Herschel/Planck

INSTRUMENT INTERFACE DOCUMENT

PART B

INSTRUMENT “SPIRE”

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TABLE OF CONTENTS

Distribution List

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Qty	Organisation	Institute
1	Herschel/Planck Project Team	ESA
1	Prime Contractor	Alcatel
1	Herschel SPIRE	Univ.Cardiff/RAL
1	ESA Project Scientist	ESTEC

Document Change Record

Issue-Rev	Date	Version	Pages affected
1-0	01/09/2000	Initial Issue for ITT	New Document
2-0	31/07/2001	Issue for SRR	Complete Revision: Renaming of FIRST by Herschel. Changes maked by change bars (including editorial changes).

1 INTRODUCTION

The purpose of the Instrument Interface Documents (IIDs) is to define and control the overall interface between each of the Herschel/Planck scientific instruments and the Herschel/Planck spacecraft.

The IIDs consist of two parts, IID-A and IID-B. There is one part A, covering the interfaces to all Herschel and Planck instruments, and one IID-B per instrument:

- The IID-A describes the implementation of the instrument requirements in the design of the spacecraft and will be a result of the spacecraft design activities performed by the Contractor.

- Each IID-B defines in its ‘interface’ section (chapter 5) the requirements of the instrument and the resources to be provided by the spacecraft. In its ‘performance’ section (last section of chapter 4) it defines the scientific performance requirements of the instrument as part of the scientific mission requirements and as agreed between the Principal Investigators and ESA.

After issue 2/0 by ESA, the Contractor will be responsible for maintenance and configuration control of the IIDs in agreement with, and after approval by, the Instruments Principal Investigators and ESA.

In case of conflict between the contents of the IID-A and the IID-Bs, the agreement or definition in the IID-B shall take precedence.

The IIDs will not cover any of the interfaces of the Instrument Control Centres (ICCs for Herschel), the Data Processing Centres (DPCs for Planck) or the Herschel Science Centre (HSC).

2 APPLICABLE/REFERENCE DOCUMENTS

2.1 APPLICABLE DOCUMENTS

AD 1	Herschel/Planck Instrument Interface Document Part A. (Ref.SCI-PT-IIDA-04624)
AD 2	OIRD Herschel/Planck Operations Interface Requirements Document
AD 3	Herschel-SIRD Herschel Science-operations Implementation Requirements Document
AD4	SPIRE Management Plan (FIRST-SPI-PRG-000011)
AD5	Product Assurance Requirements for the Herschel/Planck Scientific Instruments (SCI-PT-RQ-04410)

2.2 REFERENCE DOCUMENTS

RD 1	Caldwell, M., Richards, A., Swinyard, B., Straylight Analysis - PHOT, BOL/RAL/N/0021
RD 2	Rutherford Appleton Laboratory, SPIRE Product Assurance Plan SPIRE-RAL-PRG-00017
RD 3	Swinyard. B , Power profiles for SPIRE operating modes, SPIRE/RAL/N/0046
RD 4	SPIRE AIV Plan, SPIRE-RAL-Doc-000410

2.3 LIST OF ACRONYMS

AD	Applicable Document
AO	Announcement of Opportunity
AVM	Avionics Verification Model
BSM	Beam Steering Mechanism
CCE	Central Check-Out Equipment
CDMS	Command and Data Management Subsystem
CQM	Cryogenic Qualification Model
CVV	Cryostat Vacuum Vessel
DPU	Digital Processing Unit
DRC	Detector Readout and Control Unit
DRCU	Detector Readout and Control Unit
EGSE	Electrical Ground Support Equipment
EMC	Electro-Magnetic Compatibility
ESA	European Space Agency
Herschel	Far InfraRed and Submillimetre Telescope (FIRST)
FM	Flight Model

