SPIRE

SUBJECT: **SPIRE Instrument Qualification Requirements**

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Glossary

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
ICD	Interface Control Document
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
TMM	Thermal Mathematical Model

References

Applicable Documents

AD1	HERSCHEL/Planck IID-A SCI-PT-IIDA-04624 iss 1.0 (1/9/2000)
AD2	Structure ICD SPIRE-MSS-DOC-#######
AD3	Thermal Config Control Doc SPIRE-RAL-PRJ-000560 iss D2 (22/11/2000)
AD4	DPU ICD SPIRE-IFS-DOC-######
AD5	ICU ICD SPIRE-SAP-DOC-######
AD6	DCU ICD SPIRE-SAP-DOC-######

Reference Documents

RD1	SPIRE Instrument STM Requirements SPIRE-RAL-PRJ-######
RD2	SPIRE Instrument CQM Requirements SPIRE-RAL-PRJ-######
RD3	SPIRE Sub-system QM Requirements SPIRE-RAL-PRJ-######
RD4	SPIRE Instrument AIV Plan SPIRE-RAL-PRJ-000410 Issue 2.1 29 March 2001

1. INTRODUCTION

This document describes the approach the SPIRE instrument team will take to the instrument level Qualification to ensure that the flight model of the SPIRE instrument will be compatible with the operational and launch environment of the HERSCHEL mission.

The instrument level model philosophy to be adopted is described and the justification for adopting this philosophy is explained via a description of the instrument as a series of interrelated systems. An overview is also given of the test programme that is required to address the system level design issues associated with this system breakdown.

2. SYSTEM LEVEL MODEL PHILOSOPHY

HERSCHEL and its instruments comprise a highly complex system with many parts, each of which has complex system level interfaces with one or many of the others. In order to minimise the risk that some part of these interactions will compromise the operation of the system as a whole, the ESA project team has proposed a series of instrument and cryostat models that will be used to verify the system design (AD1 section 9.2). The instrument models that will be required to be delivered to ESA for integrated system tests have been identified and the functionality called for in AD1 is as follows:

AVM – Avionics Model. The IID-A states that this is to be used for:

- *verification of all electrical and software interfaces*
- *verification of subsystem and instrument functional performance within system environment*
- *qualification of on-board software*
- *verification of system performance*
- *verification of operational procedures.*

This is interpreted as being a DPU plus a simulator of the DRCU and the cold FPU – the latter is termed the DRCU Simulator.

CQM - Cryogenic Qualification Model. For both the cold FPU and the warm electronics it is assumed in AD1 that this is built to flight standards, but not necessarily using flight quality components, it is further assumed that the AVM DPU can be used to drive the CQM. The performance capabilities of the instrument may be less than the proto-flight model - i.e. fewer pixels in the focal plane arrays, but it should mimic as exactly as possible the thermal, electrical and mechanical properties of the flight instrument. AD1 calls for….

"The CQM standard will be the same as flight models"

That is the instrument CQM shall undergo full qualification level environmental testing. However there is no plan to carry out environmental testing on the CQM integrated at system level.

PFM – Proto-Flight Model. This will be the instrument model that is intended for flight. It will be built to full flight standards. The PFM is therefore expected undergo environmental test at both instrument and system level. This applies to both the warm electronics boxes and the cold FPU.

FS – Flight Spare. The flight spare cold FPU may be made from the refurbished CQM. The flight spare units may, when and if agreed with the ESA project, be provided as spare sub-systems to be integrated; tested and returned in the event of a failure during system level AIV within one month of the instrument unit being de-integrated from the system.

3. SPIRE SYSTEM LEVEL ANALYSIS

The SPIRE instrument itself is also a complex system with many parts and interactions between them that will require "pre-flight" models in order to ensure the integrated system will work correctly. In this section a system level analysis of the need for pre-flight instrument models is described and a logically consistent set of instrument models is proposed that is also compatible with the needs of the system level testing as described in AD1.

The SPIRE instrument can be viewed not just as a series of physical sub-systems but also as a series of interacting systems. Figure 1 is a system block diagram or topology of the SPIRE instrument that attempts to break the SPIRE instrument into a number of systems areas with over lapping areas of interest.

