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Subject: **FIRST PFM System Test Philosophy**

1. Introduction

This memo is written as an input to the telecom with the FIRST PI's on the 06.01.1999 on the FIRST PFM integration and test sequence.
It is intended to provide further insight into the integration and test philosophy applied for the preparation of the FIRST baseline schedule as presented in the Payload meeting in Paris on 21.10.1998. It is consistent with the overall schedule, however, concentrates on the detailed technical content of the various different activities.

2. FIRST PLM PFM Integration Sequence

The integration of the instruments into the FIRST cryostat starts with the open cryostat at the completion of the earlier test phase, the STM programme, where instrument dummies are mounted in the PFM cryostat. The major tests completed at that point in time are:
- thermal characterisation (lifetime, ground hold time)
- cryogenic operations verification (bake out, cooling, filling He II production, pressure drop...)
- qualification level vibration
- alignment verification and procedure development
- warm up.

The integration flow of the instruments is shown in the flow 2.1-1 below and is considered completed with the closure of the cryostat at ambient temperature and pressure.

The major steps that can be identified are:

- Instrument integration to optical bench (mechanical/thermal and electrical)
- Instrument ambient temperature functional check (no alignment, expected that mechanical adjustment is sufficient)

- Closure of optical bench (mechanical and straylight – specially w.r.t. LOU windows and filters)
- MLI closure for optical bench
- Subsequent integration (shield by shield with closure of optical bench)
- Integration of cryostat vacuum vessel outer shell upper part (connection of He filling system, leak test of the He system after connection)
- Integration of FM cryostat cover
- Closure of the cryostat and integral leak test of the cryostat vacuum vessel, pre-evacuation of the system
- Integration of the cryostat cavity, connection of external ventline, leak test
- Transport of cryostat from integration area to test area and preparation for PLM testing.

The sequence has been planned assuming nominal working hours and complication of class 100 cleanroom needs. Further the cleanliness and cleanliness control procedures have been assumed similar to the integration of the ISO system.

I would like to give some further notes to the above activities on assumptions used for the planning:

Instrument integration to optical bench and ambient temperature functional check
Each instrument is mounted separately to the optical bench. It is assumed that no alignment activities are necessary, the mechanical mounting is sufficiently accurate. The integration is done according to common practice on ECD protection in the Cl100 cleanroom. The thermal links are integrated from the tank, resp. the cooling loops. The harness is integrated from the optical bench interface connector to the FPU's. The further harness throughout the cryostat is assumed to have already been integrated and validated prior to the instrument arrival. The electrical integration is carried out by dedicated measurements of the impedance (pin by pin). After connection of the harness to the FPU and through the complete system it is foreseen to perform a short functional test, instrument by instrument, at ambient temperature. It is not yet clear, whether special protections are necessary for the local oscillator input path for straylight reasons, e.g. type of baffles from the optical bench shield interface "into" HIFI.

Closure of optical bench
After completion of the above the optical bench can be closed. This is basically just putting the shield around the instruments. At this stage it is expected that we need a type of verification of the IR tightness of the system with the exception of the optical channel. The optical entrance is closed off, together with the LO filters and the "sealing" interfaces are illuminated (visual) while having still optical sensors in the optical bench/shield cavity. The validation of the integration approach is seen as part of the CQM test sequence and follows the same lines.

MLI closure for optical bench and subsequent shields integration
The closure of the cryostat is systematic integration of the shields and closure of the MLI between the upper conical shield and the cylindrical part of the cryostat. One major element during the integration is the control and achievement of the cleanliness requirements.

Integration of cryostat vacuum vessel outer shell upper part
After integration of the insulation system the outer shell can be integrated. Besides the mechanical integration at the outer cylinder the connection of He filling system has to be performed with the corresponding leak test of the He system.

Integration of FM cryostat cover
The cryostat cover is mounted on top of the system with the opening mechanism. This is here the FM cover system. The system that was mounted beforehand is a qualification model, which is now taken for refurbishment as FS. The integration is completed by a functional test. Since the cover has to be opened later in the test sequence this needs to be verified also here.