FOV	Field Of View
FTS	Fourier Transform Spectrometer
GSE	Ground Support Equipment
HIFI	Heterodyne Instrument for the Far Infrared
HSC	Herschel Science Centre
IA	Interactive Analysis
ICC	Instrument Control Centre
ICD	Interface Control Document
IID	Instrument Interface Document
ISO	Infrared Space Observatory
JFET	Junction Field Effect Transistor
KAL	Keep Alive Line
LOU	Local Oscillator Unit (HIFI)
MGSE	Mechanical Ground Support Equipment
MOC	Mission Operations Centre
NEP	Noise Equivalent Power
OBS	On Board Software
OGSE	Optical Ground Support Equipment
OIRD	Operations Interface Requirements Document
OTF	On-Target Flag
PACS	Photoconductor Array Camera and Spectrometer (Herschel)
PFM	Proto Flight Model
QLA	Quick Look Analysis (software)
RAM	Random Access Memory
RD	Reference Document
RF	Radio Frequency
ROM	Read Only Memory
RTA	Real Time Assessment (software)
S/C	Spacecraft
SCOS	Spacecraft Control and Operations System
SIRD	Science –Operations Implementation Requirements Document
SPIRE	Spectral Photometer Imaging Receiver
SPU	Signal Processing Unit
SRD	Software Requirements Document
SVM	Service Module
TBC	To be confirmed
TBD	To be determined
TBW	To be written

3 KEY PERSONNEL AND RESPONSIBILITIES

3.1 KEY PERSONNEL

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ATC, Edinburgh	Beam steering mechanism
CEA, Grenoble	^{3}He cooler
CEA, SAp, Paris	Detector Readout and Control Unit (DRCU); ICC DAPSAS Centre; Ionising radiation effects testing
DESPA, Paris	FTS expertise and design support
GSFC, Maryland	FTS Expertise and design support; Internal calibrators
IAS, Paris	Ground Calibration support
ICSTM, London	ICC UK DAPSAS Centre
IFSI, Rome	Digital Processing Unit (DPU) and related On-board S/W
JPL/Caltech, California	Bolometer arrays and associated cold readout electronics
LAM, Marseille	Optics; FTS mechanism
MSSL, Surrey	Focal Plane Unit Structure
QMW, London	Focal plane array testing; filters, dichroics, beam dividers
RAL, Oxfordshire	Project management and Project Office; AIV and ground calibration facilities; ICC Operations Centre
Stockholm Observatory	Instrument simulator; DRCU Simulator
University of Padua	Provision of ICC Operations Staff
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4 INSTRUMENT DESCRIPTION

4.1 INTRODUCTION

For low background direct detection at wavelengths longer than around 200 μm, the most sensitive detectors are cryogenic bolometers operating at temperatures in the 0.1 - 0.3 K range.

SPIRE (Spectral & Photometric Imaging REceiver) is a bolometer instrument comprising a three-band imaging photometer covering the 200-500 μm range and an imaging Fourier Transform Spectrometer (FTS) with a spectral resolution of at least 0.4 cm^{-1} (corresponding to $\lambda/\Delta\lambda$ = 100 at 250 μm, covering wavelengths between 200 and 670 μm. The detectors are bolometer arrays cooled to 300 mK using a ^{3}He refrigerator. The photometer is optimised for deep photometric surveys, and can observe simultaneously the same field of view of 4 x 8 arcminutes in all three bands.

4.2 SCIENTIFIC RATIONALE

The wavelength range 200 - 700 μm is largely unexplored. The thermal emission from many astrophysical sources peaks in this part of the spectrum, including comets, planets, star-forming molecular cloud cores, and starburst galaxies. The short submillimetre region is also rich in atomic and molecular transitions which can be used to probe the chemistry and physical conditions in these sources.

Wavelengths between 200 and 350 μm are not observable from the ground and have not be observed by ISO. Between 350 μm and 700 μm, some low transparency submillimetre windows allow some observations to be made with difficulty from the ground, but with far lower sensitivity than can be achieved from space.

One of the most important scientific projects for the Herschel mission is to investigate the statistics and physics of galaxy formation at high redshift. This requires the ability to carry out deep photometric imaging at far-infrared and submillimetre wavelengths to discover objects, and the ability to follow up the survey observations with spectroscopy of selected sources. The Herschel SPIRE instrument is essential for this programme, and is being designed so as to be optimised for these extragalactic imaging and spectral surveys. Another key scientific project for SPIRE is a sensitive unbiased search for proto-stellar objects within our own galaxy. This will also be followed up by spectral observations using SPIRE, other Herschel instruments and ground-based facilities.