Table 1 expands on figure 1 and gives details of what each system area represents; the issues to be addressed under each system area; the physical components that can be associated with each system and which methods of analysis and verification we intend using to ensure that each area is properly considered in the implementation and verification of the SPIRE instrument.

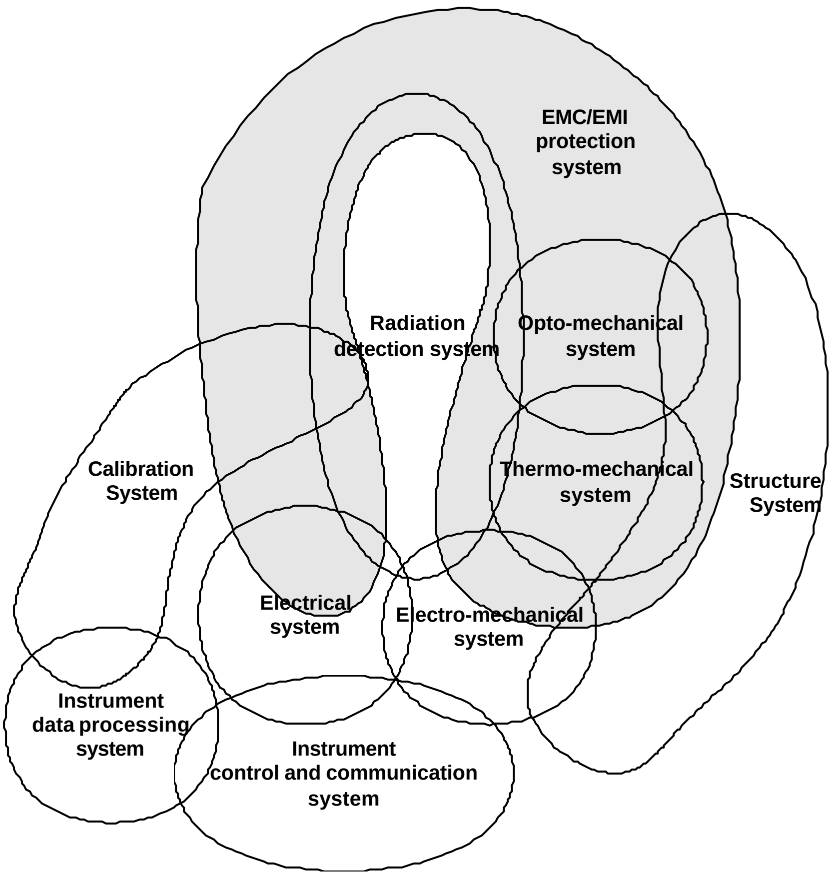

Figure 1: Simplified view of the SPIRE instrument as a broken into "systems".

Table 1: Description of the SPIRE systems

System	Description/Issues	Sub-systems	Design analysis Tools	Design verification methods
Structural	To ensure that the SPIRE instrument is mechanically compatible with the HERSCHEL system and capable of withstanding the launch environment Mechanical frequency response Ability to withstand launch environment Mechanical interface with HERSCHEL system Instrument level integration Sub-system mechanical interfaces	Primarily instrument Structure and JFET Enclosure Interfaces to all cold FPU sub-systems	CAD FEM (IDEAS)	Design Analysis Prototype material testing Sub-system level vibration tests **Instrument level vibration tests** System level integration and vibration tests
Opto-mechanical	To ensure that only the legitimate optical radiation reaches the radiation detection system and does so in a manner that fulfils the instrument requirements Optical design Optical interface to HERSCHEL system Straylight Instrument optical performance Integration and alignment Sub-system optical interfaces	Structure Optics Filters Calibration Sources Detector Arrays Baffles SMEC BSM	Synopsis ASAP APART Feedhorn model (Gaussian Mode analysis; HFSS)	Design Analysis Component testing (filters etc) Optical alignment **Instrument level optical tests**
Thermo-mechanical	To ensure that the different parts of the instrument run at the correct temperature and that the instrument functions at the correct temperature according to requirements for all defined instrument operating and environmental conditions Thermal performance under all operating conditions Thermal interface to HERSCHEL system Sub-system thermal interfaces Sub-system thermal control	Structure Cooler Thermometry JFET Amplifiers JFET Enclosure Filters Thermal straps SCU OBS	ESATAN model Other computer models	Design Analysis Prototype sub-system tests Sub-system level cold tests **Instrument level cold tests** System level cold tests
Electro-mechanical	To ensure that the moving parts of the instrument meet the instrument requirements; do not unduly influence	FPU Harnesses Detector arrays SMEC	Dynamical analysis model	Design Analysis Prototype sub-system tests

