SPIRE

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Change Record

ISSUE	DATE	
Draft	19/05/2000	First draft for comment
1	20/05/2000	Detailed changes to wording on description of DPU and DRCU QM capabilities. Version issued for Delta PDR
2.0		First draft of issue 2 to reflect new model philosophy with STM
2.1	29/03/2001	Comments from Berend Winter incorporated – slight changes to deliverables list; description of STM and testing changed
3	25 May 2003	Complete rewrite to allow programme to stay on track

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Glossary

ADP	Acceptance Delivery Package
AIV	Assembly Integration and Verification
AOCS	Attitude and Orbit Control System
ASIC	Application Specific Integrated Circuit
AVM	Avionics Model
BSM	Beam Steering Mechanism
CDMS	Command and Data Management System (on Spacecraft)
CQM	Cryogenic Qualification Model
CVV	Cryostat Vacuum Vessel
DCRU	Detector Control and Readout Unit
DPU	Digital Processing Unit
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
FINDAS	FIRST Integrated Network and Data Archive System
FOV	Field of View
FPU	Focal Plane Unit
FS	Flight Spare
FTS	Fourier Transform Spectrometer
IID-A	Instrument Interface Document part A
IID-B	Instrument Interface Document part B
JFET	Junction Field Effect Transistor
MGSE	Mechanical Ground Support Equipment
NEP	Noise Equivalent Power
OBDH	On Board Data Handling (on Spacecraft)
OGSE	Optical Ground Support Equipment
OPD	Optical Path Difference
PDU	Power Distribution Unit (on spacecraft)
PFM	Proto-Flight Model
PLM	Payload Module
QLF	Quick Look Facility
S/C	Space Craft
SMEC	Spectrometer MEChanism
SPIRE	Spectral and Photometric Imaging REceiver
SRD	Science Requirements Document
SVM	Service Module
TBC	To Be Confirmed
TBD	To Be Determined

References

Applicable Documents

Document Reference	Name	Number/version/date
AD1	Instrument Requirements Document	SPIRE/RAL/N/0034
AD2	FIRST/PLANCK Operations Interface Requirements Document (FOIRD)	SCI-PT-RS-07360 Draft 5 03 May 2000 SPIRE-ESA-DOC-000188
AD3	SPIRE Instrument Product Tree	
AD4	SPIRE Calibration Requirements Document	
AD5		
AD6	SPIRE Instrument Development Plan	
AD7	SPIRE PA Plan	
AD8	SPIRE Qualification Requirements Document	

Table B: Applicable Documents

The abbreviations in brackets are used throughout the present document.

Reference Documents

RD1	Instrument Design Description Document	
RD2	FIRST/Planck - SPIRE AVM Definition	SPIRE-RAL-COM-000387
RD3	SPIRE Instrument STM Requirements	
RD4	SPIRE Instrument CQM Requirements	SPIRE-RAL-NOT-000389
RD5	FIRST SPIRE: Optical alignment verification plan	LOOM.KD.SPIRE.2000.001-1
RD6	Operating Modes for the SPIRE Instrument	SPIRE-RAL-DOC-000320
RD7	SPIRE Science Requirements Document	SPIRE-UCF-DOC-000064
RD8	EGSE Requirements document	
RD9	SPIRE Model Definition	

1. INTRODUCTION

1.1 Scope

This document describes the sequence of events and procedures leading from the delivery of the instrument sub-systems to the final delivery to ESA of each of the deliverable models of the SPIRE instrument.

1.2 Requirements on the Instrument AIV

The instrument is described in the *Instrument Design Description* (RD1) and the requirements the instrument performance and verification are detailed in the *Instrument Requirements Document* (AD1) and the *Instrument Qualification Requirements Document* (AD8). The primary purpose of the SPIRE AIV is to verify that the Proto-Flight Model of the instrument delivered to ESA is compatible with the requirements of the Herschel (previously called FIRST) mission (launch and operational environment etc) and is capable of carrying out the scientific mission as described in the *SPIRE Science Requirements Document* (RD6).

The AIV of the instrument is also required to provide certain data tables that will enable the operation of the instrument in flight. It is also required to test the procedures to be used to operate the instrument in flight and during system level testing after integration in the satellite. Finally, the AIV of the instrument should test the observing modes to be used to take scientific data and provide the calibration tables required to process the data on the ground – the requirements on these come from the *Calibration Requirements Document* (AD4) and the *Operating Modes for the SPIRE Document* (RD5).

This is the second version of this document to be formally released. The AIV plan has been modified to take into account the change of the instrument model philosophy following the delta-PDR in July 2000.
In this release the first cross reference between the IRD requirements and the tests in the AIV plan is included

2. MODEL PHILOSOPHY

2.1 Instrument Level Models

Note in version 3 of AIV Plan: The original intention of the SPIRE project was to have three distinct instrument models – the Structural Thermal Model; The Cryogenic Qualification Model and the ProtoFlight Model. Schedule pressure now means that this philosophy has had to be revised. The revised scheme is, in outline, as follows:

A single set of structural components is used for the following “build phases” of the pre flight instrument FPU:

Structural Model (SM): This is an FPU only with the optics fitted and mass dummies for the FPU susb-systems – it will be used to correlate the structural mechanical mathematical model and to verify the integration and alignment procedures.

Alignment Model (AM): The structural model components will be used in conjunction with some OGSE to verify the optical alignment both warm and cold.

Cryogenic Qualification Model (CQM): This will use the SM/AM FPU structure and optical components with as many functioning FPU sub-systems as possible to validate the performance of the instrument and to carry out environmental qualification testing at launch temperature. The spectrometer and beam steering mirror mechanisms fitted to this model are only structural/thermal models and will not function. A single Bolometer array – the long wavelength photometer (P/LW) – will be fitted together with a working 300 mK cooler to allow photometer performance and thermal verification testing to be carried out. It will require JFET units and electronics to allow the testing to be carried out. The DPU used with this model, plus the instrument simulator, will be delivered as the SPIRE Avionics Verification Model (AVM).

Proto Flight Model (build 1) (PFM1): The proto flight FPU structure and optics will be assembled and used to carry testing on those parts of the instrument – namely the mechanisms – that were not tested on the CQM. The spectrometer mechanism used in the first build of the PFM will be the qualification model standard only. Both spectrometer bolometer arrays will be fitted but no photometer arrays. A working 300 mK cooler will be fitted. JFETs and electronics will be required to test the spectrometer operation and performance.

Proto Flight Model (build 2) (PFM2): This will use the flight standard FPU components fitted for PFM1. It will be the final build of the instrument that will be delivered for launch.

2.2 Deliverable Models

The deliverable models of the SPIRE instrument are described in AD2. The descriptions are repeated here for information purposes.

