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PLANETARY FOURIER SPECTROMETER

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PFS for VENUS EXPRESS

PLANETARY FOURIER SPECTROMETER

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APPROVAL SHEET

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A list of PFS acronyms (and abbreviations) .

ADC	analog to digital converter
APC	automatic power control
BBS	block body source
CIDL	configuration item data list
CNR	consiglio nazionale delle ricerche
COE	check out equipment
CTE	coefficienti termici di esposizione
DAM	digital arbiter module
DMA	direct memory access
EGSE	electrical ground support equipment
Em	electrical model
EPROM	erasable programmable read only memory
EQM	engineering qualification model
ESA	European Space Agency
FFT	fast fourier trasform
FIFO	first in first out
FIR	for infrared
FM	flight model
FOV	field of view
FS	flight spare
GSE	ground support equipment
HK	house keeping
HPC	high power command
ICDR	instrument critical design review
ICM	interferogram computer module
IFOV	istantaneous field of view
IFSI	istituto di fisica dello spazio interplanetario
IPDR	instrument preliminary design review
IQAR	instrument qualification and acceptance review
IRIS	infra red interferometer spectrometer
IRR	instrument requirement review
LW	long wavelength
LWC	Lw calibration
MEX	Mars Express mission
MIR	middle infrared
MLI	multi layer insulator
MMS	Matra Marconi System
NEB	noise equivalent brightness
NEP	noise equivalent power
NER	noise equivalent radionce

OBDM	**optical bench digital module**
PFS	**planetary fourier spectrometer**
PFS-E	**PFS-module E**
PFS–O	**PFS-module O**
PFSO-EB	**PFS-module O-Electronic block**
PFSO-IB	**PFS-module O-interferometer block**
PFS-P	**PFS-module P**
PFS-S	**PFS-module**
RAM	**random access memory**
ROM	**read only memory**
SAM	**supply analog module**
SIS	**spacecraft interface simulator**
SW	**short wavelength**
SWC	**Sw calibration**
SWIR	**short wavelength infrared**
TC	**telecommands**
TM TLM	**telemetry**
ZOPD	**zero optical path difference**

MECHANICAL ASPECTS

From mechanical point of view there will be no modification in the mechanical interface of PFS with the spacecraft.
In terms of resources the PFS mass will stay the same.
The qualification of PFS is therefore still valid , and only the environmental tests at acceptance level will be performed.

We understand that the prime contractor will provide a passive cooler (radiator) with a thermal strap which will have the same mechanical properties as for MEX.

The proposed mechanical modification of the spacecraft in front (at the entrance) of PFS scanner will be examined in the thermal aspect doc and in the optical aspects doc.

THERMAL ASPECTS

UPDATE OF PFS THERMAL ANALYSIS IN VEX ENVIRONMENT.

Abstract

This document describes the additional thermal analysis performed to evaluate the impact on the PFS performances of the environmental conditions foreseen for the VEX mission.

MODULE “O”

Being modulo “O” internal to the S/C the only changes analyzed for the VEX case are related to the interface temperatures and the different orbit duration and power profile.

IF temperature range

The interface temperature specified in the VEX partnership agreement are: -50   60 °C.

Being not specified if the range refers to the operational or non-operational conditions it has been assumed that the range is non-operational and the operational one had been obtained, in analogy to PID-A by narrowing the range of 10 °C on each extreme. The analysis performed consider therefore a non-op range -50 60 and an op range -40 50.

Operation profile

It has been assumed that the VEX orbit has a 24 h period and PFS is active for 2 h around the pericenter and in two additional 0.5h sessions:

-the first beginning one hour before the beginning of the pericenter main session,

-the second beginning 0.5 h after the end of the pericenter main session.

Cases

Two operational conditions have been analysed, the hot, considering the S/C IF temperature 50 °C and the cold one with S/C temperature –40 °C.

The non-op condition considered is only the cold one being the hot specification, 60°C compatible with PFS qualification range.

Results

The results of the simulations are shown in the following plots, showing the temperature behaviour during one orbit in both cold operational condition and hot operational.

The non-op analysis shows that with a S/C IF temperature of –50°C the instrument reaches –23 °C with the 4W non-op heaters always on.

