1. Introduction

As input to the proposed discussion between the instrument teams, ESA and the Prime Contractor, on the system-level AIV activities I present here the perceived needs for pre-flight system level integration from the SPIRE perspective.

2. Instrument Requirements for System Level Testing

An analysis of the qualification and verification requirements for the SPIRE instrument (SPIRE-RAL-PRJ-000592) has shown that the only instrument qualification issues that are not fully tested and verified by the instrument level tests are those associated with the thermal balance of the instrument during cold operation in the Herschel cryostat and the EMC sensitivity of the instrument in the Herschel environment.

If these issues are to be fully tested at system level, rather than relying on analysis followed by verification on the PFM, we would require a pre-flight model of the Herschel system and the instruments that is fully representative of the thermal and EMC properties of the system. It is proposed that the ISO EM cryostat can be converted into such a model. In order that it goes further than the instrument level tests performed on the SPIRE CQM it must replicate the following conditions:

1. All electrical interfaces with the system need to be present; functional and flight representative. This should really include the SVM system and all cryoharnesses with the correct shielding; lengths and operating temperatures. We will have used a simulator at instrument level with a more-or-less representative harness so repeating the test with a simulator at system level doesn't appear to offer an improvement.
2. The EMC environment in the cryostat has to be fully representative of the Herschel cryostat and demonstrated to be so by modelling or analysis.
3. The instrument must be capable of being placed into an "EMC" sensitive mode in order that we can observe any noise generated by EMI. SPIRE intends to achieve this with the ground test shutter mounted on the outside of the instrument, which will allow the correct thermal background on the detectors to be obtained. Other instruments may not have such a device and may require the cryostat to provide a "dark" environment.
4. The cryostat must have the ability to replicate the in-flight thermal conditions in terms of temperatures of the optical bench and shields nearest to the instruments and the mass flow rate through the vent pipes. Both temperatures and mass flow rates have to be achieved at the same time in order that we can really verify the performance.
5. The cryostat has to be held in flight condition for a sufficiently long time that we can recycle the cooler and run through the critical tests for the instrument thermal balance - mode switching JFET power etc. The cooler recycle will take ~1 hour and the instrument operations another hour at least.
6. In order to recycle the cooler the cryostat must be capable of being tilted to ~ 20 degrees from vertical.
7. In order to test the spectrometer mechanism the cryostat must be tilted to near to horizontal (actual angle TBD)
8. All electrical; mechanical and thermal interfaces for the system CQM model must have been verified against the specification before integration of the instruments.

If these conditions, or the majority of these conditions, cannot be met, then the tests have limited intrinsic value for the instrument level verification. If there is no meaningful pre-PFM system level verification possible, the thermal and EMC testing conducted at instrument level should be used in conjunction with the instrument and system models to predict the instrument performance in-flight.

3. System Level Requirements

From the Astrium presentations in Cannes in the April meeting, it seems that the system CQM testing is divorced from the PFM schedule - i.e., the PFM cryostat does not appear to depend on knowledge from the CQM testing. Therefore, the system level need for there to be pre-PFM models and instrument integration at system level would seem to be to verify the following aspects of the system integration and performance:

1. Integration procedures for the FPU units and the Herschel optical bench
2. Cryoharness design verification – including (presumably) EMC testing
3. System level optical alignment procedure checkout
4. Instrument interface verification: electrical, mechanical, optical, thermal, operational
5. End-to-end operational check out with all systems present
6. Verification of PFM test procedures for the instruments
7. Training of contractor staff in instrument integration and test procedures

What is not clear is whether all these things need to be done on a single system level model, or whether the proposed use of the ISO EM cryostat; the CQM instruments and an SVM simulator fulfils the requirements for an end-to-end test

4. An Alternative Pre-PFM Model Philosophy

A major problem for the proposed system level CQM test is that none of the three instruments can, on their declared schedules, deliver the CQM instruments on the date that Astrium have said they need them. Here I propose an alternative approach to the "big bang" model of the system level CQM that achieves most, if not all, of the verification tests.

If we ignore the instrument requirements on the CQM testing and accept that the major requirements for the system level testing are as listed above, we can analyse what functionality is required from the instruments and system in order that the verification can be carried out.

Table 1: Analysis of requirements for pre-PFM system level verification

Requirement	Instrument	Cryostat/harness	SVM
1. FPU Integration procedures	Form and Fit Only required to be mechanically compliant	Form and Fit Only optical bench is required. The optical bench to cryostat integration and cryoharness integration does not, presumably, require the instruments.	N/A
2. Cryoharness design	Form, fit and function Instrument needs to be set into "most sensitive" mode in order to check out EMC properties of cryoharness (same as instrument requirement)	Form, fit and function Both cryostat and cryoharness need to be as close to flight representative as possible. In addition if this is to be truly meaningful the harness *external* to the CVV must be at flight operating temperature	Function In principle, as with the requirement from the instrument, this should be present and as close to flight representative as possible.

Requirement	Instrument	Cryostat/harness	SVM
3. Optical alignment	External optical references and representative mechanical interfaces	Optical bench is required. It is not clear whether this test requires the optical bench and instruments to be cooled down.	N/A
4. Instrument interfaces			
Electrical	Interfaces to SVM need be present and flight representative This needs to address electrical interfaces to the cryoharness	Not required	Fit and function Flight representative
FPU Mechanical	Mechanical interfaces present and in correct relative arrangement	Optical bench only	N/A
FPU Thermal	All thermal interfaces as close to flight as practicable including mass; dissipation and mechanical interfaces	Cryostat must be capable of reproducing flight conditions for some period of time (same as for instrument test requirements)	N/A
Operational	Instrument must produce appropriate telemetry and signal response to commands	Not required	Flight representative – commanding environment must also reproduce flight conditions.
5. End-to-end test	To provide true end-to-end test of integration and test procedures for the PFM the instrument needs to be form, fit and function compliant (see instrument requirements above)	Again for a true end-to-end integration and test procedure check out it needs to have form, fit and functional compliance	Needs to provide all system level interfaces to the instruments and representative commanding environment
6. Test Procedure Verification	Reference data set required. Instrument must produce appropriate telemetry and signal response to commands	Not required	Commanding environment must be representative and SVM or simulator must give the appropriate response to commands
7. Training of staff	For FPU integration procedures form and fit compliance is required to allow integration procedures to be carried out. For test procedures requirements as for 6.	Only optical bench is required	Not required for FPU integration procedures. For test procedures requirements are as for 6.

From the table we can see that a working cryostat and instrument in the form of the CQM is only required in three cases:

- EMC testing of the cryoharness,
- verification of the thermal performance,
- end-to-end operational checkout verification of the integration and test procedures.

In two of these instances – EMC and thermal tests – the requirements on the complete system are essentially the same as required for the instrument testing set out above – i.e. a model of the SVM must be present and flight representative for the EMC and the cryostat needs to provide flight temperatures and gas flows for a sustained period. In fact for the cryoharness test it only becomes truly meaningful if the external harness is also at flight temperature, or if its properties at flight temperature are reproduced.

For all the other tests a combination of a mechanical/optical dummy and the AVM is all that is required for the instrument and indeed for the cryostat. A mechanical/optical dummy could possibly be provided by the instruments at the time required for the integration and test checkout of the cryostat proposed by Astrium. The AVM will anyway be deliverable at the time required. The CQM instruments could then be used only for a later end-to-end checkout and, if possible, the EMC and thermal balance checks.

Careful consideration now needs to be given to whether:

a) the test environment proposed for the CQM testing can possibly meet the requirements, and

b) the cost and complexity are justified in terms of the gain to be had in risk reduction to the overall system.