AVM – Avionics Model. *This is an electrical model of the SPIRE instrument and will consist of the AVM DPU and a DRCU simulator. It will allow the electrical and software interfaces between the SPIRE instrument and the spacecraft to be validated. This will include the capability of testing the SPIRE autonomy functions and any exchange of information required between the spacecraft and SPIRE for any SPIRE operational mode. This model is delivered to ESA.*

CQM - Cryogenic Qualification Model. *This is a model of the instrument that will be used to characterise and verify the instrument scientific performance with functionally representative cold sub-systems and warm electronics units. As many as possible cold FPU units need to function and have close to the expected flight performance, but do not need to have the full reliability and redundancy or necessarily be flight like in terms of power dissipation or speed of response. The purpose of the CQM is to verify that the design of the PFM will be capable of meeting the instrument level performance requirements and that the instrument is compatible with integration into the Herschel satellite. The requirements on the SPIRE CQM sub-systems will be judged against these criteria on a case by case basis.*

PFM – Proto-Flight Model. *This will be the instrument model that is intended for flight. It will be built to full flight quality. It will be the only fully integrated instrument model that has the full flight like performance characteristics. The PFM cold FPU and JFET boxes will therefore undergo environmental test to qualification levels for acceptance times (TBD). The SPIRE warm electronics units will have full qualification models built and tested, therefore the PFM warm electronics units will only undergo acceptance testing.*
This model is delivered to ESA.

FS – Flight Spare*. The flight spare cold FPU and JFET boxes will be constructed from the refurbished CQM (TBC). The flight spare warm electronics will consist of spare electronics cards. Whether this model is fully integrated and tested is TBD as is whether it is delivered to ESA.*

3. INSTRUMENT DELIVERABLES

The SPIRE instrument will consist of two basic components – the cold unit and the warm electronics. The cold unit is further sub-divided into the Focal Plane Unit (FPU) which contains all the optical elements; detectors and mechanisms and two JFET boxes containing the pre-amplifiers for the photometer and spectrometer bolometer arrays respectively. The JFETS are connected to the FPU by means of an external interconnect harness. Harnesses also run from the sub-systems within the cold FPU to the outside of the FPU via RF filter modules mounted on the FPU structure.

Tables n to n give details of the deliverable items and build standards that are required for the instrument integration for the SM/AM; CQM and PFM. The details for the production of these deliverables are given in the appropriate sub-system and development plans and the Instrument Development Plan (AD6) and are not discussed further in the present document. The responsible institutes for each sub-system are detailed in the Instrument Product Tree – AD3.

3.1 Warm electronics

The warm electronics will consist of a Digital Processing Unit (DPU), which is a single physical unit containing the on board processing unit and data storage, and the Detector Read Out and Control Unit (DRCU) which consists of two physical units – the Detector Control Unit (DCU) which contains the analogue amplification for all the bolometer arrays and the FPU Control Unit (FCU) which contains the drive electronics for both flight mechanisms; the power supply and distribution unit and the electronics for the cooler, calibrators and thermometers for the cold FPU. Interconnect harnesses will run between the DPU and the DCU and the FCU and between the DCU and the FCU. These are termed the warm interconnect harnesses. It is assumed that the DCU and FCU will be integrated before delivery to RAL and can be treated as a single unit – the DRCU – thereafter.

3.2 Model Build Standards

Table 3.2-1: Structure Model

Unit: HSFPU

Subsystem /component	**SM Form/Capability**
Structure/baffles/wiring standoffs etc	Flight Representative structural components
L0 straps	Detector boxes - “STM” original design Cooler - “STM” original design
Mirrors	All mirrors fitted
Filters	Not fitted
Beam steering mirror	Mass/alignment dummy (STM?)
3He Cooler	Mass dummy STM cooler
300 mK thermal straps and supports	Flight representative except use 0.5 mm kevlar
300 mK Thermal control system	Not fitted

Subsystem /component	SM Form/Capability
Photometer LW array	Suspended STM
Photometer MW array	Unsuspended STM
Photometer SW array	Unsuspended STM
SMEC	STM SMEC – no harness
Spectrometer SW array	Unsuspended STM
Spectrometer LW array	Unsuspended STM
Photometer Calibrator	Mass dummy on STM BSM
Spectrometer Calibrator	STM SCAL
FPU RF Filters	Box only no connectors fitted
Thermometry	Not fitted
FPU internal harnesses	Not fitted

Unit: HSJFP

Subsystem /component	SM Form/Capability
JFET Structure	Not used
JFET Modules and JFET box RF filter modules	Not used

Unit: HSJFS

Subsystem /component	SM Form/Capability
JFET Structure	Not used
JFET Modules and JFET box RF filter modules	Not used

Unit: HSDCU

Subsystem /component	SM Form/Capability
DCU Structure	Not used
Electrical Interfaces	N/A
Functionality	N/A
Electrical Component Level	N/A

Unit: HSFCU

Subsystem /component	SM Form/Capability
FCU Structure	Not Used
Electrical Interfaces	N/A
Functionality	N/A
Electrical Component Level	N/A

Unit: HSDPU

Subsystem /component	SM Form/Capability
DPU Structure	Not Used
Electrical Interfaces	N/A
Functionality	N/A
Electrical Component Level	N/A

Unit: HSWIH (Warm interconnect harness)

Subsystem /component	**SM Form/Capability**
WIH Mechanical form	Not Used
Electrical Interfaces	N/A
Functionality	N/A
Electrical Component Level	N/A

Table 3.2-2:Alignment Model

Unit: HSFPU

Subsystem /component	AM Form/Capability
Structure/baffles/wiring standoffs etc	Flight Representative structural components
L0 straps	Detector boxes - "STM" original design Cooler – not fitted (TBC)
Mirrors	All mirrors fitted
Filters	OGSE as specified in Alignment Procedure
Beam steering mirror	STM
3He Cooler	Not fitted (TBC)
300 mK thermal straps and supports	Flight representative except use 0.5 mm kevlar
300 mK Thermal control system	Not fitted
Photometer LW array	OGSE as specified in Alignment Procedure
Photometer MW array	OGSE as specified in Alignment Procedure
Photometer SW array	OGSE as specified in Alignment Procedure
SMEC	Alignment dummy
Spectrometer SW array	OGSE as specified in Alignment Procedure
Spectrometer LW array	OGSE as specified in Alignment Procedure
Photometer Calibrator	Mass dummy on STM BSM
Spectrometer Calibrator	STM SCAL
FPU RF Filters	Box only no connectors fitted
Thermometry	Not fitted
FPU internal harnesses	Not fitted

Unit: HSJFP

Subsystem /component	AM Form/Capability
JFET Structure	Not used
JFET Modules and JFET box RF filter modules	Not used

Unit: HSJFS

Subsystem /component	AM Form/Capability
JFET structure	Not used
JFET Modules and JFET box RF filter modules	Not used

Unit: HSDCU

Subsystem /component	AM Form/Capability
DCU Structure	Not used
Electrical Interfaces	N/A
Functionality	N/A
Electrical Component Level	N/A

Unit: HSFCU

Subsystem /component	AM Form/Capability
FCU Structure	Not Used
Electrical Interfaces	N/A

Subsystem /component	AM Form/Capability
Functionality	N/A
Electrical Component Level	N/A