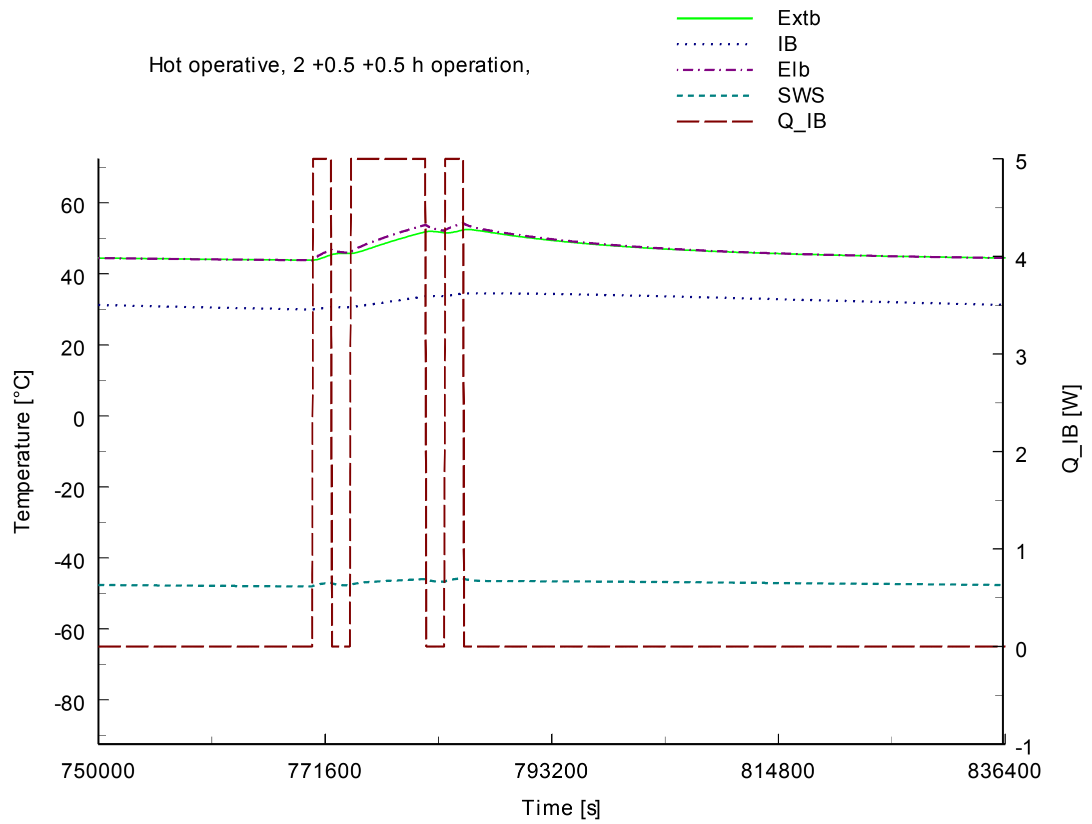


Figure 1 Hot operative condition, S/C IF temperature 50 °C

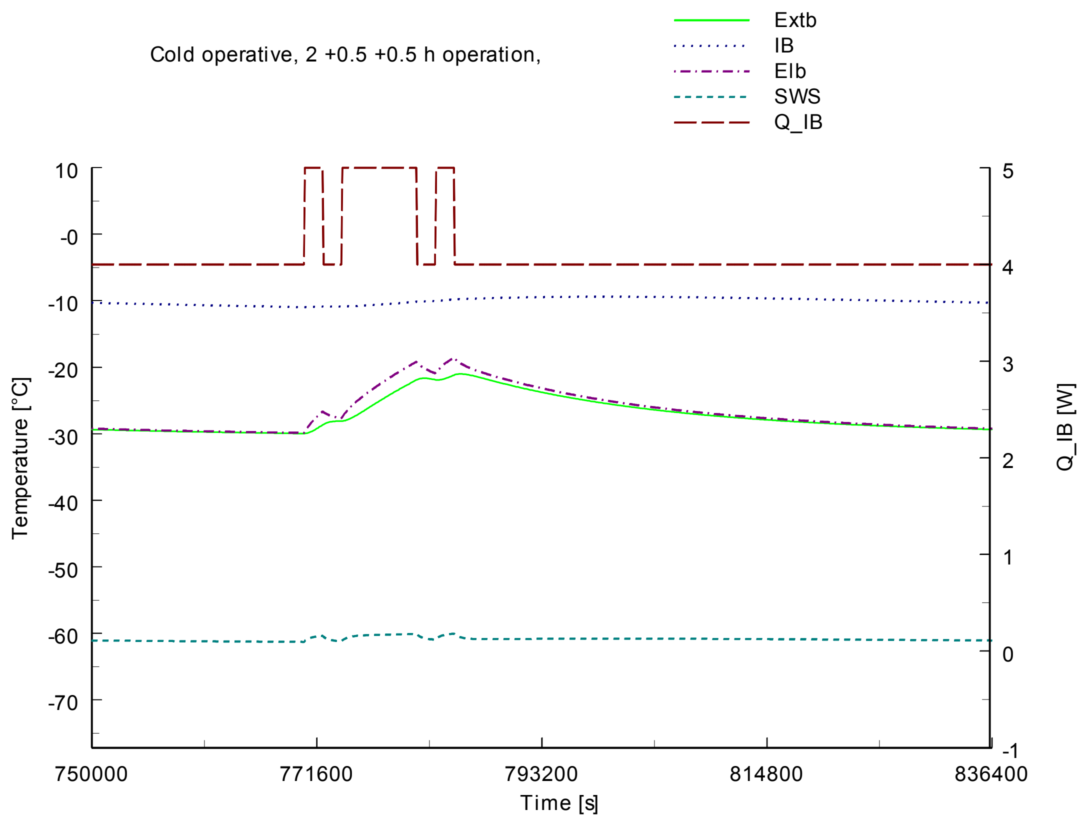


Figure 2 Cold operational conditions, S/C IF temperature –40°C

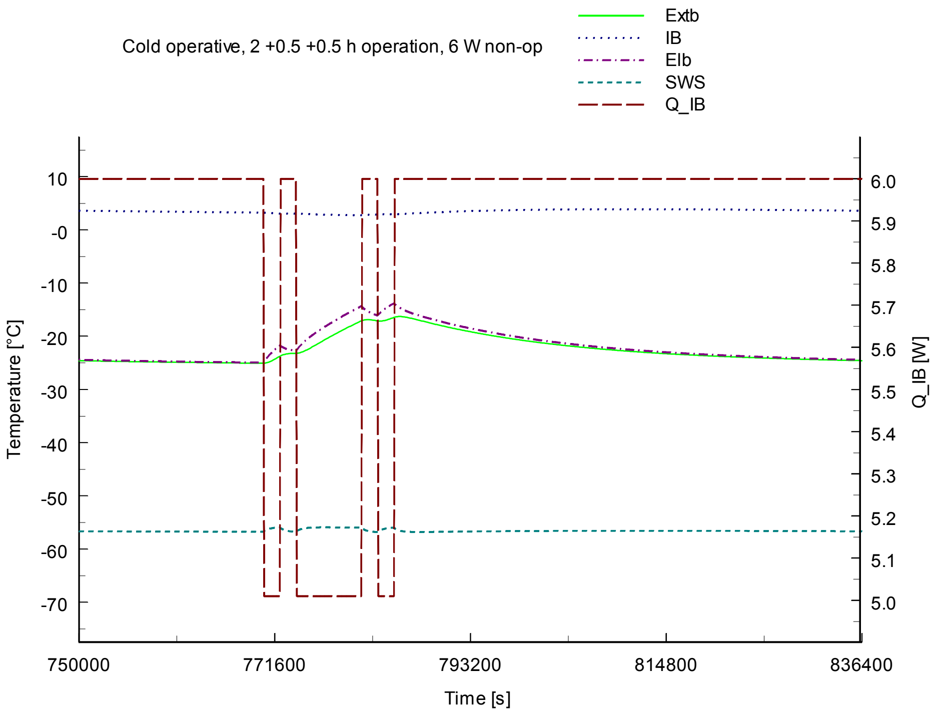


Figure 3 Cold operational case with increased non-op power.

Module "S"

Having module "S" a field of view to space the different environment expected in orbit around Venus has an impact not only for the S/C IF temperature but also because of the higher solar and albedo fluxes.

Analysis

The analysis performed consider the sun entering in the S/C slot constituting the PFS un-obstructed FOV and in particular aligned with –X direction.

For the S/C MLI it has been assumed an effective emittance of 0.02 and a for the optical properties of the outer layer a 2MIL second surface VDA-Kapton with emittance 0.71 and absorptance 0.44.

The optical properties of module "S" have been kept as they are in MEX FM i.e. VDG kapton with =0.03, =0.15.

Results

The steady state analysis shows that the temperature reached in full sun illumination is 69 °C, still compatible with the operational ranges of all its components. The heat flux at conductive interface in this condition, with the S/C at 60°C, is about 3.5 W.

For the cold case with the 2 W non-op allocated power the steady state condition leads to a temperature of –49.5, still compatible with most of the components.

Conclusions

Module "O" with the environmental conditions foreseen for VEX mission is still within a range of temperatures where it can operate.

While there is experience in operating the instrument up to 30 °C for the cold case the –10 °C foreseen for the optical bench have not extensively tested though no major effects on alignment are expected. A simple increasing of the non-op power from 4 to 6 W would allow to keep the operational minimum at about 5 °C already applied to the instrument during qualification.

Module "S" in both hot and cold cases is in a temperature range not critical for operation though a delta qualification is required. Changing the optical properties of the external coating to an higher / ratio would lead to larger emissivities, creating troubles for the cold case unless more power for thermal control is available, different solutions can be investigated (MLI instead of the VDG kapton for all the surfaces but the rotating drum) however the baseline is to keep the module as it is.

