0 Document History

November 2000 –	First draft for System Review and comment
March 2001 –	First issue after discussion with JPL on provision of BDAs – requirements on pixels present in all arrays dropped. Requirements on AIV facility expanded

1 Introduction

This note outlines the test philosophy and requirements for the SPIRE instrument CQM. It expands upon this to give the requirements on the instrument CQM sub-systems; the requirements on the AIV facility and the tests that we would wish to carry out at payload module level.

2 Instrument Level Test Philosophy

The basic requirement to build a CQM instrument is governed by the need to ensure that the proto-flight instrument can be integrated successfully and will fulfil the scientific and technical requirements. The instrument STM programme combined with the sub-systems' qualification model programmes will demonstrate that the PFM will be capable of surviving the environmental conditions of launch and space operation. This being so the cold units for the CQM will be constructed from the structure; mirrors; thermal hardware and cooler from the STM programme with the addition of engineering model sub-systems. The engineering models, whilst they will have close to all the performance capabilities of the flight instruments, will not necessarily be built to flight standards or using flight quality parts. For instance, although some of the detector arrays must be fully populated with flight like pixels, it is possible that some of the channels could have only resistors present to verify the overall thermal performance of the instrument. Naturally all these engineering model sub-systems must meet the mechanical interface requirements so that they can be integrated into the cold FPU.

The warm electronics units for the CQM will consist of the AVM DPU (see AVM Requirements Document) and the first "Qualification Model" of the DRCU units and the warm interconnect harnesses. The warm electronics units will be built with full flight capability and form and fit but with no redundant electronics and with commercial or extended range parts only.

3 Test Programme

3.1 System Level

The system level issues that will be addressed by the CQM test programme will be as follows.

Electrical interface to Herschel satellite

The cryoharness for the instrument test facility will simulate the Herschel cryoharness as closely as possible. The CQM test programme will test all aspects of the electrical interfaces between the SPIRE cold units and the cryoharness. The CQM warm electronics units will be entirely flight representative bar the use of flight quality components and the presence of cold redundant circuitry. The electrical interfaces between SPIRE and the Herschel satellite will be verified in a more realistic operating situation compared to the tests carried out on the AVM (see AVM Requirements Document)

Electrical grounding

The CQM will offer the first opportunity to have an all up test of the instrument grounding scheme under realistic operating conditions. Any excess noise in the detection system can be quickly identified and trouble shooting undertaken.

Limited EMC testing:
The CQM will enable us to determine whether the proposed method providing the Faraday cage offers sufficient protection against radiated EMI in the laboratory environment. Although will be very difficult to be quantitative in this, because the test cryostat environment is very different from the Herschel cryostat, it may be possible to have some dedicated qualitative tests to probe for sensitivity at particular frequencies. It will be possible to do some conducted susceptibility tests to check the performance of the RF filtering and the cryoharness.

Operations and Software
The CQM will have all the cold sub-systems operational. Although they may not be fully flight representative in terms of thermal dissipation or ability to withstand vibration, they will have a scientific performance equivalent or nearly equivalent tot he flight sub-systems. This will allow us to test and characterise the behaviour of the instrument and give much better definition to the instrument commanding scheme and the real-time control aspects of the on board software. We will also be able to start to define better the operating modes for the instrument and the methods of calibration that will be employed during observations.

Having an operational instrument will also allow the finalisation the ground commissioning and calibration plans and procedures and a start to be made on the in-flight commissioning and calibration plan.

Optical
The CQM will be capable of allowing the far infrared and sub-mm optical performance of the instrument to be characterised to some extent and the straylight performance of the instrument *in toto* to be evaluated. This will complete the instrument optical alignment plan.

End-to-end system performance
The scientific capabilities of the instrument will be tested for the first time. This end-to-end testing will be the most important feature of the CQM test programme as it will tell us what the real capabilities of the flight instrument will be for the first time and, if things are wrong, allow us to adjust the PFM final design.

Electromechanical System
As it is not required that the mechanisms are completely flight compatible only a limited amount of realistic testing on the two mechanisms may be possible. However things that can be verified will be whether there is any exported micro-vibration that will trouble the detectors; whether the shutter design works reliably and whether the control of the BSM and SMEC is really sufficient for the scientific performance of the instrument.