Unit: HSDPU

Subsystem /component	AM Form/Capability
DPU Structure	Not Used
Electrical Interfaces	N/A
Functionality	N/A
Electrical Component Level	N/A

Unit: HSWIH (Warm interconnect harness)

Subsystem /component	AM Form/Capability
WIH Mechanical form	Not Used
Electrical Interfaces	N/A
Functionality	N/A
Electrical Component Level	N/A

Table 3.2-3: Cryogenic Qualification Model

Subsystem /component	CQM Form/Capability
Structure/baffles/wiring standoffs etc	Flight Representative structural components
L0 straps	Detector boxes – upgraded to protoflight design Cooler – upgraded to protoflight design
Mirrors	All mirrors fitted
Filters	CFIL-1 – flight representative PFIL-2 – flight representative PFIL-3 – flight representative PDIC-1 – flight representative (TBC) PDIC-2 – flight representative (TBC) Spectrometer filters not fitted
Beam steering mirror	STM
3He Cooler	Flight representative (CQM)
300 mK thermal straps and supports	Flight representative with 0.29 mm Kevlar on “in line” mounts
300 mK Thermal control system	Not fitted
Photometer LW array	Flight representative (CQM)
Photometer MW array	Unsuspended STM
Photometer SW array	Unsuspended STM
SMEC	STM
Spectrometer SW array	Unsuspended STM
Spectrometer LW array	Unsuspended STM
Photometer Calibrator	If BSM is alignment dummy then not fitted else CQM
Spectrometer Calibrator	STM
FPU RF Filters	Flight representative box and connectors
Thermometry	Flight representative
FPU internal harnesses	Flight representative

Unit: HSJFP

Subsystem /component	CQM Form/Capability
JFET Structure	Flight representative
JFET Modules	One 48 channel module flight representative Rest STMs
JFET box RF filter modules	Flight representative
JFET Backharness	Flight representative
JFET/FPU Harness	Flight representative

Unit: HSJFS

Subsystem /component	CQM Form/Capability
Subsystem /component	**CQM Form/Capability**
JFET Structure	Flight representative
JFET Modules	Both STM
JFET box RF filter modules	Flight representative
JFET Backharness	Flight representative
JFET/FPU Harness	Flight representative

Unit: HSDCU

Subsystem /component	CQM Form/Capability
DCU Structure	Flight representative (TBC)
Electrical Interfaces	Flight representative
Functionality	At least 48 LIA-P channels must function DPU interface must function – no redundancy
Electrical Component Level	Commercial/industrial

Unit: HSFCU

Subsystem /component	CQM Form/Capability
FCU Structure	Flight representative
MCU	QM1 Fitted
Electrical Interfaces	Flight representative
Functionality	Flight representative (no redundancy)
Electrical Component Level	Commercial/industrial
SCU	QM1 Fitted
Electrical Interfaces	Flight representative
Functionality	Flight representative (no redundancy)
Electrical Component Level	Commercial/industrial
PSU	Not fitted – replaced by EGSE “Power Bench”
Electrical Interfaces	N/A
Functionality	N/A
Electrical Component Level	N/A

Unit: HSDPU

Subsystem /component	CQM Form/Capability
DPU Structure	Flight representative
Electrical Interfaces	Flight representative
Functionality	Flight representative (no redundancy)
Electrical Component Level	Commercial/industrial

Unit: HSWIH (Warm interconnect harness)

Subsystem /component	CQM Form/Capability
WIH Mechanical form	Flight representative
Electrical Interfaces	Flight representative
Functionality	Flight representative (no redundancy required)
Electrical Component Level	Commercial/industrial

Table 3.2-4: Protoflight Model build I

Subsystem /component	**PFM I Form/Capability**
Structure/baffles/wiring standoffs etc	Flight structure – all components to flight standard
L0 straps	Flight standard
Mirrors	All mirrors fitted flight standard
Filters	CFIL-1 – flight PFIL-2 –not fitted PFIL-3 – not fitted PDIC-1 – not fitted PDIC-2 – not fitted SFIL-2 - flight SBS-1 – flight SBS-2 – flight SFIL3-S - flight SFIL3-L -flight
Beam steering mirror	Flight
3He Cooler	Flight representative (CQM or flight if available)
300 mK thermal straps and supports	Flight
300 mK Thermal control system	Prototype fitted if available
Photometer LW array	Either not fitted of unsuspended STM if available
Photometer MW array	Either not fitted of unsuspended STM if available
Photometer SW array	Either not fitted of unsuspended STM if available
SMEC	Qualification model
Spectrometer SW array	Flight
Spectrometer LW array	Flight
Photometer Calibrator	Flight
Spectrometer Calibrator	Flight
FPU RF Filters	Flight
Thermometry	Flight
FPU internal harnesses	Flight

Unit: HSJFP

Subsystem /component	**PFM I Form/Capability**
JFET Structure	Not fitted
JFET Modules	Not fitted
JFET box RF filter modules	Not fitted
JFET Backharness	Not fitted
JFET/FPU Harness	Not fitted

Unit: HSJFS

Subsystem /component	**PFM I Form/Capability**
JFET Structure	Flight
JFET Modules	Flight
JFET box RF filter modules	Flight
JFET Backharness	Flight
JFET/FPU Harness	Flight

Unit: HSDCU

Subsystem /component	**PFM I Form/Capability**
DCU Structure	TBD
Electrical Interfaces	Flight representative
Functionality	All LIA-S channels must function All LIA-T/C channels must function DPU interface must function – no redundancy
Electrical Component Level	Commercial/industrial

Unit: HSFCU

Subsystem /component	**PFM I Form/Capability**
FCU Structure	TBD
MCU	QM1 fitted
Electrical Interfaces	Flight representative
Functionality	Flight representative (no redundancy)
Electrical Component Level	Commercial/industrial
SCU	QM1 Fitted
Electrical Interfaces	Flight representative
Functionality	Flight representative (no redundancy)
Electrical Component Level	Commercial/industrial
PSU	Not fitted – replaced by EGSE “Power Bench”
Electrical Interfaces	N/A
Functionality	N/A
Electrical Component Level	N/A

Unit: HSDPU

Subsystem /component	**PFM I Form/Capability**
DPU Structure	Flight representative
Electrical Interfaces	Flight representative
Functionality	Flight representative (no redundancy)
Electrical Component Level	Commercial/industrial

Unit: HSWIH (Warm interconnect harness)

Subsystem /component	**PFM I Form/Capability**
WIH Mechanical form	Flight representative
Electrical Interfaces	Flight representative
Functionality	Flight representative (no redundancy required)
Electrical Component Level	Commercial/industrial

4. OUTLINE INSTRUMENT AIV SEQUENCE FOR PRE-FLIGHT MODELS

The verification of the flight design of SPIRE will be done using the Structural; Alignment and Cryogenic Qualification instrument models and the qualification models of the SPIRE sub-systems. In this section an overview of the "pre-flight" instrument model AIV programme is given together with an indication of the system level issues that are addressed at each stage of the sequence. This is intended as a guide only – the detailed sequencing of the integration and test of the instrument models is given in the test plans for each model.