Present situation IN scanner is :

- electronic components are specified up to +125C,

- DC motors, which we used, are specified up to +125C,

- stepping motors which we probably use for VEX are specified up to +85C , but we have not finished looking for suitable motors,

- Black body : high temperature is not problem .

- magnetic sensors are specified up to 200C.

- we have to look carefully at ball bearing , worn gear reductor and freewheel clutch, but it should not be problem.

RADIATION ENVIRONMENT

We assume valid the curve aluminium thickness / radiation provided by ASTRIUM in the addendum to the partnership agreement.

MODULE O.

Module O electronics is either inside O-EB or inside O-IB. In both cases we shall consider that Module O is inside the spacecraft (1.5 mm aluminium).

Let us consider separately the 6 directions from which particles radiation may come to the electronics:

+X we have the entire body of the spacecraft (10 mm) plus the high gain antenna (1.5 mm) , thermal blanket (1mm) , plus 1 mm outer box , + 1.5 mm inner electronic box in total = 15 mm at least.

-X we have the radiator (1 mm) , the outer shell of the spacecraft (1.5 mm), thermal blanket (1mm) , plus 1 mm outer box , + 1.5 mm inner electronic box gas tight , + 5 mm interferometer . in total = 11 mm aluminium plus 1 mm cupper for electronics in O-IB, while for electronics in O-EB we have 11 mm + at least another 10 mm aluminium (the entire interferometer) .

+ - Y we have at least 2 times the spacecraft (3 mm) , plus two experiments 20 mm (?) , plus thermal blanket (1 mm) , extheral box (1 mm) , internal box (1.5 mm) , in total 26.5 mm aluminium.

+Z we have the spacecraft (1.5 mm) , the thermal blanket (1 mm) , the upper plate (6 mm) , the gas tight or the electronics box (2 or 1 mm) . In total 9.5 or 10.5 mm aluminium.

-Z we have the spacecraft (1.5 mm) , half body of spacecraft equipment star sensors etc , equivalent to 10 mm plus thermal blanket (1 mm) , extheral box (1 mm) , internal box (1.5 mm) . In total 15 mm .

In conclusion we have 15, 21, 26.5 , 10 , 15 mm aluminium.

We have to sustain 2 or 4 Krad for the nominal or extended mission.

All the components are up to 10 Krad standard.