Radiation Detection System
This will be the first time that representative detector arrays have been integrated with the cooler and 300 mK hardware with all the correct temperature stages present. Extensive testing of the array performance under realistic operating conditions (including mimicking the background loading from the telescope) will be carried out to fully characterise the behaviour of the radiation detection system. Tests will also be conducted to characterise the performance of the various elements of the radiation detection system (arrays; JFETs; warm electronics etc) under different environmental conditions – we will be able to change the loading on the detectors and the temperatures of the various stages.

Also all the detector sub-system interfaces will be able to be verified and we will gain some indication that the cryoharness specification is adequate.

Instrument Thermal Performance
Although the STM will have tested most of the thermal performance aspects of the SPIRE instrument, the fact that the CQM has real operation mechanisms; detectors; JFET amplifiers and the correct optical filtering scheme, means that the thermal performance of the instrument can be evaluated in a more realistic environment. In particular, the performance of the 300 mK temperature stage will be much more critically examined as there will be real bolometers present.

Sub-system interfaces
The CQM will give final verification of the sub-system optical; electrical; operational; control and data interface definitions.

3.2 Performance Checks

Here is an example list of the performance checks that will be carried out on the CQM at instrument level.

Detector performance and characterisation
- Load curves under nominal operating conditions
- Speed of response under nominal operating conditions
- Noise performance under nominal operating conditions
- Performance versus thermal loading and instrument operating temperature
- (Possibly) Performance versus microphonic input
- Electrical cross talk
- Linearity

Performance and characterisation of photometer optics
- Alignment using sub-mm/FIR radiation
- Focus sensitivity using sub-mm/FIR radiation
- FOV of instrument
- Variation of instrument sensitivity versus position in FOV
- Beamsize versus position in FOV
- Straylight both non-optical path and far off axis into instrument aperture
- Spectral response and instrument bandpass
- Absolute optical efficiency
- Optical crosstalk
- Distortions and aberrations

Performance and characterisation of spectrometer optics
- Alignment using sub-mm/FIR radiation
- Focus sensitivity using sub-mm/FIR radiation
- FOV of instrument
- Beamsize versus position in FOV
- Straylight both non-optical path and far off axis into instrument aperture
- Absolute optical efficiency at ZPD
- Optical crosstalk

Distortions and aberrations

Spectrometer performance

Spectral resolution
Influence of position and velocity jitter on signal to noise in spectrum
Fringe contrast versus spectral resolution
Fringe contrast versus position in FOV
Fringe contrast versus wavelength
Nulling of telescope signal
Electrical filtering characteristics
Out of band signal rejection of system
Beamsize versus mirror position
Variation of ZPD position versus position in FOV.
Exported microphonics

BSM performance

Position calibration using sub-mm/FIR
Stability and repeatability for all operational modes
Exported microphonics

Calibrator performance and characterisation

Photometer calibrator observed signal versus position of detector
Photometer calibrator speed of response
Spectrometer hot calibrator observed signal versus position of detector
Spectrometer hot calibrator speed of response
Spectrometer cool calibrator observed signal versus position of detector
Spectrometer cool calibrator stability

Shutter performance

Radiation rejection
Characterisation of thermal source

EMC/EMI

Test of conducted susceptibility of cold FPU(?)

4 CQM Functionality

4.1 General

All sub-systems will need to have the same mechanical and electrical interfaces and be form and fit compliant. The thermal dissipation of the cold sub-systems can be higher than anticipated for the flight units but it is highly desirable that it is as close as possible to the flight units. The conducted loads from the cold sub-systems must be as close as possible to that anticipated for the flight units. There is no requirement that the mass or c.o.g. be the same as the flight units. The performance of all sub-systems must be as close as possible to the flight specification.

The warm electronics units do not need to have the same power consumption as the flight designs or the same operating temperature range. They will have the same form and fit as the flight units. If meaningful EMC tests are to be carried out then the full QM model DPU and the QM2 model

DRCU will be required. These will have fully populated boards built to flight standards with flight quality components.

4.2 Implications for the detector provision

Although the detectors modules need not be fully scientifically representative, they will have to have to be externally structurally representative that is have the correct mechanical interfaces. It is highly desirable that they also have representative thermal behaviour. The JFET boxes will be externally structurally representative and those modules that are required for the detectors that will be present should have flight like performance. All internal harnesses and connectors will be fully representative and it is desirable that all signal lines have signals. The latter implies that resistors could be provided to replace any missing detectors and/or JFETs. No thermal control hardware will be fitted to the CQM.