Figures 4-1 through 4-3 show an outline integration and test sequence for the instrument models. Given alongside the activities for each model are the systems issues that will be verified on each model. Some of these appear in more than one place indicating that different aspects of the systems design will be tested on different instrument and sub-system models.

Once the SM and AM testing has been completed, the QM sub-systems can use any results necessary from the testing in their development programme which, it is assumed, will largely overlap the instrument level SM/AM and CQM programme leading to a CDR at the end of the CQM programme. At this point all the system and sub-system design issues should largely have been addressed and the final design for the PFM can be confirmed. In fact it will be possible to confirm the design for some sub-systems, the structure (except for straylight concerns); the cooler and the mirrors, at the end of the SM/AM programme. The issues associated with the design of the spectrometer will not now be addressed until the first build of the PFM.

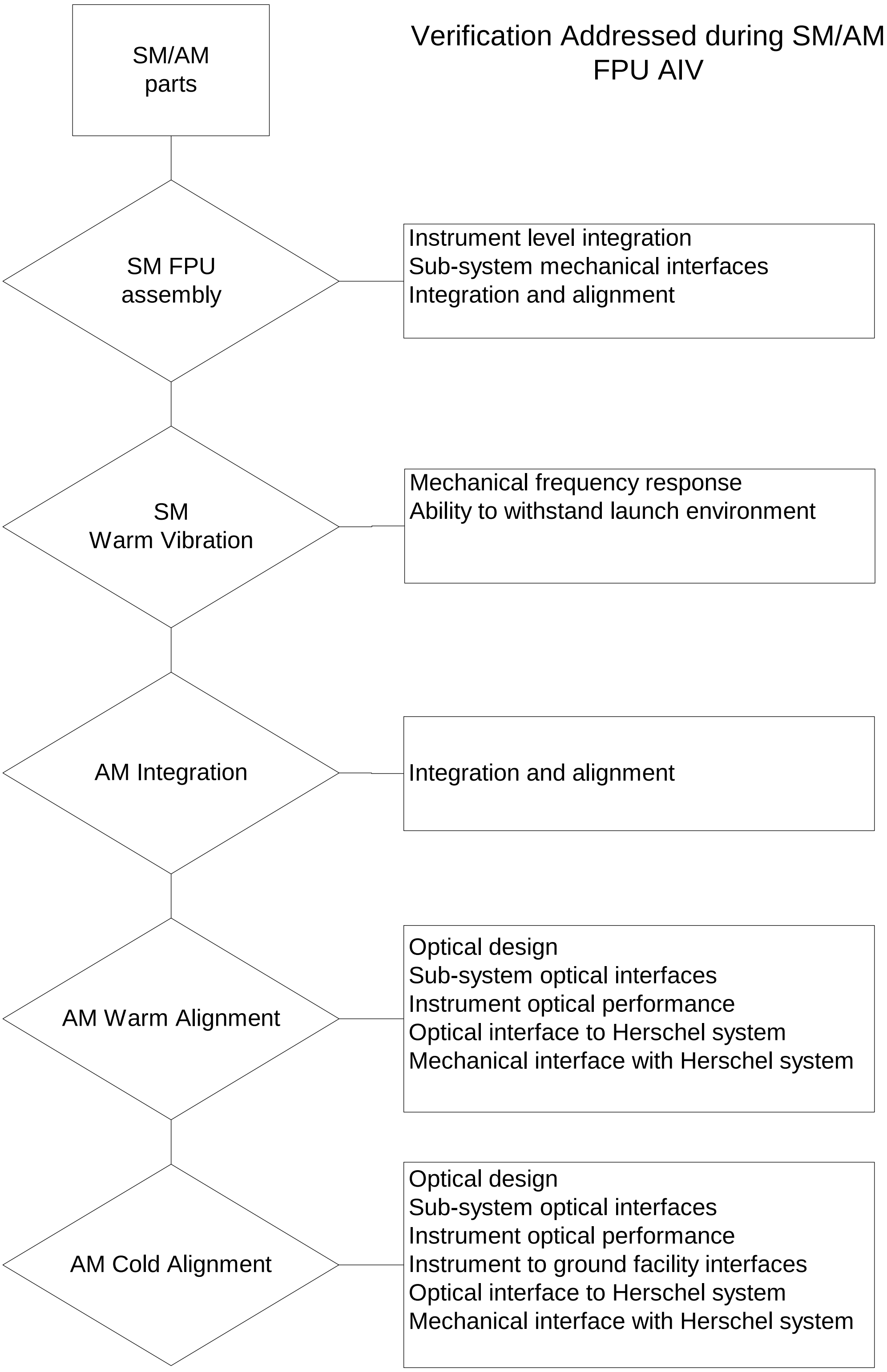

Figure 4-1: Outline SM/AM integration and test sequence showing which system level issues are addressed at each stage.

