ALL
TIME	EVENTS	REMARKS	
-3600 sec	Wake up, Switch on Module O and Scanner	According to the Cyclogram	
-3590 sec	Wait for warm up	If Module O delay is set to 30 min	
-3000 sec	Autonomous Test		
-2900 sec	Calibration LW	If 10 measurements should be taken	
-2800 sec	Calibration SW	If 10 measurements should be taken	
-2700 sec	Calibration deep space	If 10 measurements should be taken	
-2600 sec	Move scanner to nadir position		
-2400 sec	Start Martian observations		
+2600 sec	Stop Martian observations	According to the Cyclogram	
+2600 sec	Calibration LW	If 10 measurements should be taken	
+2700 sec	Calibration SW	If 10 measurements should be taken	
+2800 sec	Calibration deep space	If 10 measurements should be taken	
+2900 sec	Autonomous Test		
+3400 sec	Switch off Module O and Scanner		
+3600 sec	Go to Sleeping Mode		

Time related events are referred to Pericenter Pass

5 - TELEMETRY

5.1 - TELEMETRY SUBSYSTEM

DAM prepares Data Packs obtained during the Measurement Session according to the Data Transmission Mode.

Depending on the Data Transmission Mode, the Data Pack can contain fields:
- MH1 - time of acquisition, Scanner position, OBDM status, etc.
- MH2 - OBDM MC data
- MH3 - OBDM Control Table and selftest; other stuff related to Session
- SW - either SW interf., or SW spectrum, or SW part of Autotest
- LW - either LW interf., or LW spectrum, or LW part of Autotest

The full definition is given in 3.1.4.

The telemetry information is prepared according to ESA and MARS-EXPRESS mission standards. The main telemetry data unit, Source Packet, contains following fields:
- Source Packet Header
- Data Field Header
- Source Data

The Source Packet Header and the Data Field Header have predefined structure. Only the Source Data can contain private PFS information. There is no use to store headers together with the Source Data.

The Telemetry subsystem prepares only Source Data and stores them in the Mass Memory. The Source Data will be extracted from the Mass Memory, included into the Source Packet and sent to the spacecraft by the TM interface task.

Since the maximal length of the Source Data field is 4096 bytes, when the full size of the Data Pack can be as big as 40 Kbytes, the data segmentation should be used. The Telemetry subsystem cuts the Data Pack by pieces and adds a header to each piece. The header contains:
- acquisition number within the Session
- segment number within the acquisition

This allows to distinguish all segments obtained during the Session rather than during one acquisition.

5.2 - Structure of the Telemetry Source Packet

As defined by [12] (ME-ESC-IF-5001), the Telemetry Source Packet has following fields:

Field name	Size[b]	Comment
Packet ID	2	Identifies the experiment
Packet Sequence Control	2	Contains packet counter
Packet Length	2	Length £ 4106 incl. Data Field Header
Data Field Header	10	Contains service stuff
Source Data	Variable	Contains PFS TM information

The Packet ID field is costant. It contains following fields:

Field Name	Size[bit]	Value	Comment
Version Number	3	000b	Fixed by [12]
Type	1	0b	Fixed by [12]
Data Field Header Flag	1	1b	Fixed by [12]
Process ID (PID)	7	1010110b	=86d - PID assigned to PFS
Packet Category	4	1100b	Fixed by [12]

The Process ID allows to distinguish PFS packets among other ones from different experiments.
The Packet Sequence Control field contains following fields:

Field Name	Size[bit]	Value	Comment
Segmentation Flags	2	11b	Fixed by [12]
Source Sequence Count	14	0..3FFFh	Packet counter

The Packet Length field contains a value which gives information about the length of both Data Field Header and Source Data. The value is given by: Packet Length = 10 + length(Source Data) - 1.

The content of Data Field Header is fixed by [12]. The Data Field Header has following structure:

Field Name	Size[bit]	Value	Comment
SCET Time	48	time	Packet creation time
PUS Version	3	000b	To be corrected
Checksum Flag	1	0b	To be corrected
Spare	4	0000b	To be corrected
Packet Type	8	00010100b	=20 - for TM(20,3)
Packet Subtype	8	00000011b	=3 - for TM(20,3)
Pad	8	00000000b	To be corrected

5.3 - STRUCTURE OF THE SOURCE DATA

Since the size of the Packet Source Data field can not exceed 4096 bytes, the content of the Data Pack is cutted by segments. A header is added to each segment. The header contains an acquisition number and a segment number. The Source Data field has following fields:

Field name	Size[b]	Comment
Acquis. Number	2	Abs. number within Session, starting from 0
Segment Number	2	Abs. number within Data Pack, start from 0
TM segment	1024	Piece of the Data Pack

5.4 - Structure of MH1, MH2 and MH3 fields

The field MH1 (128 bytes) is generated during each acquisition and contains common information about conditions of the acquisition, obtained from different sources:

The acquisition time is taken at the moment when OMES "Acquisition completed" was received.

During the Autotest the Data Pack is prepared at DTM=0 although the current DTM is different. The "Actual DTM" field in the MH1 reflects this fact.

During the acquisition from a calibration source the Data Pack is prepared at DTM=1 although the current DTM is different. The "Actual DTM" field in the MH1 reflects this fact.
In the case of ICM failure the Data Pack is prepared at DTM=1 although the current DTM is different. The "Actual DTM" field in the MH1 reflects this fact.

The field MH2 is generated during each acquisition and contains the measurement conditions (128 bytes) obtained from OBDM during the acquisition.

The field MH3 (256 bytes) is generated at the beginning and termination of the Session and contains general information related to the Session:

6 – EVENTS

If something goes wrong, DAM considers this as an Event and sends an Event Report to the spacecraft. The Event Report can be also sent in order to inform PFS team that some checkpoint passed. All failures detected by DAM are considered as Events. EventInfo gives additional information about the Event.

In the case of some Events the DAM software performs operations in order to avoid the cause of the Event. But if the Event is ignored, the DAM software only sends a report and continues normal operations. The possibility to ignore the Event should be used in the case of wrong information about the failure due to the hardware damage. The Event is ignored if a corresponding bit in the Event Ignore Mask is set. There are masks for different subsystems.