4.3 INSTRUMENT OVERVIEW

SPIRE contains a three-band imaging photometer and an imaging Fourier Transform Spectrometer (FTS), both of which use 0.3-K “spider-web” NTD germanium bolometers cooled by a ^{3}He refrigerator. The bolometers are coupled to the telescope by close-packed single-mode conical feedhorns. The photometer and spectrometer are not designed to operate simultaneously. The field of view of the photometer is 4 x 8 arcminute, the largest that can be achieved given the location of the SPIRE field of view in the Herschel focal plane and the size of the telescope unvignetted field of view. Three photometer arrays provide broad-band photometry ($\lambda/\Delta\lambda \approx 3$) in wavelength bands centred on 250, 350 and 500 µm. The 250, 350 and 500 µm arrays have 149, 88, and 43 detectors respectively, making a total of 280. The field of view is observed simultaneously in all three bands through the use of fixed dichroic beam-splitters. Spatial modulation can be provided either by a Beam Steering Mirror (BSM) in the instrument or by drift scanning the telescope across the sky, depending on the type of observation. An internal thermal calibration source is available to provide a repeatable calibration signal for the detectors. The FTS uses novel broadband intensity beam dividers, and combines high efficiency with spatially separated input ports. One input port covers a 2.6-arcminute diameter field of view on the sky and the other is fed by an on-board calibration source which serves to null the thermal background from the telescope and to provide absolute calibration. Two bolometer arrays are located at the output ports, one covering 200-300 µm and the other 300-670 µm. The FTS will be operated in continuous scan mode, with the path difference between the two arms of the interferometer being changed by a constant-speed mirror drive mechanism. The spectral resolution, as determined by the maximum optical path difference, will be adjustable between 0.04 and 2 cm^{-1} (corresponding to $\lambda/\Delta\lambda$ = 1000 - 20 at 250 µm wavelength).

The focal plane unit has three separate temperature stages at nominal temperatures of 4 K, 2 K (provided by the Herschel cryostat) and 300 mK (provided by SPIRE's internal cooler). The main 4-K structural element of the FPU is an optical bench panel which is supported from the cryostat optical bench by stainless steel blade mounts. The photometer and spectrometer are located on either side of this panel. The majority of the optics are at 4 K, but the detector arrays and final optics are contained within 2-K enclosures. The ^{3}He refrigerator cools all of the five detector arrays to 0.3 K. Two JFET preamplifier modules (one for the photometer an one for the FTS) are attached to the optical bench close to the 4-K enclosure, with the JFETs heated internally to their optimum operating temperature of ~ 120 K.

The SPIRE warm electronics consist of two boxes with direct connection to the FPU, the Detector Control Unit (DCU) and the Focal Plane Control Unit (FCU) (together these boxes are termed the Detector Readout and Control Unit (DRCU)) plus a Digital Processing Unit (DPU) with interfaces to the other two boxes and the spacecraft data handling system. The DCU provides bias and signal conditioning for the detector arrays and cold readout electronics and reads out the detector signals. The FCU controls the FPU mechanisms and the ^{3}He cooler and handles housekeeping measurements. The DPU acts as the interface to the spacecraft, including instrument commanding and formats science and housekeeping data for telemetry to the ground.