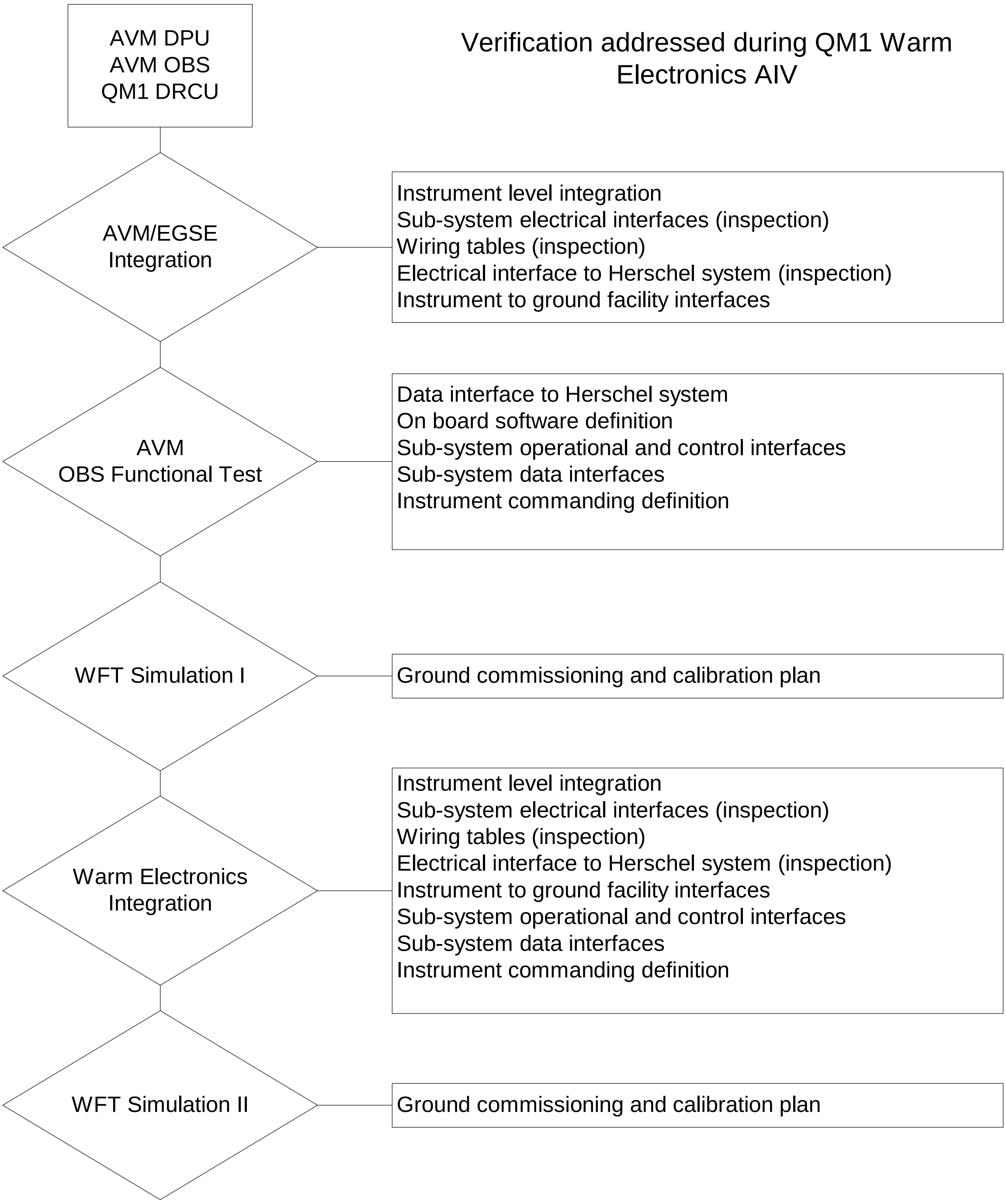

Figure 4-2: Outline AVM/QM1 warm electronics units integration and test sequence showing which systems issues are addressed at each stage.

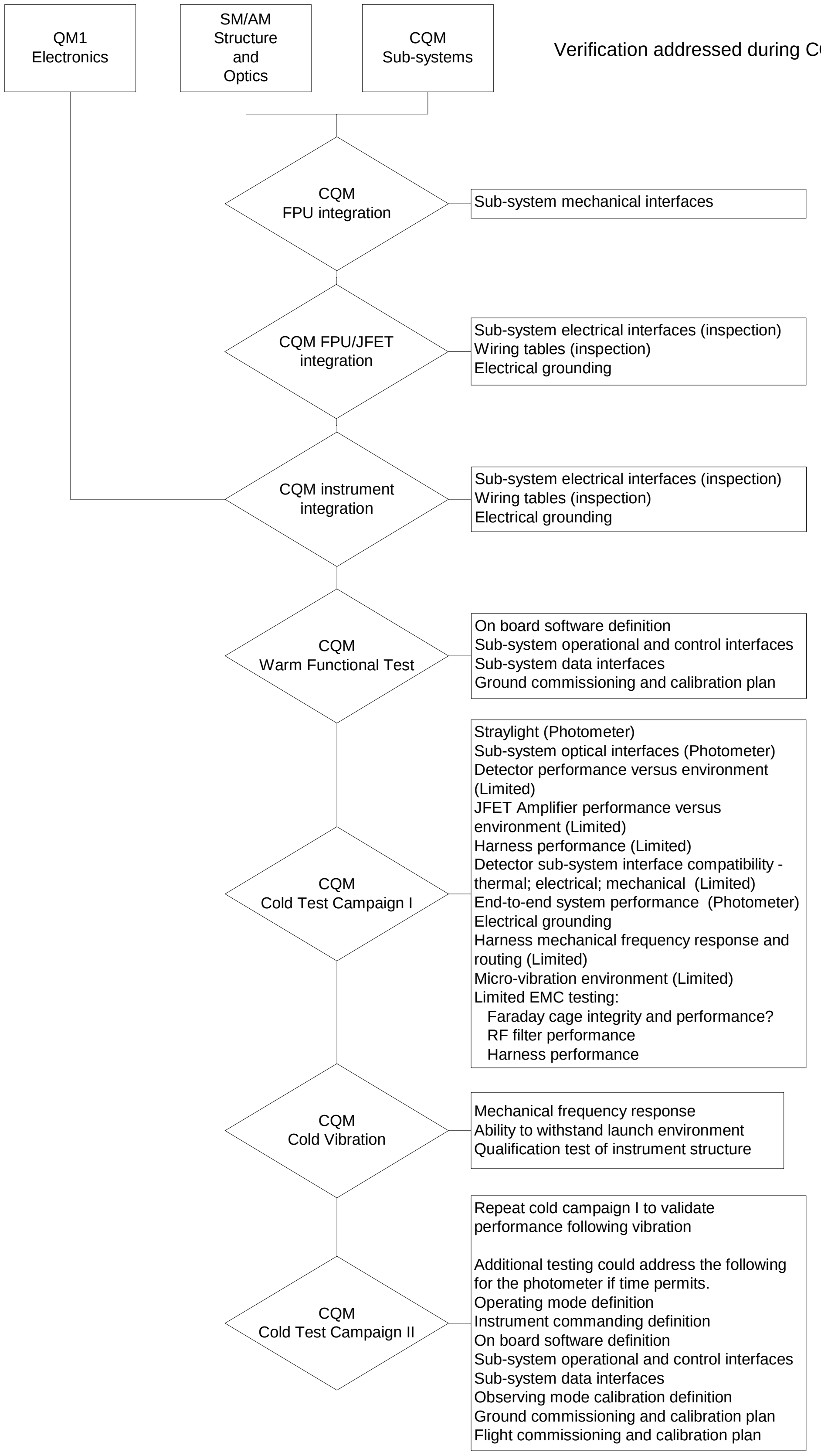

Figure 4-4: CQM outline integration and test sequence showing which systems issues are addressed at each stage.

5. WARM ELECTRONICS AIV

5.1 Overview

Production of the warm electronics units for SPIRE is phased differently to the cold FPU and JFET Box production. This is dictated by the resources available and complex nature of the interfaces between the sub-systems and the warm electronics. In this section we describe the assembly and integration of the units that go to make up the warm electronics used to test each instrument model and those which will be delivered to ESA.

5.2 AVM/QM1 Warm Electronics

5.2.1 Capabilities

The AVM warm electronics consists of the AVM model of the DPU and a simulator of the DRCU and cold FPU. It is intended that these will be delivered to ESA.

The DPU will have the full functionality of the flight version but it will be built with commercial grade parts and will not have redundant systems fitted. It will be identical in external form and fit to the flight unit. This unit will also be used for the testing of the CQM cold FPU and JFET box.

The DRCU simulator will be a computer with interface cards to the DPU that is capable of receiving commands from the DPU and returning realistic data to mimic the operation of the DRCU; cold FPU and JFET box. Several DRCU simulators will be required at different institutes.

The functionality of the EGSE to be delivered with the AVM is given in table 2.2-3 and discussed further in RD8.