MODULE E, P

These 2 modules are well inside the spacecraft with module O on top , other structures and electronic boxes all around , the aluminium thickness is evaluated to be larger than 10 mm in all directions except the –X one . from this direction we have the radiator (1 mm) , the outer shell of the spacecraft (1.5 mm) , plus 1 mm outer box . It is not known if there is some other equipment on this side of these two modules . The aluminium thickness therefore is at least 3.5 mm. For both modules, however , the electronic boards are mounted to be sideways from this direction, so al the components are seen sideways , which we consider

equivalent to at least 2 mm aluminium.
In conclusion we have either more than 10 mm or 5.5 mm .
We have to sustain 4 or 6 Krad for the nominal or extended mission.
All the components are up to the 10 Krad standards.

MODULE S

+ - Y we have at least 2 times the spacecraft (3 mm) , plus two experiments 20 mm (?) , plus thermal blanket (1 mm) , exthernal box (1 mm) , internal box (1.5 mm) , in total 26.5 mm aluminium.

+X we have the entire body of the spacecraft (10 mm) plus the high gain antenna (1.5 mm) , thermal blanket (1mm) , plus 1 mm outer box , + 1.5 mm inner electronic box in total = 15 mm at least.

-X We have only the body of module S = 5 mm aluminium . We have to examine one by one the components and either replace them with rad hard (if they exist) or protect them with aluminium layer.

-Z we have the spacecraft (1.5 mm) , half body of spacecraft equipment star sensors etc , equivalent to 10 mm plus thermal blanket (1 mm) , exthernal box (1 mm) , internal box (1.5 mm) . In total 15 mm .

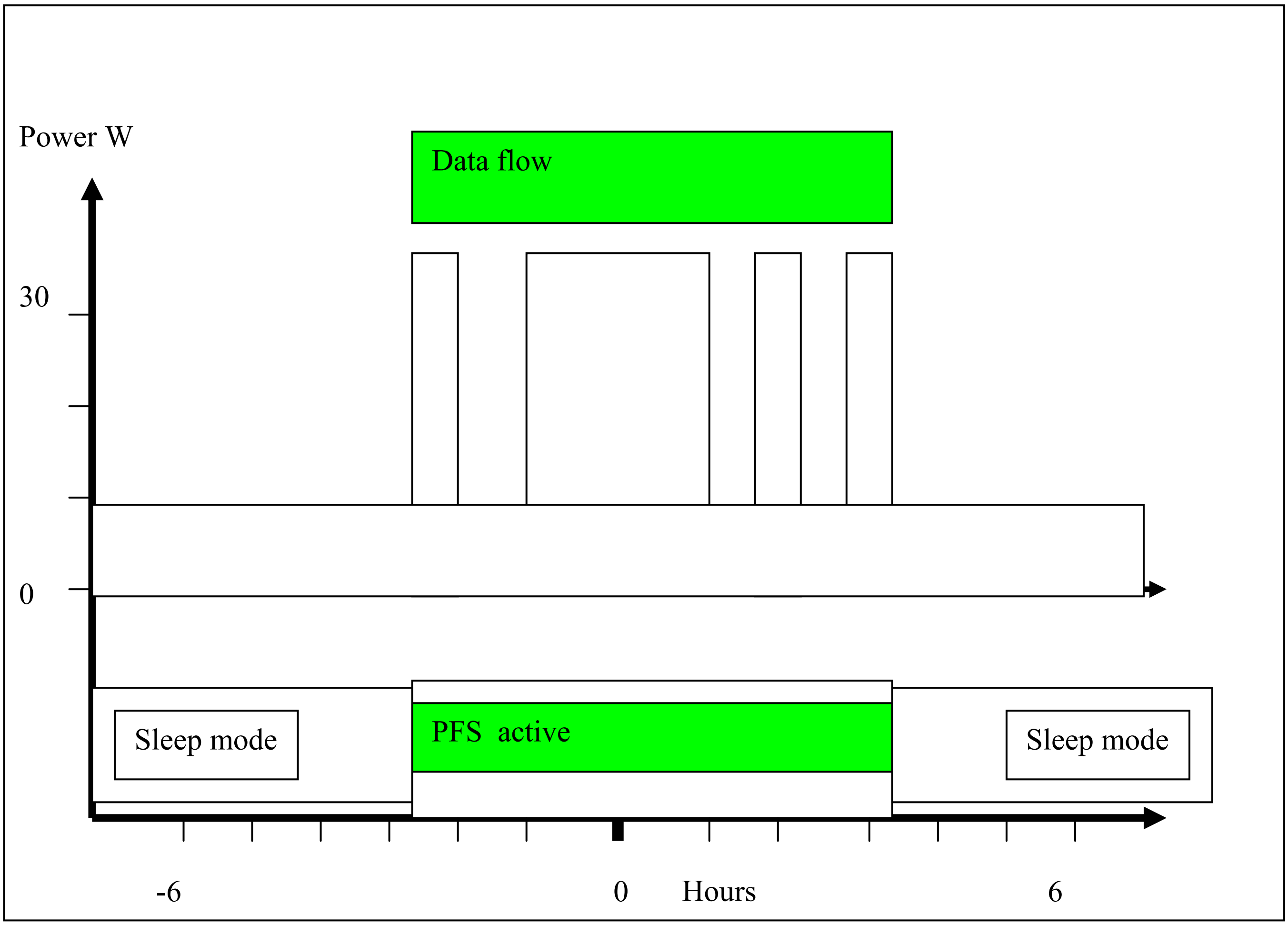
+Z We have only the body of module S = 2 mm aluminium . We have to examine one by one the components and either replace them with rad hard (if they exist) or protect them with aluminium layer.