Closure of the cryostat and completion of integration
Upon completion of the cover integration the system is closed and ready for the integral leak test of the insulation system. The cryostat is pre evacuated and integral leak test performed. The system further is now ready for transport from the integration area to the test area and the start of the test sequence.
The remaining items for integration are the cavity on top of the cryostat and the connection of the vent gas piping to the cavity. This is carried out later in the sequence, since it is not compatible with the cryogenic instrument test.

Transport of cryostat
The transport of the cryostat from the cl100 cleanroom to "normal" cleanroom conditions is the last activity of the integration sequence.

3. FIRST PFM Test Sequence

3.1 FIRST PLM PFM Test Flow

The test sequence after integration considers the following major stages:

- Evacuation and bake out
- Alignment checks of the FPU's
- Cooldown of the system and filling with He I
- Alignment check after cooling
- He II production and complete filling
- Integrated Module Test
- Transport to system AIV

As can be seen the test sequence is dominated by activities that are related to the payload. Since the same cryogenic system has already been verified in the STM sequence the task to do here for the cryostat is reduced to validating that the performance is the same, i.e. no degradation. The telescope is not planned to be mounted in this sequence as part of the PLM activities, but as part of the system activities. As a performance test of the three instruments is foreseen it has been assumed that the control electronics are available and can be connected to appropriate EGSE. In this sequence there are a number of parallel activities, therefore further explanations are given for each step.

Evacuation and bake out
The cryostat is on its MGSE in the cleanroom and the vacuum pumps are finally connected (should be mounted already since needed for pre-evacuation). The Helium venting system is connected to high temperature Helium or eventually Nitrogen flow that increases the temperature of the Helium tank and piping to around 80°C. This is done in a controlled manner, to keep the instrument units always at the highest temperature (avoid contamination). The purpose of the bake out is twofold, on one side removal of contamination from the system on the other hand removal of water from the MLI to increase the later low temperature performance.

As a parallel activity to the evacuation and bake out the GSE cavity is mounted on top of the cryostat. This cavity is planned to be designed for alignment and test purposes and allows opening of the cryostat cover with vacuum in the system or even when filled with Helium. It is not clear whether this could be a multi purpose GSE cavity or whether it is simpler to use more than one but simpler systems. The local oscillator unit is not yet mounted.

Alignment checks of the FPU's
The FPU position is now measured through the opened cover and alignments via the cryostat suspension system is performed. The other expected alignment measurement is via the local oscillator windows into the HIFI. The alignment is measured w.r.t. a cryostat fixed reference system.

Cooldown of the system and filling with He I
The system is evacuated and aligned so it is time to cool the system to cryogenic temperatures. It is expected that this have to be done in a controlled way, i.e. with the instrument cooldown rate controlled and the instruments as the warmest element in the system. The cover would be kept closed during this activity. The system is filled up to 100 % filling level at this temperature.

Alignment check after cooling
The FPU position is now measured through the open cover. The cryostat suspension pretensioning system (GSE) can now be removed. At this point the alignment of the local oscillator unit is performed, first via measurement of the FPU and then after integration of the unit either via an external reference or, if possible, directly to the FPU.

He II production and complete filling
As a preparation of the integrated module test, the temperature of the Helium tank is reduced to 1.6 K and the tank filled up completely. This is done in a sequential way, i.e. pumping the tank, filling, pumping, etc. The final condition is that the He II tank is filled with He at around 1.6 K and the instruments "see" the "real" expected environment. During this time, as a parallel activity, the electrical connection can be made to the warm electronic units. No time is foreseen at present for the integration of the recently mentioned waveguides from the local oscillator to the warm control unit or mounting of the SPIRE buffer amplifier unit (if to come). This could be to a good extent performed in parallel, so would not add immediately time here. The external cryostat harness is expected to come completely new for the FM and is also integrated in parallel (already during the above activities, but need to be ready now). The GSE cavity could at this point be exchanged, if one would go for different GSE items. The definition of the cavity for the integrated module test would be such as to simulate/provide a low temperature background to the instruments, similar to the orbit case. Since later the telescope will be mounted to the cryostat, this is the only point in time of the FM sequence, where such low temperature background could be provided.