Table 1: Description of the SPIRE systems

System	Description/Issues	Sub-systems	Design analysis Tools	Design verification methods
	the operation of other parts of the instrument and that the instrument can operate according to requirements in the micro-vibration environment expected in the HERSCHEL satellite Micro-vibration environment Mechanism control Harness mechanical frequency response and routing	BSM Shutter JFET Amplifiers Cryostat cold harness Cryostat warm harness MCU Shutter electronics	(DSPACE?) at sub-system level only FEM	**Instrument level cold tests** System level cold tests
Radiation Detection	To ensure that the radiation transmitted by the opto-mechanical system is efficiently detected and converted into digital signals without excess noise or contamination from other electrical signals. Detector performance versus environment (temperature; photon background; micro-vibration; EMC) JFET Amplifier performance versus environment *(ditto)* Harness performance Detector sub-system interface compatibility – thermal; electrical; mechanical End-to-end system performance	Detector Arrays Thermal Straps Temperature Control Cooler FPU Harnesses RF Filters JFET Amplifiers Cryostat cold harness Cryostat warm Harness DCU	Mathcad Models System analysis	Design Analysis Prototype cold units in representative environment with representative electronics Sub-system cold units for thermal and environmental test Sub-system end to end test **Instrument level end to end test** System level end to end test
EMI/EMC protection	To ensure that no radiofrequency EM radiation enters the radiation detection system from any source within the HERSCHEL system. Also that the SPIRE instrument does not emit any radiofrequency EM radiation that might influence the operation of any part of the HERSCHEL system EMC susceptibility and emission – radiated/conducted Electrical grounding Faraday cage integrity and	Structure FPU Harness RF Filters JFET Box (HSFTB) Cryostat cold harness Cryostat warm harness DRCU (HSDRC)	Systems Analysis HSPICE model	Design Analysis Electronics units as sub-system with simulator and EMC tested (conductive only?) **Instrument level testing (conductive only?)** System level testing (radiated and conductive?)

Table 1: Description of the SPIRE systems

System	Description/Issues	Sub-systems	Design analysis Tools	Design verification methods
	performance RF filter performance Harness performance Power supply cleanliness Digital/analogue separation			
Electrical	To ensure that the SPIRE instrument is electrically compatible with the HERSCHEL system and that the different parts of the SPIRE instrument are mutually electrically consistent with each other Electrical interface to HERSCHEL system Power supply distribution and control Sub-system electrical interfaces Wiring tables Analogue to digital interfaces Digital to digital interfaces	DRCU (HSDRC) SPIRE Warm harness (HSWIH) DPU (HSDPU) S/C PDU S/C Warm harness DRCU Simulator FPU Simulator	Systems analysis	Design Analysis Electronics units tested as sub-system with simulator(s) **Instrument level functional testing** System level testing
Instrument control and communica tion	To ensure that the SPIRE instrument communicates with the HERSCHEL system; that the different parts of the SPIRE instrument are mutually consistent with the operations concept and that the instrument operates safely and to requirements in all operational modes Data interface to HERSCHEL system Operating mode definition Instrument commanding definition On board software definition Sub-system operational and control interfaces Sub-system data interfaces	DRCU (HSDRC) SPIRE warm harness (HSWIH) DPU (HSDPU) S/C CDMS FPU Simulator DRCU Simulator OBS	Systems analysis Software simulators	Design Analysis Electronics units tested as sub-system with simulator(s) **Instrument level operations testing** System level testing
Instrument data processing	To ensure that the data produced by the SPIRE instrument are compatible with the requirements of the HERSCHEL system and are processed into the required data products Interfaces to the ICC	DPU (HSDPU) DRCU Simulator FPU Simulator ICC	Systems analysis Software simulators	Design Analysis Data sets produced by simulators and electronics units tested as sub-system with simulator(s)