POWER ASPECTS

The average power of PFS will stay the same.
The peak power will stay the same.
The power profile will change in the sense that , being the orbit 24 hours, we shall operate PFS in 3 or 4 sessions

See the plot below.

More accurate plots of the power profile will be possible when the final orbit will be available.



PFS operating sessions around pericenter

DATARATES, VOLUMES AND OPERATIONAL ASPECTS.

The data rates , as for MEX will depend on the Data Telemetry Mode. Indeed PFS is able to reduce the amount of data presented to the spacecraft , on the basis of the partial data compression or cutting performed in preparation of the DTM.
On MEX the nominal data rate is 32 Kbps. On VEX the baseline is the same , with some possible variations . As on MEX the double pendulum speed can be changed +- 50%. Furthermore on VEX the SW interferogram is changed to be not 16384 words, but 16384 + 8192 = 24576 words. If we keep the repetition rate 10 seconds, the measurement being
24576 + 4096= 28 672 words = 458 752 bits equivalent to 46 Kbps (including haeder) .

OUR REQUEST FOR VEX IS THEREFORE TO HAVE 46 Kbps.

As previously stated our request will vary on the basis of the actual Data Telemetry Mode which will reduce the data rate , when needed , by a factor 2 or 4 .
It should also be understood that the data rate is rather a relative requirement in the sense that when it is not available to PFS , measurements can be stored in the PFS Mass Memory (32 Mbits) .
It is also important to note that while on MEX we take 540 measurements around pericenter, on VEX we shall take

540 measurements around pericenter
11x20 measurements , image before pericenter pass
11x20 measurements , image after pericenter pass
11x11 south pole image

in total 1101 measurements per orbit plus 120 calibrations = 1221 measurements.
In the DTM 17 these are 562 Mbits per orbit.

ELECTRICAL INTERFACE

The PFS electrical interface will stay the same. In this sense the EM unit presently in Astrium in Toulouse is well representative of the experiment.
As the software of the experiment is going to be changed , mostly because of the different size of the SW channel interferograms, we request to have the opportunity to modify the on board Module E software , before the EM activity starts , in June 2003.

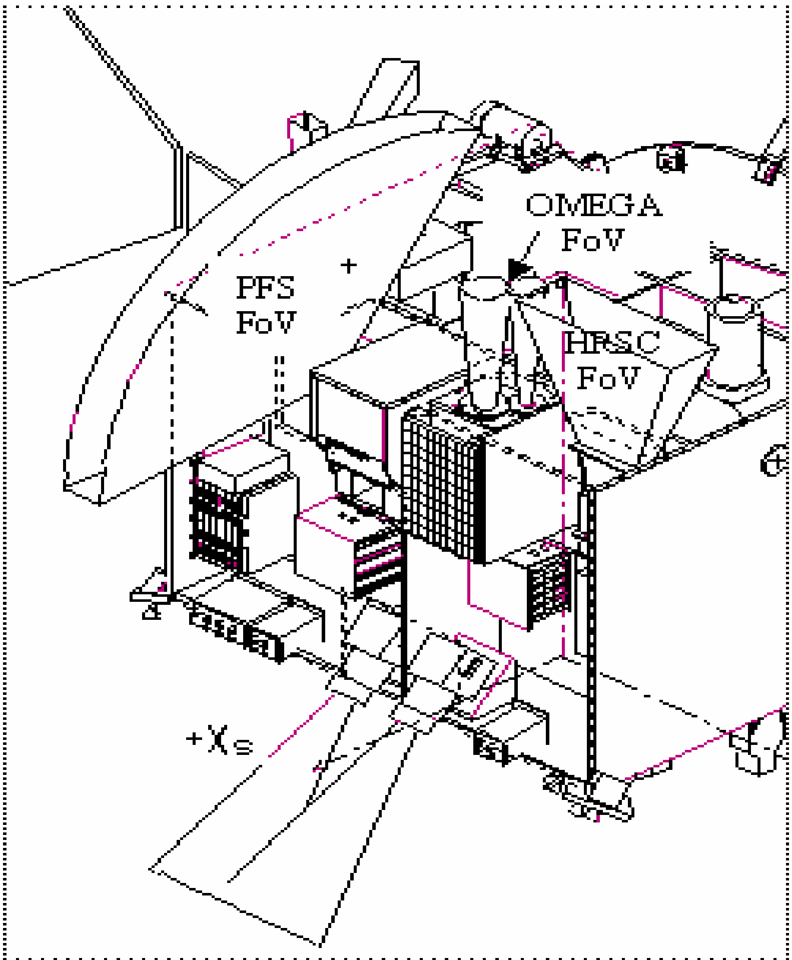
OPTICAL ASPECTS.

We discuss here the fact that occasionally solar light may enter the scanner aperture on the spacecraft.

We shall discuss : IFOV , Unobstructed FOV , Straylight , Protection from solar light.

IFOV
PFS IFOV has been measured to be
SW channel : FWHM = 1.6 deg , 2 deg max entrance.
LW channel : FWHM = 2.8 deg , 4 deg max entrance.