5.2.2 Outline Integration and Verification

The outline integration and test of the AVM DPU is as follows:

DPU and OBS Acceptance Tests
These will be designed to test the specifications written out in the DPU Specification Document (RD9) and the OBS URD (RD10). Some of the specifications reflect higher level requirements in the Instrument Requirements Document and, therefore, these tests form part of the instrument level verification

We wish to discover from these tests whether the DPU/OBS can "run" the instrument in all its operating modes with the correct data collection; extraction of real time parameters (if necessary); algorithm execution and real time commanding and execution of a command queue from the S/C to simulate instrument operation – again with correct data collection; TM formatting and transmission to CDMS.

We also need to test the response of the OBS/DPU to various failure conditions both in the DRCU (failure to initialise; PSU failure; interface failure etc) and within one of the sub-systems (loss of SMEC position sensor; loss of drive coils etc). We will also test the autonomy functions of the OBS –

that is switching to SAFE mode in the event of DRCU/sub-system failure of OFF in the event of DPU failure.

AVM verification following CQM programme
This AVM DPU will be delivered to ESA together with the DRCU simulator #3 and the EGSE#3 to form the Instrument AVM. This delivery will occur at the end of the instrument CQM programme. Before the Instrument AVM can be delivered it has to be integrated and the AVM verification procedures carried out to ensure that any changes to the OBS; the DRCU simulator and/or the EGSE do not affect the performance of the integrated unit.

5.3 CQM Warm Electronics

5.3.1 Capabilities

The warm electronics for the CQM testing consist of the DPU AVM and he QM1 model of the DRCU that has the build standard given in table 3.2-3. The QM1 DRCU will be identical in external form and fit to the flight unit except for the use of a GSE power bench to replace the internal power supply unit. An engineering model of the warm interconnect harness will also be used. Again this will have external form and fit identical to the flight unit but will be built with commercial grade parts. In order to verify the function of the warm electronics for the CQM testing a simulator of the cold FPU and JFET box is required to give realistic responses to the DRCU in the absence of the real sub-systems. This FPU simulator is intended to be as passive as possible, i.e. resistors in place of JFETs; coils; thermistors etc.

5.3.2 Outline Integration and Verification

The QM1 DRCU will be tested against its specification before delivery to RAL. At RAL it will integrated to the AVM DPU and EGSE and the acceptance test partially repeated to verify the interfaces. A warm functional test will be done using the FPU simulator as a further test of the integration and to verify the procedures for use on the integrated instrument.

5.4 Warm Electronics Qualification Model

5.4.1 Capabilities

This is the present plan – it is under review – May 2003

The QM electronics consists of the qualification model DPU; the second qualification model (QM2) DRCU and the second qualification model warm interconnect harness. These are identical in function; form and fit to the flight units. They will be built to flight standards with some parts in both the DPU and DRCU being “extended range” or commercial grade rather than flight grade. The DPU QM will undergo full environmental and EMC (TBC) testing at IFSI before delivery. The DRCU QM2 will undergo full environmental and EMC testing at CEA before delivery. This set of electronics will be used to carry out the majority of instrument PFM tests, however they are not intended for flight and will not be delivered to ESA.

5.4.2 Outline Integration and verification

This will follow the same procedure as for the CQM electronics with any additional steps or alterations as found during the CQM programme.

5.5 PFM Warm Electronics

5.5.1 Capabilities

The PFM electronics consist of the flight models of the DRCU; the warm interconnect harness and the DPU. These are the units intended for flight and have, naturally all the functions required including redundancy and are fully compliant with the satellite interface requirements. The DRCU; warm interconnect harness and the DPU will have been through environmental acceptance testing before delivery to RAL.

5.5.2 Outline Integration and verification

This will be the same as for the QM2

5.6 FS Warm Electronics

5.6.1 Capabilities

It is intended to provide flight spare electronics at board level only. In order to test the electronics the boards will be assembled into the qualification model DRCU and QM DPU frames (QM2 and QM respectively). Once assembled into the appropriate frames the FS boards will have fully flight like function and external form and fit. The QM2 warm interconnect harness will be used for flight spare testing and there will be no FS warm interconnect harness. The boards will undergo environmental acceptance testing in the qualification model boxes. It is assumed that the QM2 harness remains at RAL. This set of electronics will be used to carry out the calibration and functional performance tests on the FS instrument. The boards within the electronics will be available to replace PFM boards in the PFM instrument in the event of failures during system level AIV.

5.6.2 Outline integration and verification

The FS boards will be integrated into the QM boxes at IFSI and CEA respectively. The integrated boxes will be functionally tested and undergo environmental test before delivery to RAL. Once at RAL the integration will follow the same procedure as used for the PFM.

6. SM/AM AIV

6.1 Capabilities

The SM and AM are models of the cold FPU only consist of the CQM structure; optics and, for part of the programme, OGSE. Mass dummies or structural models will be used for the other sub-systems. The SM is designed to allow for a verification of the structural design of the FPU by conducting a warm vibration test early on in the instrument AIV programme. The AM is designed to allow the optical design of the FPU to be verified warm and cold using visible light alignment techniques. The build standard of the SM/AM is given in RD3.

Note – as some parts of the SM/AM will be used for both the CQM and, later, for refurbishment into the flight spare, the SM/AM FPU will be subject to the PA/QA procedures detailed in the SPIRE PA Plan (AD7).

6.2 SM Test Programme

The following system level design issues will be addressed during the SM AIV programme:

Mechanical interface with Herschel system
The FPU will have the same form and fit as the PFM and will be interfaced to a mock up of the Herschel optical bench.

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

Instrument mechanical frequency response and ability to withstand launch environment
A programme of warm vibration will be conducted on the integrated FPU that will check for mechanical resonance and gradually lead to a full qualification level vibration test.

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

6.2.1 SM Outline AIV Programme

SM Assembly
The first task in the SM programme is to integrate the mirrors and sub-system structural models into the structure. The FPU structure – notably the optical bench – will require support during integration and alignment. Specialised MGSE will be provided for this task and is considered to be part of the structure delivery.

SM Warm Environmental Test
A warm vibration test will be carried out to verify overall mechanical responses; to give a reference level for the cold vibration check and to give realistic vibration levels at the interface locations of the sub-systems. The structure will be instrumented to allow this to happen.

6.3 AM Test Programme

The following system level design issues will be addressed during the SM AIV programme:

Optical interface to Herschel system
The optics fitted to the SM/AM 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. The ability to accurately place the SPIRE instrument on the Herschel optical bench and its alignment stability when cooled will be verified.

Instrument level integration and alignment
The AM 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.

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.

6.3.1 AM Outline AIV Programme

Alignment following integration
After the warm vibration the OGSE items are assembled into the structure and their alignment verified optically using visible light. Various optical tests will be carried out on the integrated structure and optics to verify the performance of the optical design.

Cold Alignment Verification

Once the optical alignment and performance has been verified warm, it must also be verified cold. The integrated structure; optics and OGSE is placed onto the Herschel optical bench simulator and thence into the facility cryostat. The optical alignment of the instrument with respect to the Herschel optical bench and the internal alignment of the instrument will then be verified cold.

