0 Document History

November 2000 - First draft for system review and comment

March 2001 - First issue reflecting updates to Qualification Requirements Document and to changes in the provision of the cooler - STM then CQM.

1 Introduction

This note outlines the test philosophy and requirements for the SPIRE instrument STM. It expands upon this to give the requirements on the instrument STM sub-systems and the requirements on the test facility to be provided at RAL.

2 Instrument Level Test Philosophy

A model philosophy for the SPIRE instrument has been adopted that has three cold FPU models: a Structural Thermal Model (STM), a Cryogenic Qualification Model (CQM) and a Proto-flight model (PFM). These are described in the *SPIRE Instrument Qualification Requirements Document* (SPIRE-RAL-PRJ-000592). In essence the STM will be only mechanically and thermally representative and, apart from the hardware necessary to provide the different temperature levels within the FPU, will have no functioning sub-systems. The idea behind the STM is to have as early an indication as possible in the overall instrument AIV plan of the vibration levels that will be experienced by the sub-systems in the FPU during launch. It will also to verify the FPU structural design with both warm and cold vibration testing – it serves, therefore, as the qualification model of the SPIRE FPU structure. Also the STM will be cooled down to operating temperatures in the instrument test cryostat. If the appropriate thermal architecture is implemented in the STM then the thermal performance of the instrument can be assessed and the Thermal Mathematical Model of the instrument verified and calibrated.

One other use of the STM is that, if flight like mirrors are fitted, then most of the optical alignment checks and geometric optical performance verification can be carried out. This will allow the Instrument Geometrical Optical Model to be verified and the basic optical interfaces between SPIRE and Herschel and between the SPIRE subsystems to be confirmed.

3 Test Programme

The system level issues that will be addressed to some extent by the STM test programme will be:

Mechanical interface with Herschel **system**

The FPU and JFET boxes will have the same form and fit as the PFM and will be interfaced to a mock up of the Herschel optical bench. The ability to accurately place the SPIRE instrument and its alignment stability when cooled will be verified.

Optical interface to Herschel **system**

The optics fitted to the STM will be of near flight quality. Optical light tests will be carried out to verify the performance of the optical system with respect to the Herschel telescope optical design.

Thermal interface to Herschel **system**

The STM will be placed in a thermal environment in the SPIRE instrument test cryostat that is as close to the Herschel cryostat as possible. The same temperature levels will be present although the heat capacity of the various stages may be different. The sorption cooler will be capable of being recycled and these tests will give an indication of whether the specified thermal interface (loads; required conductances etc) is correctly specified.

Instrument level integration and alignment
The STM will give the first opportunity to test and refine the instrument level integration and optical alignment procedures for the subsequent models.

Optical design and instrument optical performance
The optical light test programme will be designed to verify the geometrical optical model of the instrument and, therefore, to give confidence that the instrument optical performance will meet the requirements.

Instrument thermal performance
The instrument thermal balance will be simulated for each operating mode and further diagnostic tests will be devised to allow the instrument Thermal Mathematical Model to be verified. Heaters will be placed at strategic points in the STM to allow this testing. Of especial importance to the ultimate performance of the SPIRE instrument will be the behaviour of the 300 mK temperature stage. The cooler and 300 mK architecture and all the interfaces between the cooler and the detectors will be, at some point in the STM programme, fully flight representative in this respect and there will be at least one thermally representative detector module.

Instrument to ground facility interfaces
This will be the first opportunity to check all the physical interfaces between the cold FPU and the instrument ground facility. This will include checking the form and fit of the test facility cryoharness with respect to the FPU and JFET boxes.

Instrument mechanical frequency response and ability to withstand launch environment
A programme of warm vibration will be conducted on the integrated FPU and JFET boxes that will check for mechanical resonance and gradually lead to a full qualification level vibration test. If the warm vibration programme shows no problems, it is expected that a cold vibration of the integrated FPU and JFET boxes will be carried out.

Harness mechanical frequency response and routing
The internal routing of the sub-system harnesses can be confirmed. The routing and support of the FPU to JFET boxes harnesses can be verified both thermally and with respect to the launch environment. It may be possible to devise a test programme during the warm vibration that will test the mechanical resonance of the detector harness assembly (?)