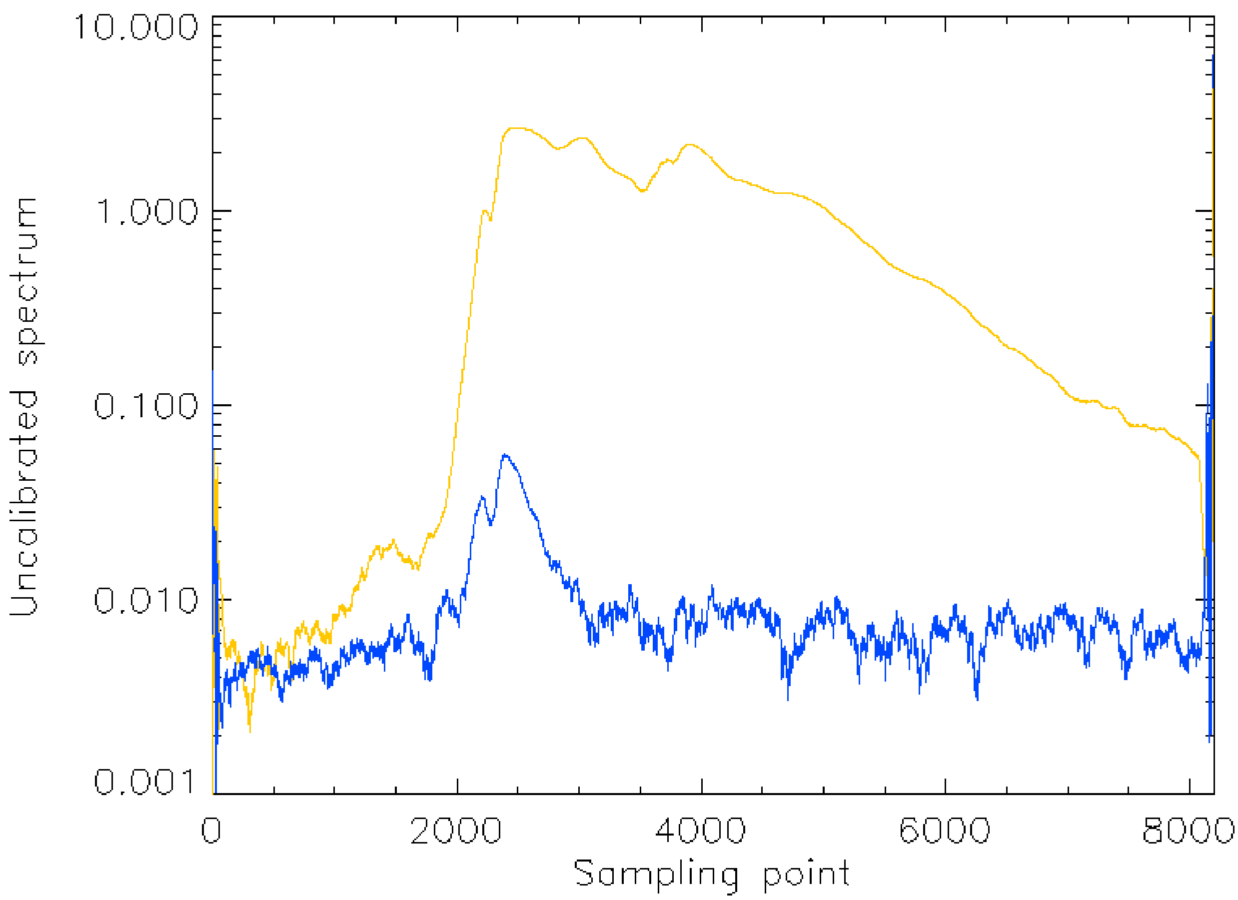
PFS has a pointing device because needs to point nadir to measure Martian radiation, but in order to calibrate the measurements, we need to point also to a Blackbody of known temperature , and to deep space. Occasionally , also , we may use our scanner to point off nadir. The IFOV is 4 deg for the LW 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.



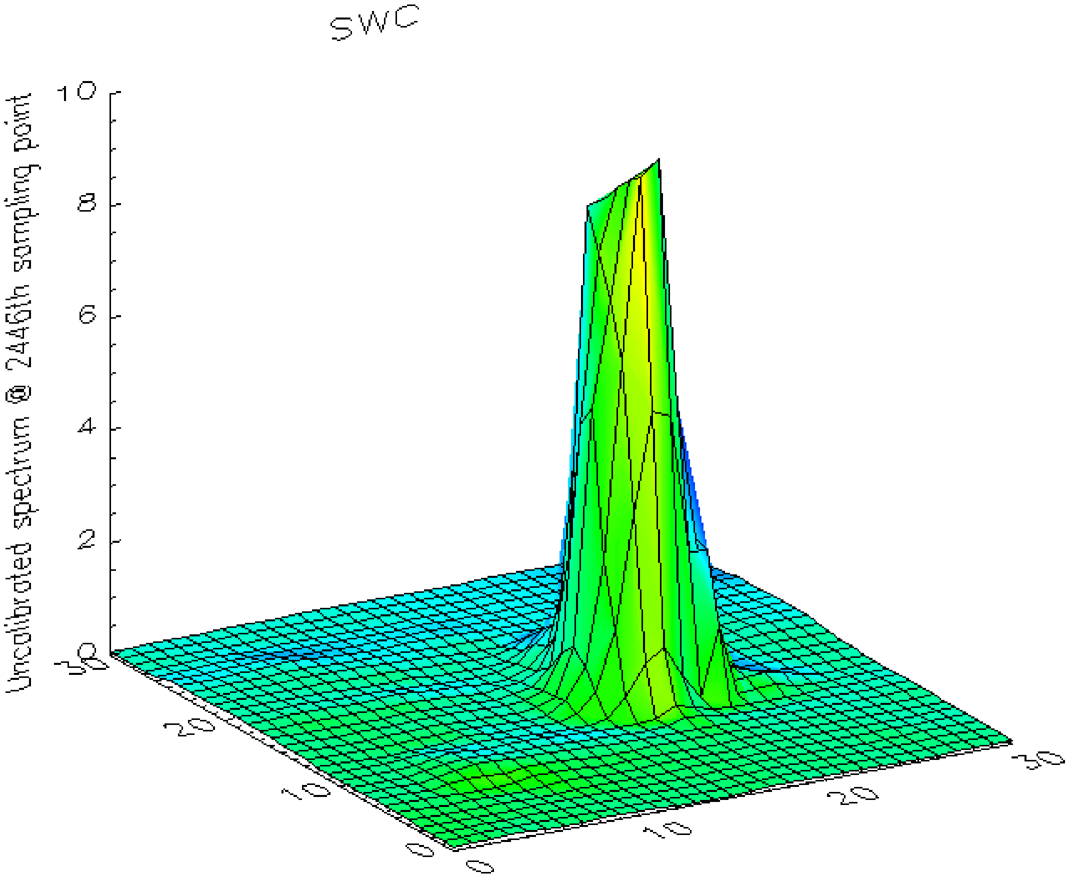
Unobstructed FOV
We request an unobstructed FOV of 10 x 120 deg .
As it has been shown in PID-B documentation , this is equivalent to ask an entrance aperture of 126 mm at the spacecraft surface.