Table 1: Description of the SPIRE systems

System	Description/Issues	Sub-systems	Design analysis Tools	Design verification methods
	Data product definition Data processing definition Sub-system data processing interfaces Observing mode data processing interfaces			produces data sets **Instrument level observation verification** System level tests for end to end verification
Calibration	To ensure that the data produced by the instrument can be converted into meaningful physical units to allow the correct operation of the instrument in all modes and the processing of the instrument data into the required data products Observing mode calibration definition Ground commissioning and calibration plan Flight commissioning and calibration plan Instrument to ground facility interfaces Ground facility definition Ground based observing programme definition	Photometer Calibrator Spectrometer Calibrator DPU (HSDPU) ICC	Systems analysis Instrument performance models	Design Analysis Prototype sub-system tests **Instrument level performance verification** Ground based observing programme

3.1 Instrument Level Verification Programme

From Table 1 we can see that a basic set of Qualification tests has to be carried out at instrument level to ensure that the Flight Model instrument will meet the requirements placed upon it – these are highlighted in the table. Some of these tests are of particular concern at instrument and system level. We can identify these as:

Vibration to ensure the instrument/sub-system will survive the launch

Thermal balance to ensure the correct operation of the instrument and sub-systems in the HERSCHEL cryostat

Interfaces to HERSCHEL to ensure that the instrument will be compatible with all aspects of the HERSCHEL system design

EMC/EMI to ensure that the design of the electrical system and harnesses give the appropriate level of protection for the signals from the detectors

In order to address these basic concerns as early as possible in the instrument development programme it would be normal practice to build one or more instrument models before the flight model (as proposed in AD1 for instance). These would be used to test the design and implementation of the instrument against the instrument and system level requirements.

We can see that, with sufficient attention to the representation of the sub-system and system function, the mechanical interfaces; structural and thermal aspects of the instrument design could be verified at instrument level with a single instrument model that need not have the ability perform any electrical and electro-mechanical function. The electrical interfaces to the HERSCHEL satellite and between the warm electronics units could be tested on an entirely electrical model of the instrument with the cold units represented by an electrical simulator. And the EMC/EMI concerns could be addressed by an instrument model that had all the electrical and functional aspects of the instrument without necessarily the ability to withstand the vibration environment during launch. Such an instrument model could also be used for optical and operational performance verification if the sub-systems had sufficient fidelity.

3.2 SPIRE Instrument Models

An additional constraint on the instrument level verification programme is the need to develop highly complex sub-systems within a restricted budget, thus leading to long design and procurement times. We have therefore devised the following series of instrument models that balances the need to have as much instrument level testing as early as possible in the programme against the need to give the sub-system suppliers as much time as possible to design and develop their flight units.

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.

STM – Structural Thermal Model. This is a model of the cold FPU and JFET boxes that will be used to verify the vibration levels that will be experienced by the cold sub-systems during launch and to verify that the thermal design of the instrument meets the instrument level performance requirements. A visible light optical alignment procedure will also be carried out on this model as the first stage in the verification of the SPIRE optical design. This model will also be used to qualify the design of the SPIRE structure. It will consist of the CQM structure, thermal hardware and optics, the CQM cooler and mass/thermal models of the cold sub-systems. In order to test the real vibration levels and thermal environment that will be experienced at the sub-system interfaces it will be necessary to have some of the sub-system STMs as mechanically representative as possible although there is no requirement that they should actually function. The FPU harnesses for the cold sub-systems and between the JFET boxes and the FPU should also be present to allow early test of the integration procedures and environmental robustness of the harness design. This model will be vibrated to full qualification levels at ambient temperature and, if possible, at cryogenic temperature. The model will be placed in the instrument test cryostat and full thermal characterisation will be carried out. This model is not 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. The structure, optics, cooler and FPU harnesses will be those used for the STM. All other cold FPU units need to function and have close to the expected flight performance, but do not need to be capable of withstanding the launch environment. Further they do not

need have the full reliability and redundancy or, in the case of the FTS mirror mechanism and beam steering mirror, necessarily have the correct power dissipation. The detectors provided for the CQM may not have flight like sensitivity 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 of 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.
This model is delivered to ESA.