Integrated Module Test
The integrated module test is the full performance function test of the instruments, instrument by instrument and together. It has to be assumed that the procedures have already been validated with the CQM, so this test sequence is for validation and not procedure development. However, note that this is the first time that the PFM instruments are together in the proper environment. During this test some information is obtained on the performance of the cryostat, w.r.t. temperatures and lifetime, but this is gathered as a separate information and should not drive or dominate any of the sequences. At the end of the test sequence the He bath is heated to ambient pressure (He I) and prepared for transport. At the end of the sequence the flight cavity is mounted to the cryostat and connected to the He ventline system.

Transport to system AIV
It is not expected that the cryostat tests will be carried out at the same facility as the system tests (planned to be at ESTEC). So the cryostat has to be transported to the system test facility. This means packing into the container and shipment. The cryostat without the telescope is still compatible with road transport.

3.2 FIRST PFM System Integration

After transport and unpacking of the cryostat the system integration can start. It is assumed that the SVM for FIRST has already been integrated and validated. The remaining items to be integrated can be listed as:

- FIRST telescope
- External structures
- FIRST Sunshield
- Service module with PLM.

The complete integration is performed with the He tank of the cryostat at normal pressure conditions, i.e. at 4.2 K. One filling is expected during the integration period. The total available time for integration without filling would be only 2 months, what is too short for the complete integration activity.

In the same way as above I tried to provide some additional explanations for each of the major integration steps:

Integration of the telescope
The cryostat has been unpacked and is on mounted to the MGSE in the cleanroom. The telescope is mounted together with the PLM to telescope interface struts. Some special protection is applied to the telescope to avoid contamination. The external references of the telescope will be adjusted to the PLM reference. The thermal insulation/heating of the telescope will be mounted now, after completion of the mechanical/optical integration. The alignment measurement to the Local oscillator and the external cryostat reference provide the basis for the later comparisons. It is not planned to perform any real telescope performance measurements now, e.g. measurement of the WFE.

External structures
The title is not really a summary of the planned activities here. The activities foreseen comprise the integration of the external insulation of the cryostat on the front side, i.e. the side facing the sunshield, the upper conical part and the lower interface to the SVM. This includes, partially mounting the interfaces to the supporting struts for the sunshield. At least the brackets need to be integrated now. Depending on the design of this supporting system (see e.g. the L_2 configuration as given on the WWW page) the supporting system also provides interface points to the startrackers. Otherwise a dedicated structure has to be mounted with proper insulation to the cryostat.
During these activities the cryostat will be refilled to 100 % with He I. The activities include mounting of the cryogenic GSE, filling and partial removal of the GSE. During these times the system needs to be connected to EGSE for control and commanding. The instruments need not be connected during this period. The ambient temperature units of the instruments as coming from the PLM PFM test sequence need to be mechanically and electrically (functionally) integrated to the FIRST SVM to be ready for the integration of the SVM to the PLM.

Integration FIRST Sunshield
The sunshield fixation design is expected to have mechanical interfaces only to the cryostat. This allows the "stand alone" integration without the SVM. The duration of the integration depends on the actual design. It has been assumed here that the sunshield consists of several panels that need to be integrated sequentially with insulation material (MLI) to be mounted to each of the panels after mechanical integration. This is considered not yet an optimum design approach.

Integration of the Service Module with PLM
The integration of the SVM includes the mechanical mounting and the electrical integration. Since this requires lifting of the cryostat with the 3.5 m telescope on top and the sunshield attached on one side, this is considered a quite complicated step. The integration and de-integration of the necessary MGSE for lifting and handling is part of the total duration. At the end of the integration steps the system is expected to be mounted on the lower interface adapter, actually the cylindrical ring to the Planck S/C and now at a height of nearly 10 m.

for T. Passvogel