The detector arrays will have to be sufficiently well populated to allow the optical performance of the instrument, both the spectrometer and photometer, to be fully characterised. The straylight and diffraction effects are likely to be worst at the longest wavelengths in both sub-instruments.

The minimum requirements for the CQM detectors are as follows:

Spectrometer:

LW: Fully populated with 19 detectors. Only the central seven pixels need to be of full scientific quality.
This will allow any change in the spectrometer performance in terms of vignetting or straylight effects to be fully characterised.

SW: Needs to be present at some point for verification of the high frequency performance of the FTS. It is planned to use a flight model array for this purpose.

Photometer:

500 μm: Fully populated but don't need to be all scientifically optimised. Again this will allow the optical performance to be fully characterised over the full focal plane.

Only the LW array need have working detectors as all optics issues associated with straylight etc will be worst for the longest wavelengths. This leaves the issue of verifying the co-alignment of the three arrays. This will have been done using visible light and replacements for the dichroics and the performance of the dichroics can be verified at unit level. Given the schedule and resource constraints the final verification will have to be done on the PFM.

4.3 Summary of Sub-system Requirements

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

Subsystem /component	CQM Requirements	Comments
Structure/baffles/wiring standoffs etc	Flight Representative	Used for STM
Mirrors	Flight Representative	Used for STM
Filters	Flight representative	All filters ; beam splitters and dichroics must have full flight performance
Beam steering mirror	Form and fit compliant Functionally representative in at	We could get away with only having one axis working, although given the

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

Subsystem /component	CQM Requirements	Comments
	least one axis No redundancy required. Electrical interfaces must be compliant Thermal conduction flight representative.	test programme we wish to carry out this is not desirable. The thermal dissipation can be higher than the flight design but the conduction to the mirror should be flight like to test that the mirror gets cold.
3He Fridge/thermal straps	Flight representative	Used for STM
Thermal control system	None	
Photometer LW array	Ideally a full flight like array This could be used for PFM or FS	See section 4.2
Photometer MW array	Form and fit compliant Resistors used to represent detectors. Temperature monitors functionally representative (TBC)	See section 4.2
Photometer SW array	Ditto	
SMEC	Form and fit compliant Functionally representative – mirror travel TBD Control system must be performance representative Electrical interfaces must be compliant Thermal conduction flight representative. SMECp function and performance flight represenative	We need to have the optical encoder in place with its amplifier to test for straylight and EMI problems. The actuator can be a commercial one with higher dissipation. The thermal conduction to the moving mirrors must be flight representative to ensure that the mirrors get cold.
Spectrometer SW array	Will use a flight model array delivered untested and removed before delivery of CQM to ESA	See section 4.2
Photometer LW array	Ideally a full flight like array This could be used for PFM or FS	See section 4.2
Photometer Calibrator	Form and fit compliant Functionally representative Electrical interfaces compliant Thermal interfaces compliant No redundancy necessary	Desirable that this has as near to flight representation as possible to allow thermal dissipation and performance to be verified. Should be integrated into the BSM.
Spectrometer hot calibrator	Form and fit compliant Functionally representative Electrical interfaces compliant Thermal interfaces compliant No redundancy necessary	Desirable that this has as near to flight representation as possible to allow thermal dissipation and performance to be verified.
Spectrometer cool calibrator	Form and fit compliant Performance representative Electrically interfaces compliant Thermally interfaces compliant No redundancy necessary	As the list implies it is desirable that this is flight representative.

Detailed requirements on the cold FPU sub-systems for the SPIRE CQM		
Subsystem /component	**CQM Requirements**	**Comments**
Shutter	Form and fit compliant Functionally representative Electrical interfaces compliant	Launch latch need not be fitted if not desired by provider.
JFET Enclosures	Flight Representative	Used on STM
JFET Modules and JFET box RF filter modules	Form and fit compliant Functionally representative Electrical interfaces compliant Thermal interfaces compliant Only needs JFETs for "live" detector channels Can use resistors for thermal dissipation in other channels	Need to simulate thermal dissipation of all up flight instrument to probe thermal interface characteristics. Could use STM modules for the non-working channels if these were configured correctly?
FPU RF Filters	Form and fit compliant Electrical interfaces compliant Not necessarily flight standard components.	Used on STM?
Thermometry	Form and fit compliant Performance compliant Electrical interfaces compliant Not necessarily flight standard components	Used on STM?
FPU internal harnesses	Flight representative	Used on STM