Protection from solar light
We request that if the sun direction comes closer than 15 deg from the optical axis or the optical plane (the plane in which the IFOV is rotated) , the scanner shall be closed and the experiment to be switched off. Once the orbit will be known we will study also if the planned scientific activity brings the sun too close to the limits stated above. In those cases the activity is going to be cancelled.

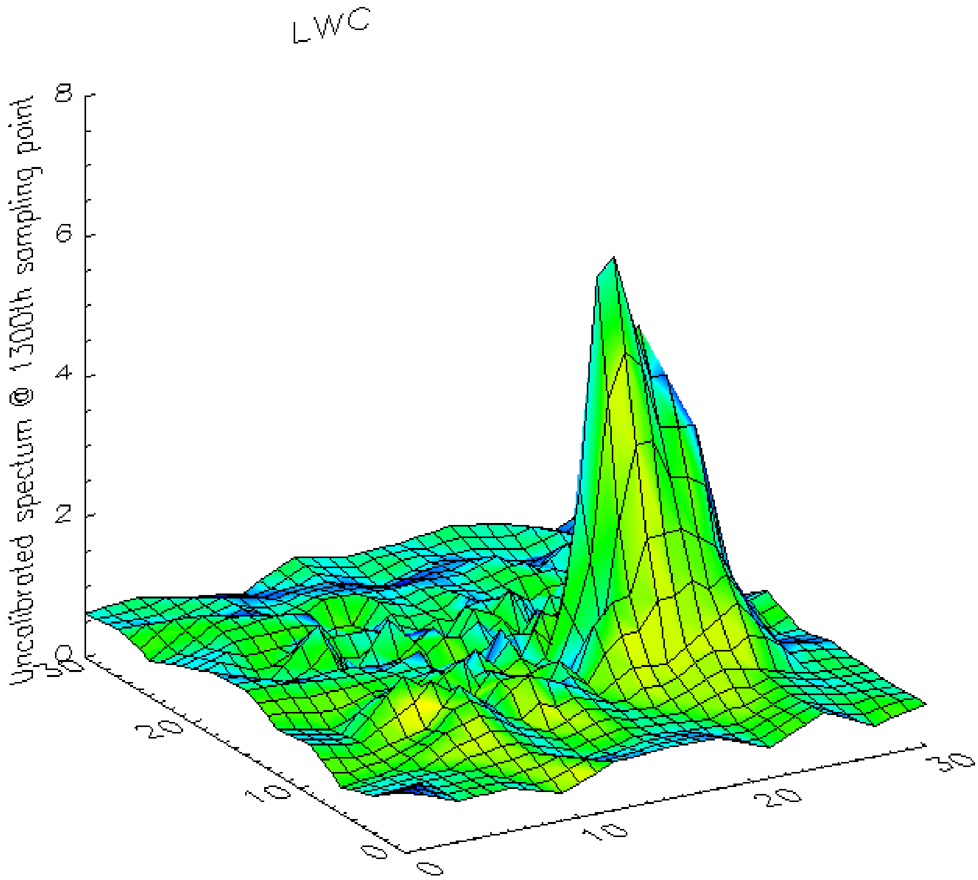
Straylight
In performing the FOV measurements for PFS MEX we have also measured the straylight . The study has been performed by moving a source (not collimated) at 1 m from the O module entrance over a square of 30 by 30 cm (equivalent to 10 deg on one side and 10 deg on the other side). In performing these measurements we have not been able to really see the straylight , but when the source was out of the IFOV , we could see the background : i.e. the