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.

Sub-system Qualification Models. In addition to the deliverable instrument models, there will be “Qualification Models” of some of the sub-systems built (for instance the warm electronics units) to ensure Qualification at unit rather than instrument level. These will be close to flight like; will be built to flight standards and capable of withstanding the environmental test programme. As they are planned to be delivered rather later than the FPU CQM they may not be available for the CQM test programme. Rather they will follow a parallel track and, following qualification testing, will be available for the initial phases of the PFM test programme as required.

4. MODEL CHARACTERISTICS

4.1 Nomenclature

We can use table 1 to identify what requirements we need to place on each instrument model to ensure that the systems level issues are addressed in a logical order ahead of the final commitment to build the proto-flight model. The basic capabilities any sub-system or instrument model may require can be summarised as follows – this nomenclature is used from here-on:

Characteristic	Description	Shorthand
Form and Fit	Model must comply as closely as possible with the mechanical; electrical and thermal interfaces specified in the ICD(s). This to include mass; c.o.g.; connector type and positions; envelope; thermal dissipation. However, the model need not function nor need it have the capability to precisely mimic the unit under all environmental conditions. For example a lumped mass with a resistive heater may replace the mechanisms.	FF
Mechanically Compliant	Model must have essentially the same mechanical properties (mass; c.o.g.; Q; resonant frequency etc) as the proposed proto-flight model and be able to meet the mechanical environmental test criteria i.e. the model must comply with the Structure ICD (AD2)	MC
Thermally Compliant	Model must have as essentially the same thermal properties (dissipation; conductive interface; time constant etc) as the proposed proto-flight model. I.e. the model must comply with the Thermal Configuration Control (AD3)	TC
Electrically Compliant	Model must have essentially the same electrical properties (wiring; connectors; power consumption; response to external stimulus – either digital or analogue etc) as the proposed proto-flight model i.e. the model must comply with the appropriate electrical ICD (AD4; AD5; AD6)	EC
Performance Compliant	The model must perform its function as if it were the proposed proto-flight unit – that is, whilst the unit need not be compliant in one or more of its interfaces or specifications, its functional performance must meet the flight specification. For instance a model of the SMEC might be built that is not designed to survive launch but which does operate in a manner very close to the flight unit.	PC
Data Compatible	The model has to provide data in the correct format and with suitable values in all locations with the data packets. The model has to respond to requests for data for any operating mode by providing with the correct form and content for that mode - again compatible with AD4; AD5; AD6.	DC
Flight Like	The model must be as close as possible to the proposed proto-flight model in all particulars including ability to survive environmental test. This implies that the model has all the characteristics detailed above.	FL

4.2 Analysis of the Instrument Model Philosophy

Table 3 presents a compliance matrix between the requirements on the integrated instrument and the sub-systems at unit level in order that each of the system level issues can be tested using the pre-flight instrument models. The requirements are compared to the expected specification of the instrument and sub-systems for the instrument STM; the instrument AVM and/or CQM and for the sub-system unit level qualification models.

The "FPU" column under "Compliant Model" indicates which instrument cold focal plane unit model fulfils the Qualification requirement. The "WE" column under the same heading indicates which of the warm electronics units is required to fulfil the qualification requirements – QM means the qualification model of all units must be used; AVM means the AVM DPU plus DRCU simulator; AVM/QM1 means the AVM DPU plus the QM1 model of the DRCU units. The "Unit Level" column indicates whether extra testing on the unit level qualification model is required in addition to the instrument level testing to complete the qualification process.

Table 3: Compliance matrix between what is needed for the pre-flight instrument models and what is actually planned to be provided by the various instrument models.