5 PLM level testing

5.1 Expected Environment

The IID-A gives a résumé of the expected environment for system level testing:

The cryostat will give flight representative temperatures at thermal interfaces.
The cryostat will have a large gas flow with the CVV at ambient temperature – the heat lift will therefore be greater than expected in space. A configuration may be possible to allow a gas flow nearer to that expected in-flight.
The cryostat shields will be warmer – possibly much warmer than flight.
The radiation environment will not be representative without some GSE in place. Notably the cryostat lid will be at a minimum of ~300 K
A configuration with the final radiation shield blanked off is being considered – this will give a lower background than expected in space.
A representative telecommanding and data handling environment will be provided by the prime contractor/ESA and the instrument will provide a quick look facility.
The nominal orientation of the cryostat means that SMEC is in the wrong orientation and cannot be operated unless the cryostat is tilted through 90 degrees – the test cryostat will provide for this.
The cooler will not recycle unless the cryostat is tilted to at least 17 degrees – the test cryostat will provide for this.

5.2 System level tests

The tests we can expect to be carried out at system level are more or less these:

FPU integration procedures
Instrument to optical bench alignment procedures
Integration with CCE
Test of system level checkout procedures to be done for PFM
Test of parallel operation with PACS (if necessary)

5.3 Instrument tests in PLM

The instrument tests we might consider carrying out after system level integration could be along these lines:

Functional checks using standard test procedure to debug procedures for PFM testing
Thermal balance tests under more representative conditions. This will include cooler recycle and some mechanism operations.
Test switching sequences between all modes. Check length of time required to change modes – including waiting for thermal environment to stabilise.
Test thermal dissipation in each "operating mode".
Straylight checks with GSE fitted or with final shield blanked off. This is an extreme test as the other shields will be at higher temperatures than expected in flight.
EMC test of conducted susceptibility only.

5.4 Instrument Requirements for system level tests

It would be desirable, but not essential, if the SPIRE CQM had near to flight like cold thermal dissipation for each instrument operating mode. For some sub-systems (the two mechanisms) the possibility of swapping the sub-system QMs into the instrument CQM before delivery to ESA could be investigated as these will be essentially flight like in all respects.

The warm electronics delivered with the CQM will not be capable of switching to redundant systems or suitable for more than the most rudimentary EMC testing.

6 Requirements on the Test Facility.

In addition to the requirements laid out on the Test Facility given in the EGSE; AVM and STM requirements, the Test Facility shall have the following capabilities that will allow the CQM test programme to be carried out.

1. The test cryoharness will be as close as possible to the electrical specification of the Herschel cryoharness.
2. The filtering on the optical input to the cryostat will be such as to provide as nearly as possible the equivalent optical power on the SPIRE detectors as expected from the Herschel telescope when in flight.
3. A telescope simulator shall be provided that will simulate the optical specification of the Herschel telescope, including diffraction pattern, over the whole field of view of the SPIRE instrument.
4. The telescope simulator/cryostat shall allow as much as possible of the SPIRE FOV to be viewed instantaneously.
5. The telescope simulator/cryostat window shall be configurable to allow the far field straylight performance of the SPIRE instrument to be investigated.

6. A source shall be provided at the input of the telescope simulator that will allow the relative detection efficiency of all parts of the photometer and spectrometer fields of view to be measured.
7. It is desirable that the telescope simulator offers the ability to continuously scan a point source, or simulate the scanning of a source, over the field of view of the SPIRE instrument. The maximum rate of scan required is to be the equivalent of 60 arcsec/sec. This will simulate the scanning mode of the Herschel telescope.
8. A source will be provided that will instantaneously fill the SPIRE field of view and give an accurately calibrated signal that allows the absolute efficiency of the SPIRE instrument to be determined.
9. A narrow spectral line source will be provided to allow the determination of the FTS modulation efficiency over the spectrometer FOV and over the travel of the moving mirrors.
10. An external spectrometer (FTS) is to be provided at the input of the telescope simulator to allow the characterisation of the spectral bandpass of the SPIRE instrument and to identify any channel fringing arising due to multiple reflections within the instrument. This spectrometer needs to have a resolution of no more than 0.04 cm^{-1}.
11. A method of testing the conducted EMI susceptibility of the instrument shall be provided.