Sub-system mechanical interfaces
The sub-system STMs will be form and fit compliant and will include representative connectors.

Sub-system optical interfaces
Any sub-system with an optical interface to the SPIRE instrument will provide a suitable piece of OGSE (that may be removable) or will be compliant with the specified interface.

Sub-system thermal interfaces
All sub-systems that dissipate significant power in the cold FPU or JFET boxes must provide STMs with the same or similar thermal characteristics and an ability to replicate their expected thermal dissipation under nominal operating conditions.

4 STM Sub-system Requirements

4.1 General

All cold subsystem STMs will need to be mechanically and thermally representative and capable of undergoing the environmental tests to be done on the STM instrument. For the mechanical compliance the STMs need to have at least the same mass as the flight equipment to within 1% (TBC) and have the same centre of gravity to within a 0.5 mm (TBC) radius sphere. Table 1 in section 4.4 gives a summary and comments on the requirements on each cold sub-system. The detectors; the cooler and associated drive electronics are discussed in a little more detail in sections 4.2 and 4.3 respectively.

4.2 Implications for the detector provision

In principle, in order to fully characterise the thermal performance of the 300 mK system, one would like to have all five detector modules as thermally representative as possible. This would mean that the module structure is present with the Kevlar suspension system; the correct mass and thermal capacity at each temperature level and with the correct thermal interface between the detectors and the 300 mK busbar. Temperature sensors with the same sensitivity as the bolometers would also be desirable to test the short and long term temperature stability of the 300 mK system. These would require some sophisticated drive electronics.

In practice it is unlikely that all five modules can be represented in this fashion. At least one must be and the others will be mass dummies mounted on the level 0 (1.7 K) structure. This being the case we will need to consider further how to provide the thermal representation of the 300 mK part of the mass dummy detector modules .

4.3 Electronics

To test the 300 mK thermal performance a working cooler will be required. It is considered too dangerous integrate the CQM cooler before at least a warm vibration of the structure has been carried with a mechanically representative cooler Structural Model (see the *SPIRE Instrument AIV Plan* SPIRE-RAL-DOC-000410). Once a warm vibration has been done and the mechanical response of the structure and cooler within it has been verified, the CQM cooler will be fitted to allow the thermal testing to be carried out.

The CQM sorption cooler will require some drive electronics in order to function. Also the temperature sensors and any heaters will require drive electronics and some form of data recording system. Any high sensitivity temperature probes mounted on the detector modules will require a bridge circuit type readout – this will have to be provided by JPL as laboratory electronics.

Two possibilities exist for the provision of the for the cooler and “standard” temperature sensor electronics:

1. A development model of the SCU is delivered along with the sorption cooler. This would only require a rudimentary output interface that could be read by a standard PC based data logger.

2. Dedicated commercial electronics is purchased. It is assumed that the sorption cooler will anyway have its own laboratory drive electronics and a copy of these could be made and there are several suppliers of commercial temperature sensor read electronics.

4.4 Summary of Subsystem STM Requirements

Detailed requirements on the cold FPU sub-systems for the SPIRE STM		
Subsystem /component	**STM Requirements**	**Comments**
Structure/baffles/ wiring standoffs/2-K thermal straps etc	Flight representative	This is the CQM
Mirrors	Flight representative	This is the CQM – the vibration test programme will be designed not break them!
Filters	Input filter flight representative All others TBD – may not be present except as mass dummies for the filter support rings	The filter at the entrance to the instrument must be present for at least the thermal performance tests as the thermal balance of the instrument will be different without it present. The STM testing can be used to qualify the filter designs is this is compatible with the filter development schedule.
Beam steering mirror	Form and fit Mechanically compliant Thermally compliant	The BSM STM should behave mechanically as close to the flight design as possible. This may mean that the flex pivots on the chop axis are present with a flight equivalent mass suspended from them. Any proposed launch latch system must be represented. A heater and a thermometer with a flight like connector must be present.
3He Fridge	**Initial delivery**: Form and fit Mechanically compliant **Delivery for thermal testing**: Flight representative	Cooler STM has structure with “kevlar stringup” This is the CQM cooler it will be present during the cold STM vibration only if no problems have been seen with the warm vibration of the STM instrument with the STM cooler fitted
300 mK thermal straps	Flight representative	These are the busbars that connect the cooler cold tip to the detector arrays. They are integrated as part of the SPIRE structure and therefore come as part of the CQM structure.
Thermal control system	None	
Photometer LW array	Form and fit Mechanically compliant Thermally compliant	See section 4.2
Photometer MW array	Form and fit Mechanically compliant Thermally compliant	See section 4.2