		Req'ment		STM Spec.		AVM/CQM Spec.		QM Spec.	Compliant Model		
Req. ID	**System Issue**	**Inst.**	**SS**	**Inst.**	**SS**	**Inst.**	**SS**	**Unit Level**	**FPU**	**Unit Level**	**WE**
VRD-01.	Mechanical frequency response	FF MC	FF MC	FF MC	FF MC?	FF	FF	FL	STM	QM	QM
VRD-02.	Ability to withstand launch environment	FF MC	FF MC	FF MC	FF MC	FF	FF	FL	STM	QM	QM
VRD-03.	Mechanical interface with HERSCHEL system	FF	N/A	FF	N/A	FF	FF	N/A	STM CQM	N/A	AVM QM1
VRD-04.	Instrument level integration	FF	FF	N/A	FF	N/A	FF	N/A	STM CQM	N/A	AVM QM1
VRD-05.	Sub-system mechanical interfaces	FF	FF	FF	FF	FF	FF	N/A	STM CQM	N/A	AVM QM1
VRD-06.	Optical design	FF PC	FF PC	FF PC	FF PC	FF PC	FF PC	N/A	STM CQM	N/A	N/A
VRD-07.	Optical interface to HERSCHEL system	FF PC	FF PC	FF PC	FF PC	FF PC	FF PC	N/A	STM CQM	N/A	N/A
VRD-08.	Straylight	FF PC	FF PC	FF	FF	FF PC	FF PC	N/A	CQM	N/A	N/A
VRD-09.	Instrument optical	FF PC	FF PC	FF	FF	FF PC	FF PC	N/A	CQM	N/A	N/A

Table 3: Compliance matrix between what is needed for the pre-flight instrument models and what is actually planned to be provided by the various instrument models.

		Req'ment		STM Spec.		AVM/CQM Spec.		QM Spec.	Compliant Model		
Req. ID	**System Issue**	**Inst.**	**SS**	**Inst.**	**SS**	**Inst.**	**SS**	**Unit Level**	**FPU**	**Unit Level**	**WE**
	performance										
VRD-10.	Integration and alignment	FF PC	FF PC	FF PC	FF PC	FF PC	FF PC	N/A	STM CQM	N/A	N/A
VRD-11.	Sub-system optical interfaces	FF PC	FF PC	FF PC	FF PC	FF PC	FF PC	N/A	STM CQM	N/A	N/A
VRD-12.	Thermal performance	FF TC	FF TC	FF TC	FF TC	FF TC	FF TC?	FL	STM CQM	QM	QM
VRD-13.	Thermal interface to HERSCHEL system	FF TC	FF TC	FF TC	FF TC	FF TC	FF TC?	FL	STM CQM	QM	QM
VRD-14.	Sub-system thermal interfaces	FF TC	FF TC	FF TC	FF TC	FF TC	FF TC?	FL	STM CQM	QM	QM
VRD-15.	Micro-vibration environment	MC PC	MC PC	FF	FF	FF MC PC	FF MC? PC	FL	CQM	QM	N/A
VRD-16.	Mechanism control	N/A	PC	N/A	FF	N/A	FF PC	FL	CQM	QM	AVM QM1
VRD-17.	Harness mechanical frequency response and routing	MC	FF MC PC	FF	FF MC	MC	FF MC PC	N/A	STM CQM	N/A	AVM QM1
VRD-18.	Detector performance versus environment	N/A	PC TC EC	N/A	FF	N/A	PC TC EC	FL	CQM	QM	AVM QM1
VRD-19.	JFET Amplifier performance versus environment	N/A	EC TC PC	N/A	FF	N/A	EC TC PC	FL	CQM	QM	AVM QM1
VRD-20.	Detector Harness performance	FF EC	FF EC PC	FF	FF	FF EC	FF EC PC	FL	CQM	QM	N/A
VRD-21.	Detector sub-system interface compatibility – thermal electrical	FF EC TC	FF EC TC PC	FF TC	FF TC	FF EC TC	FF EC TC PC	FL	STM CQM	QM	AVM QM1

Table 3: Compliance matrix between what is needed for the pre-flight instrument models and what is actually planned to be provided by the various instrument models.