6.4 FPU Interim Design Review

Once the SM warm vibration and AM warm/cold alignment has been carried out the optical and structural performance can be assessed and any design changes required can be initiated. If none are required then this can form part of the structure CDR and the go ahead given for the production of the long lead item flight model structural components. This will be a formal review to which ESA and prime contractor representatives will be invited.

CQM AIV

7.1 Capabilities

The instrument level CQM programme is designed to allow the performance and functionality of the instrument design to be explored and characterised ahead of the flight model. As originally conceived the CQM was not intended to be used for environmental verification . In the new programme the CQM will be subjected to full environmental verification. Therefore, the sub-systems must be capable of withstanding vibration. It is proposed that the CQM FPU will have, in addition to the optics and structure from the SM/AM programme, only the structural models of the BSM and SMEC, a single photometer array and the qualification model of the cooler. The JFETs will consist of one active module to run the P/LW plus STMs to represent the thermal performance of the other modules. This will allow the thermal verification of the instrument to a high fidelity and some performance testing on the photometer. No testing will be possible on the spectrometer.

The electronics used will be the QM1 model as described above.

Note – as some parts of the CQM will be used for refurbishment into the flight spare, the CQM instrument will be subject to the PA/QA procedures detailed in the SPIRE PA Plan (AD7).

7.2 Test Programme

The following system level design issues will be addressed during the CQM AIV programme:

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

Thermal interface to Herschel system
The CQM 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 conductance etc) is correctly specified.

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 flight representative bar the use of flight quality components and absence of cold redundant circuitry. However, although the MCU will be present, there will be no active SMEC or BSM in the FPU so the mechanism operation will not be verified. 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) although a GSE power supply will replace the PSU.

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 it 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 only some of the cold sub-systems operational – the cooler; the two calibration sources and the long wavelength photometer. The software and operations modes for these sub-systems can be tested and the real-time control of the cooler can be verified.

Optical
The CQM will only be capable of allowing the far infrared and sub-mm optical performance of the photometer 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 for the photometer.

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
The CQM will be used to test most of the thermal performance aspects of the SPIRE instrument, as it will have operating detectors; JFET amplifiers and the correct optical filtering scheme. This means that the thermal performance of the instrument can be evaluated in a realistic environment.

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

7.2.1 CQM Outline AIV Programme

Preparation of CQM
The OGSE will be removed and the sub-system QM and STMs fitted as appropriate. Further harnesses will also be fitted and the JFET boxes will be integrated with the FPU on the Herschel Optical Bench simulator.

At the end of the integration activities a CQM Warm Vibration Test Readiness Review will be held.

CQM Warm Vibration
The integrated FPU and JFET boxes will vibrated warm in three axes. The vibration programme will be designed to build up towards full qualification levels with suitable checking by resonance searches as the level is increased.

Post vibration test
Once the vibration has been carried out there will be a series of post vibration checks on the optical alignment and the structural integrity. – *perhaps not*

Installation of Test Thermistors
The instrument will have extra thermistors temporally installed to allow more detailed monitoring of the FPU temperature during the thermal verification testing. The FPU and JFETs on the HOB simulator will be placed into the test cryostat and attached to the cryoharness.

CQM Warm Electronics Integration
In parallel to the FPU/JFET integration the CQM warm electronics will be integrated and functionally checked as discussed in section 5.3. The electronics will be integrated to the FP and JFETs.

CQM Test Readiness Review
A review will be held prior to the commencement of the instrument cooldown to confirm that all systems are functioning correctly and that the test plan and procedures are correctly established. This will be a formal review to which ESA and prime contractors will be invited.

CQM Cold Test I
Assuming no major deficiencies are identified in the integration or test readiness the cryostat will be evacuated and the cold instrument units cooled to their operating temperature. Once the operating temperature has been reached a cold functional test will be conducted followed by a thermal verification test. During the thermal verification test the cooler will be recycled and it will be possible to start operation of the detectors. A cold functional test of the detectors will then be carried out. Assuming all is well with the detector operation the final part of the photometer alignment verification can be completed using far infrared and sub-millimetre radiation via the telescope simulator.

CQM Cold vibration campaign
The FPU and JFETs will be packed and shipped to CSL for a cold (<10 K) vibration test at the Herschel common cold vibration facility. Before the instrument is shipped a CQM Cold Vibration Test Readiness Review will be held. After instrument has reached the facility and been prepared the three axis vibration test will be done and the instrument returned to RAL for further testing. Note that this test can only be done at this time if no severe problems were identified during the warm vibration testing – this is especially true for the cooler as the instrument will contain a working cooler at this

time. This test verifies the mathematical model of the structure and is the qualification test for the SPIRE instrument structure mechanical design.

CQM Cold Test II
Following the cold vibration test the instrument thermal performance will be tested once more in the facility cryostat. The instrument will be unpacked; integrated onto the Herschel optical bench simulator and placed into the test cryostat. The CQM Cold Test I procedures will be repeated

CQM Post Test Review
At the conclusion of the CQM programme a review of the instrument performance thus far will be conducted. Any design changes necessary for the flight model will be identified and initiated. This will be the CDR for the cooler; the thermal design of the instrument and the completion of the CDR for the structural design of the instrument. This will be a formal review to which ESA and prime contractor representatives will be invited.

CQM Delivery Preparation
The instrument will be prepared for shipment to ESA and the End Item Delivery Package (EIDP) prepared. At this time any items needed for use on later models may be removed from the instrument and replaced by STM’s or QM’s.

CQM Readiness Review
Before shipment to ESA a readiness review will be help to check the instrument status and to review the contents of the EIDP. This will be a formal review to which industry and ESA representatives will be invited.

8. PFM BUILD 1 AIV

8.1 Capabilities

The first build of the PFM is designed to verify the operational and performance aspects of the spectrometer and the operational aspects of those sub-systems that were not represented during the CQM programme – the BSM and calibrators. The build standard of this model is as given in table 3.2-4. The electronics used with this model will be either the QM1 or, if they arrive in time , the QM2.

8.2 Test Programme

The CQM programme will have addressed most of the issues related to the basic thermal operations of the instrument and the photometer performance. However no mechanism tests will be done and no performance tests on the spectrometer. The PFM build I will therefore address the following system level verification aspects.

Optical
The final verification of the instrument optical design, i.e. those aspects related to the spectrometer, will be carried out on this model.

Electromechanical System
The SMEC will be a QM model and, therefore, may not have full flight compatibility. Tests carried on the spectrometer will however validate the flight design and can be used to look at issues such as exported microphonics. The BSM will be the flight model and a full verification of its performance should be possible will this model.

Operations and Software
This model 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. Except for operationing modes involving use of the photometer detectors.

Commissioning and Calibration
Having a partially 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.

End-to-end system performance
The scientific capabilities of the spectrometer will be tested for the first time. This end-to-end testing will be the most important feature of the 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.