Detailed requirements on the cold FPU sub-systems for the SPIRE STM

Subsystem /component	STM Requirements	Comments
Photometer SW array	Form and fit Mechanically compliant Thermally compliant	See section 4.2
SMEC	Form and fit Mechanically compliant Thermally compliant	The movable structure of the SMEC will need to be represented and have the same resonant frequency as the flight design. Any launch latch will need to be represented. Heaters to represent the dissipation from both the actuator and the optical encoder (including the amplifiers) will need to be present as will at least one thermometer. Flight representative connector(s) will be provided.
Spectrometer SW array	Form and fit Mechanically compliant Thermally compliant	See section 4.2
Photometer LW array	Form and fit Mechanically compliant Thermally compliant	See section 4.2
Photometer Calibrator	Form and fit Mechanically compliant Thermally compliant	This should be integrated with the BSM STM and a heater provided to simulate the action of the flight design.
Spectrometer hot calibrator	None	
Spectrometer cool calibrator	Form and fit Mechanically compliant Thermally compliant	A heater and a thermometer must be provided to represent the load from both the hot and cool calibration sources and a flight representative connector must be present.
Shutter	Form and fit Mechanically compliant	Mass dummy only.
JFET Racks	Flight representative	Will be the CQMs. The integrated JFET boxes will need to be mass and c.o.g compliant to within TBD %
JFET Modules and JFET box RF filter modules	Form and fit Mechanically compliant Thermally compliant	At least one of the JFET modules should be close to looking flight like. This will allow the final verification of the module design. The other modules need only be form and fit compliant and have the connectors present. Their dissipation can be represented by resistors in one or more of the modules. Thermometers must be fitted to at least one module per JFET box.
FPU RF Filters	Form and fit Mechanically compliant	All connectors must be present. If they were available these could be the CQM modules.

Detailed requirements on the cold FPU sub-systems for the SPIRE STM		
Subsystem /component	**STM Requirements**	**Comments**
Thermometry	As necessary for thermal monitoring during cold tests – not to be vibrated.	Extra thermometry, over and above that provided by the sub-system STMs, will be provided for the cold testing. How this is wired up is TBD, but it may be possible to use the instrument harness.
FPU internal harnesses	Flight representative.	These are the CQM harnesses and connectors.

5 Requirements on the Test Facility

The ground test facility to be provided at RAL will need to provide the following to allow the STM programme to be carried out:

1. A mechanical metrology system capable of measuring the positions of the mirror interfaces with a precision of <10 microns (TBC)
2. A clean area (at least class 1000) where the sub-systems can be integrated with the structure
3. A clean area (class 1000) with sufficient space to allow the optical alignment procedures to be carried out
4. A cryostat that will accommodate the cold FPU and JFET boxes integrated on a Herschel optical bench simulator.
5. The cryostat must simulate the temperature stages specified for the Herschel cryostat.
6. The cryostat must allow the cold optical alignment verification procedures to be carried out.
7. The environment around the cryostat during instrument integration must be class 1000 or better.
8. The Herschel optical bench simulator shall impart no forces (twisting; shrinking etc) into the SPIRE instrument during cooldown or warm up
9. Any movement of the Herschel optical bench simulator in the cryostat during cooldown shall not prevent the optical alignment procedures being carried out.
10. The rate of temperature change of the instrument in the cryostat shall be controllable during cooldown and warm up
11. The rate of vacuum pumping of the cryostat shall be controllable
12. The temperature of the different temperature stages of the cryostat shall be controllable within the limits specified for the Herschel cryostat.
13. An ambient temperature vibration facility shall be made available. This should be capable of accepting the integrated FPU and JFET boxes and vibrating to the qualification levels specified for the Herschel optical bench.
14. TBD accelerometer channels shall be made available for the ambient temperature vibration of the integrated FPU and JFET boxes.