		Req'ment		STM Spec.		AVM/CQM Spec.		QM Spec.	Compliant Model		
Req. ID	**System Issue**	**Inst.**	**SS**	**Inst.**	**SS**	**Inst.**	**SS**	**Unit Level**	**FPU**	**Unit Level**	**WE**
	mechanical										
VRD-22.	End-to-end system performance	FF EC TC PC	FF EC TC PC	FF TC	FF TC	FF EC TC PC	FF EC TC PC	FL	CQM	QM	AVM QM1
VRD-23.	EMC susceptibility and emission radiated/conducted	FF EC PC	FF EC PC	FF	FF	FF EC PC	FF EC PC	N/A	CQM?	N/A	QM
VRD-24.	Electrical grounding	FF EC PC	FF EC PC	FF	FF	FF EC PC	FF EC PC	N/A	CQM	N/A	AVM QM1
VRD-25.	Faraday cage integrity and performance	FF EC PC	FF EC PC	FF	N/A	FF EC PC	FF EC PC	N/A	STM CQM	N/A	AVM QM1
VRD-26.	RF filter performance	FF EC PC	FF EC PC	FF	FF	FF EC PC	FF EC PC	N/A	CQM	N/A	AVM QM1
VRD-27.	Non-detector Harness performance	FF EC PC	FF EC PC	FF	FF	FF EC PC	FF EC PC	FL	CQM	QM	AVM QM1
VRD-28.	Power supply cleanliness	EC	EC PC	N/A	N/A	EC PC	EC PC	N/A	CQM	N/A	AVM QM1
VRD-29.	Digital/analogue separation	EC	EC PC	N/A	N/A	EC PC	EC PC	N/A	CQM	N/A	AVM QM1
VRD-30.	Electrical interface to HERSCHEL system	EC	EC PC	FF	N/A	EC PC	EC PC	N/A	CQM	N/A	AVM QM1
VRD-31.	Power supply distribution and control	EC	EC PC	N/A	N/A	EC PC	EC PC	N/A	N/A	N/A	AVM QM1
VRD-32.	Sub-system electrical interfaces	EC	EC PC	N/A	N/A	EC PC	EC PC	FL	CQM	QM	AVM QM1
VRD-33.	Wiring tables	FF EC	FF EC	N/A	N/A	FF EC	FF EC	N/A	CQM	N/A	AVM QM1
VRD-34.	Analogue to	EC	EC	N/A	N/A	EC	EC	N/A	N/A	N/A	AVM

Table 3: Compliance matrix between what is needed for the pre-flight instrument models and what is actually planned to be provided by the various instrument models.

		Req'ment		STM Spec.		AVM/CQM Spec.		QM Spec.	Compliant Model		
Req. ID	**System Issue**	**Inst.**	**SS**	**Inst.**	**SS**	**Inst.**	**SS**	**Unit Level**	**FPU**	**Unit Level**	**WE**
	digital interfaces		PC			PC	PC				QM1
VRD-35.	Digital to digital interfaces	EC	EC PC	N/A	N/A	EC PC	EC PC	N/A	N/A	N/A	AVM QM1
VRD-36.	Data interface to HERSCHEL system	EC DC	EC DC	N/A	N/A	EC DC	EC DC	N/A	N/A	N/A	AVM
VRD-37.	Operating mode definition	EC PC DC	EC PC DC	N/A	N/A	EC PC DC	EC PC DC	N/A	CQM	N/A	AVM QM1
VRD-38.	Instrument commanding definition	EC PC DC	EC PC DC	N/A	N/A	EC PC DC	EC PC DC	N/A	CQM	N/A	AVM QM1
VRD-39.	On board software definition	EC PC DC	EC PC DC	N/A	N/A	EC PC DC	EC PC DC	N/A	CQM	N/A	AVM QM1
VRD-40.	Sub-system operational and control interfaces	EC	EC PC	N/A	N/A	EC	EC PC	FL	CQM	QM	AVM QM1
VRD-41.	Sub-system data interfaces	EC	EC PC DC	N/A	N/A	EC	EC PC DC	N/A	CQM	N/A	AVM QM1
VRD-42.	Interfaces to the ICC	DC	N/A	N/A	N/A	DC	N/A	N/A	N/A	N/A	AVM
VRD-43.	Data product definition	PC DC	N/A	N/A	N/A	PC DC	N/A	N/A	CQM	N/A	AVM QM1
VRD-44.	Data processing definition	PC DC	N/A	N/A	N/A	PC DC	N/A	N/A	CQM	N/A	AVM QM1
VRD-45.	Sub-system data processing interfaces	PC DC	PC DC	N/A	N/A	PC DC	PC DC	N/A	CQM	N/A	AVM QM1
VRD-46.	Observing mode data processing interfaces	PC DC	PC DC	N/A	N/A	PC DC	PC DC	N/A	CQM	N/A	AVM QM1
VRD-47.	Observing mode calibration definition	PC	PC	N/A	N/A	PC	PC	N/A	CQM	N/A	AVM QM1

Table 3: Compliance matrix between what is needed for the pre-flight instrument models and what is actually planned to be provided by the various instrument models.