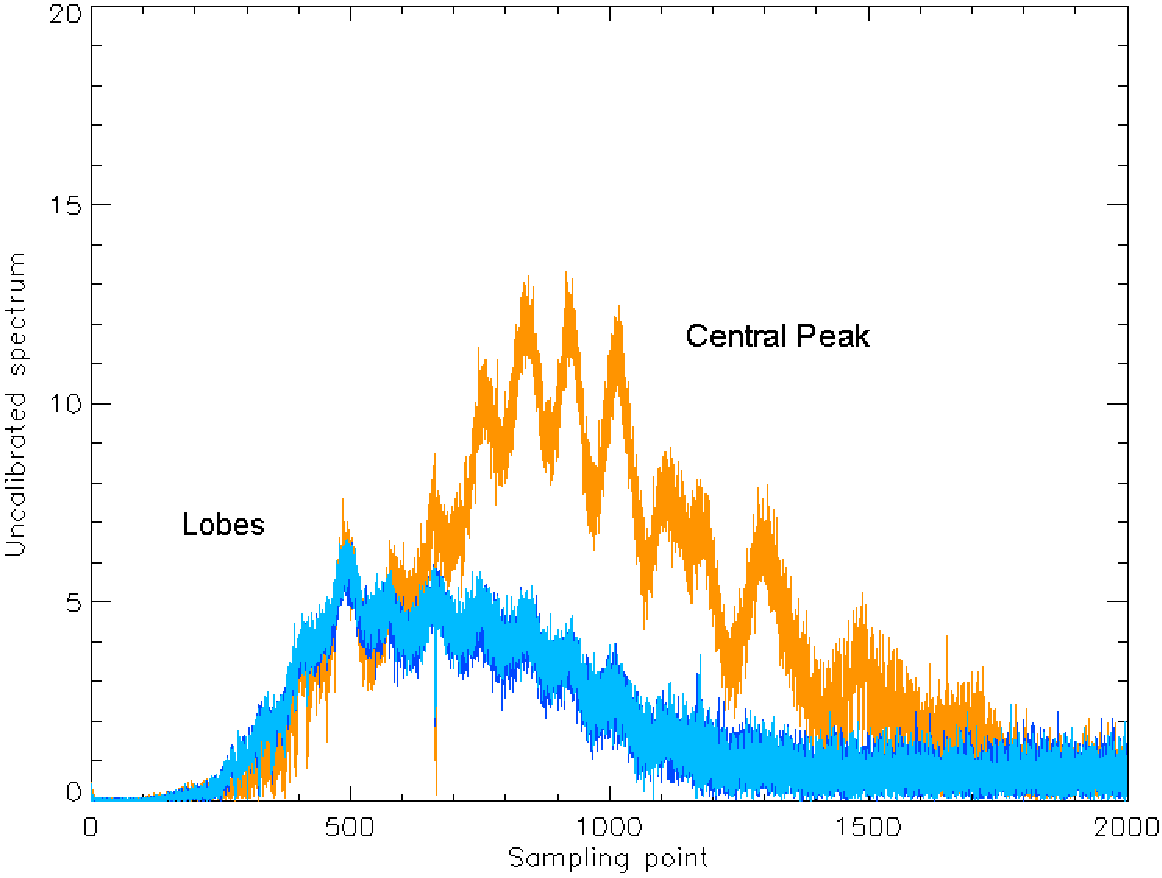
back wall of the room. The thermal radiation from this wall was seen in both channels. As the source was an hot ceramic element, the difference was very big in the SW channel . In the figure above we have a rejection factor of at least 300. The small peak observed at 2500 cm-1 is thermal radiation from the wall : at 4000 cm-1 the rejection factor is larger than 300 , and what is observed is only noise.



The figure above gives the IFOV of the SW channel in the worst wavenumber : 2500 cm-1.



The above figure gives the IFOV of the LW channel. Away from the IFOV the thermal radiation from the wall of the room is evident. The difference between source and wall radiation is clear in the following figure.



The spectral difference is tipical for a hot source (yellow) and room temperature (bleu).

In conclusion we are not sensitive to straylight radiation . The rejection factor is at least of the order of 300. In any case , only if the radiation comes inside our IFOV will be modulated by the interferometer and detected. Steady radiation from the instrument arrives on the detector and contributes to the continuum, but being not modulated by the moving mirrors, is not detected.

SOFTWARE CHANGES

As the dimensions of the SW interferogram will be changed from 16 384 to 24 576 , the software must be changed to allow the new conditions in all the digital hardware , namely :

Module O software OBDM.
Module E software DAM.
Module E software ICM (FFT on line) .

The timing and the transmission of data from O to E should also be optimised .

IB HARDWARE MODIFICATION

Module O-IB will have

new laser diode (0.9 microns , as 1.2 microns are not available any more).
New SW detector (PbS+PbSe) and not only PbSe as for Mex.
New optical window to define the upper edge of the SW channel wavenumber.

Beam splitters and dichroic mirror should be kept the same.

PERFORMANCES MODIFICATIONS.

LW channel : no modification.
SW channel : SNR will be increased by a factor 10 roughly.
The wavenumber range will change from 2000 – 8200 cm-1 (16384 points interferogram) to 2000 – 11000 cm-1 (24 576 points interferogram) .

Furthermore with a minor modification inside the Scanner , and taking advantage of the orbit at Venus, an "imaging" mode will be implemented, which from a distance of the order of 20 000 Km altitude will allow to take 11x20 or 11x30 measurements with a footprint of the order of 300 Km contiguous in raws and columns so that an "image" can be built.

SCHEDULE.

```
2002            2003                     2004
 N  D   J  F M   A M  J  J  A S  O  N  D   J
I++I++I++I++I++I++I++I++I++I++I++I++I++I++I++I
=====    P+E acceptance testing
================ software
                ==== EM update
============  parts acquisition
     =============  O-IB fabrication
     scanner update    ======
O-IB assembly   =============
PFS integration               ===
O+S environmental testing        ==
Calibrations                       =====
Delivery                                 ===
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