8.2.1 PFM Build I Outline AIV Programme

Assembly and Alignment of FPU

The FPU structure and mirrors will be assembled and the alignment verification carried out according to the alignment procedure. Both the photometer and spectrometer alignment will be carried out. This will include a cold alignment verification check.

Spectrometer Sub-system Integration

The spectrometer side of the FPU will have all sub-systems fitted. The cooler will also be fitted at this time. If the FM cooler has not been delivered at this time, the CQM cooler will be used until the FM arrives. The FM spectrometer JFET unit will be integrated.

Warm Electronics Integration

In parallel to the FPU/JFET integration the QM warm electronics will be integrated and functionally checked as discussed in section 5.3. The electronics will be integrated to the FP and JFETs. If a second set of electronics has not been delivered in time the QM1 electronics will be used.

Test Readiness Review

A review will be held prior to the commencement of the instrument cooldown to confirm that all systems are functioning correctly and that the test plan and procedures are correctly established. This will be a formal review to which ESA and prime contractors will be invited.

Warm and Cold Functional Tests

With the FPU and JFETs in the cryostat and integrated to the electronics warm and cold functional tests of the instrument can be conducted. These will verify the basic operations of the instrument prior to full performance testing.

Instrument Thermal Performance

A sub-set of the thermal verification procedures will be carried out to ensure that the instrument is functioning correctly. Also, those parts of the thermal verification test using real working mechanisms not done on CQM will be carried out in full on this model.

Instrument Cold Verification

Assuming no problems have arisen, the spectrometer should now be fully functioning and its basic optical; electrical and thermal functionality will have been verified. We are now in a position to carry out more extensive performance and operational characterisation tests. The indicative order of the tests to be carried out is: to verify the performance of each sub-system against a set prescription from the sub-system providers; to run a set of instrument level performance and characterisation tests and finally to run a set of tests to verify and explore the optimum observing mode strategies for the SPIRE spectrometer.

EMC and microphonics testing

With the mechanisms fitted it will be possible to assess the compatibility of the mechanisms in the correct operating environment. A microphonics susceptibility and compatibility test will also be carried at this time.

Spectrometer Post Test Review

Before the FP and JFETs are warmed up a review will be held to ensure that all tests have been carried out; that all data required are available and to assess the performance of the spectrometer with a view to any changes required for the flight model.

Cold and Warm Functional Check

Before warm up commences the standard cold functional test will be carried out as a final cold health check. Once the instrument is warm a warm functional test will be done. The cold units will then be removed from the cryostat.

9. PFM BUILD 2 AIV

9.1 Capabilities

The PFM FPU and JFET Boxes must be fully compliant with the Instrument Requirements Document. The electronics used to test the PFM FPU and JFET Boxes are initially the QM of the DRCU and DPU. However, in order to fully calibrate the instrument prior to integration in the satellite the PFM electronics units must be integrated with the FPU and JFET boxes and the calibration procedures carried out with the full proto-flight instrument.

9.2 Test Programme

Most of the design requirements on the SPIRE instrument will have been verified on the AVM; SM/AM; CQM and PFM build 1 programmes and at unit level on the sub-system QM's. The test programme for the PFM will be designed to verify that the instrument is capable of meeting its performance requirements and will be capable carry out the defined observing modes. In addition, and most importantly, the AIV programme for the PFM instrument is geared towards carrying out the instrument calibration tests that will fulfil the requirements set out in the Instrument Calibration Requirements Document.

9.2.1 PFM Build 2 Outline AIV Programme

Sub-system Integration
The photometer side of the FPU will have all sub-systems fitted. Any non-flight sub-systems on the spectrometer will be replaced by the flight units. The FM photometer JFET unit will be integrated.

Warm Electronics Integration
If the QM electronics were not used for the PFM build 1, then in parallel to the FPU/JFET integration the QM warm electronics will be integrated and functionally checked as discussed in section 5.4. The electronics will be integrated to the FP and JFETs.

Test Readiness Review
A review will be held prior to the commencement of the instrument cooldown to confirm that all systems are functioning correctly and that the test plan and procedures are correctly established. This will be a formal review to which ESA and prime contractors will be invited.

Warm and Cold Functional Tests
With the FPU and JFETs in the cryostat and integrated to the electronics warm and cold functional tests of the instrument can be conducted. These will verify the basic operations of the instrument prior to full performance testing.

Instrument Thermal Performance
A sub-set of the thermal verification procedures will be carried out to ensure that the instrument is functioning correctly.

PFM Cold Test I
A sub-set of the instrument level performance procedures will be carried out to give a baseline measurement prior to the cold vibration.

CQM Cold vibration campaign
The FPU and JFETs will be packed and shipped to CSL for a cold (<10 K) vibration test at the Herschel common cold vibration facility. Before the instrument is shipped a PFM Cold Vibration Test Readiness Review will be held. After instrument has reached the facility and been prepared the three axis acceptance level vibration test will be done and the instrument returned to RAL for further testing.

PFM Cold Test II
Following the cold vibration test the instrument thermal performance will be tested once more in the facility cryostat. The instrument will be unpacked; integrated onto the Herschel optical bench simulator and placed into the test cryostat. The PFM Cold Test I procedures will be repeated to verify the FPU and JFETs have survived vibration.

Instrument Cold Verification
Assuming no problems have arisen, the instrument should now be fully functioning and its basic optical; electrical and thermal functionality will have been verified. We are now in a position to carry out the full performance and operational characterisation tests.

FM Warm Electronics Integration
The FM electronics will only become available late in the PFM AIV programme. In parallel to other activities, the FM warm electronics will be integrated and functionally checked as discussed in section 5.5. The electronics will then be integrated to the FPU and JFETs.

Cold Functional Check
The functional check will be repeated using the FM electronics.

Instrument Calibration
Once the flight instrument has been fully integrated the calibration procedures for the instrument will be carried out in order to populate the calibration database with the correct values.

PFM Post Test Review
Before the FPU and JFETs are warmed up a review will be held to ensure that all tests have been carried out and that all data required are available. This will be a formal review to which ESA and prime contractor representatives will be invited.

Cold and Warm Functional Check
Assuming that no further tests have been identified at the Post Test Review, before warm up commences the standard cold functional test will be carried out as a final cold health check. Once the instrument is warm a warm functional test will be done. The cold units will then be removed from the cryostat.

PFM Delivery Preparation
The instrument will be prepared for shipment to ESA and the End Item Delivery Package (EIDP) prepared.

PFM Readiness Review

Before shipment to ESA a readiness review will be help to check the instrument status and to review the contents of the EIDP. This will be a formal review to which industry and ESA representatives will be invited.

10. FS AIV

10.1 Capabilities

The FS FPU and JFET Box will be identical to the PFM. The electronics used to test the FS FPU and JFET Box consist of boards the are identical to the PFM electronics assembled into the qualification model frames.

10.2 Outline Assembly and Integration and Verification

The FS AIV will be identical to the PFM AIV except we plan only a warm vibration and the testing planned with the QM electronics, which is not required as the calibration and functional characterisation will be carried out with the electronics that will ultimately be used with the flightspare.

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