		Req'ment		STM Spec.		AVM/CQM Spec.		QM Spec.	Compliant Model		
Req. ID	**System Issue**	**Inst.**	**SS**	**Inst.**	**SS**	**Inst.**	**SS**	**Unit Level**	**FPU**	**Unit Level**	**WE**
VRD-48.	Ground commissioning and calibration plan	PC	PC	N/A	N/A	PC	PC	N/A	CQM	N/A	AVM QM1
VRD-49.	Flight commissioning and calibration plan	PC	PC	N/A	N/A	PC	PC	N/A	CQM	N/A	AVM QM1
VRD-50.	Instrument to ground facility interfaces	FF EC DC	FF EC	FF	FF	FF EC DC	FF EC	N/A	CQM	N/A	AVM QM1

4.3 Outstanding Issues

A question mark appearing after any of the entries in the specification columns indicates that the performance of the instrument or sub-system for that model is either unclear or not expected to be fully compliant with the qualification requirement. The particular areas where verification may not be possible at instrument/unit level ahead of the flight model and/or system level integration are:

- **Micro-vibration environment** – some sub-systems may not be mechanically compliant on the CQM and the environment at instrument level testing may not be representative of HERSCHEL. This issue is extremely difficult to deal with as the environmental issues are almost certainly the overriding consideration here. Any obvious non-compliances in the CQM sub-systems can be dealt with by re-design and testing of the QM sub-systems but the final test may only come in-orbit.
- **EMC susceptibility and emission** – some sub-systems may not be fully EMC emission compliant and the environment at instrument level testing will not be representative of HERSCHEL. This issue must finally be resolved during system level testing, however any non-compliance in the CQM sub-systems will be attended to by a combination of re-design and testing in the sub-system QM.
- **Thermal performance during operating modes** – whilst the basic thermal balance of the instrument will be very well explored and tested at instrument level using the STM and CQM, one or two of the CQM sub-systems may show excess dissipation as they may not have flight quality components. This issue will be addressed by a combination of verification of the Thermal Mathematical Model (TMM) and vigorous testing of the sub-systems in question at unit level on the QMs.

  The thermal performance of the instrument may also not be fully characterised at instrument level because the environment during instrument level testing will be different to that in the HERSCHEL cryostat. This will be addressed by further verification of the TMM during the system level CQM testing.

4.4 Test Programme and Sub-system Detailed Requirements

Table 3 sets out the basic requirements on the sub-systems that are listed under each of the system areas in Table 1. The details of the test programmes and the detailed requirements on each sub-system for each instrument model are addressed in RD1; RD2; RD3 and RD4. The Flight Model qualification requirements are essentially identical to those given in table 3 with the additional requirement for calibration that will be addressed in the SPIRE Instrument Calibration Requirements Document.

5. CONCLUSIONS

A logical sequence of instrument models is presented in this document that aims to address the system level design issues at an early stage in the SPIRE development programme to ensure that the flight model will fulfil the scientific and technical requirements of the HERSCHEL mission. This model sequence takes into account the constraints imposed on the instrument level development programme by the technical difficulties encountered in the design and development of many of the SPIRE sub-systems and the limited resources available for that development.

A compliance matrix has been presented between the specification required to carry out each of the identified system level verification tests and the expected specification of each instrument model. This analysis shows that, although the major concerns will be addressed by the instrument level STM/CQM programme, additional unit level testing on the sub-system qualification models and system level testing after integration into the HERSCHEL CQM cryostat will be needed to fully verify the instrument systems design before final confirmation of the flight model design.

The instrument level qualification requirements set out in this document will be used as the starting point for the detailed specification of the components for each of the instrument models and for the detailed SPIRE AIV Plan.