4.4 HARDWARE DESCRIPTION

The SPIRE instrument consists of:

HSFPU	Cold Focal Plane Unit (FPU): This interfaces to the cryostat optical bench, and the 4-K and 2-K temperature stages provided by the cryostat. Within the unit, further cooling of the detector arrays to a temperature of around 300 mK is provided by a ^{3}He refrigerator which is part of the instrument.
HSFBP	JFET box for the photometer detectors This box is mounted on the optical bench next to the photometer side of the FPU and contains JFET preamplifiers for the detector signals. The JFETs operate at around 120 K, and are thermally isolated inside the enclosure.
HSFBs	JFET box for the spectrometer detectors This box is mounted on the optical bench next to the spectrometer side of the FPU and contains JFET preamplifiers for the detector signals. The JFETs operate at around 120 K, and are thermally isolated inside the enclosure.
HSDCU	Detector Read-out and Control Unit (on Herschel SVM) A warm analogue electronics box for detector read-out analogue signal processing, multiplexing, A/D conversion, array sequencing, mechanism control, temperature sensing and general housekeeping and ^{3}He refrigerator operation.
HSFCU	Focal Plane Control Unit (on Herschel SVM) A warm analogue electronics box for mechanism control, temperature sensing and general housekeeping and ^{3}He refrigirator operation.
HSDPU	Digital Processing Unit (on Herschel SVM) A warm digital electronics box for signal processing and instrument commanding and interfacing to the spacecraft telemetry.
HSWIH	Warm interconnect harness (on Herschel SVM) Harness making connections between the electronics boxes.

4.5 SOFTWARE DESCRIPTION

The OBS will carry out the following functions:

- Read and log housekeeping data
- Control and monitor the instrument mechanisms and internal calibration sources
- Carry out pre-defined observing sequences
- Implement pre-defined procedures on detection of instrument anomalies

The on-board software (OBS) will be written in “C” (TBC) language and will be designed to allow the instrument to operate in an autonomous fashion for 48 hours as required in the IID-A. The basic implication of this requirement is that there must be the facility to store enough commands for a 48 observing programme and enough mass memory on the satellite to store 48 hours of instrument telemetry. More sophisticated autonomy functions may include the on-board analysis of scientific or housekeeping data and the ability to react on the basis of that analysis. The type of automatic operation undertaken following such an analysis may range from the raising of a warning flag to the switching over to a redundant sub-system or the switching off of a defective sub-system. All autonomy functions will require extensive evaluation and test before they are implemented to avoid the possibility of instrument failure. No instrument autonomy mode will be implemented that will affect the satellite operation.

Memory load commands will be used to send single instructions to the instrument or to command pre-defined sequences of operations. The command words will be interpreted by the OBS according to a given algorithm and the relevant sequence of digital commands sent to the subsystems. Each command will be formed with a variable number of words having the following general structure: (i) a header describing the command function; (ii) the number of words to follow; (iii) the new values of the parameters, if any. There will be at least four types of commands: macro commands, subsystem commands, peek-and-poke commands; and spare commands. The macro commands define the timing and sequence of instrument operation. The subsystem commands allow the immediate control of each instrument subsystem. The peek-and-poke commands allow the down-link of RAM or ROM content as well as the ability up-link patches, new programmes or tables. There will also be the possibility to run new commands by up-linking the specific code in RAM recalled by the spare command.

A detailed description of the on-board software will be given in Chapter 5

4.6 OPERATING MODES

This section gives a brief description of the operating modes for the SPIRE instrument.

4.6.1 OFF Mode

All instrument sub-systems will be switched off - including the DPU and there will be no instrument telemetry.

4.6.2 Initialise (INIT) Mode

This is an intermediate mode between OFF and ON. This will be the mode the instrument enters after a power on or re-boot. In this mode only a limited sub-set of commands may be executed. This mode allows updates of DPU on-board software and/or tables to be carried out safely before they are used for instrument control.

4.6.3 ON Mode

The DPU will be switched on and can receive and interpret all instrument commands, but no other sub-systems will be switched on (including the DRCU). For engineering purposes it will be possible to command the instrument to switch on individual sub-systems from this mode. Full DPU housekeeping data will be telemetered.

4.6.4 Ready (REDY) Mode

The DPU and DRCU are powered on and the on-board software is ready to receive commands. No other sub-systems are switched on in this mode. DRCU housekeeping data will be telemetered.

4.6.5 Standby (STBY) Mode

The spacecraft may be pointed in an arbitrary direction (observing with another instrument for instance). The instrument will telemeter only housekeeping information, and perhaps some degraded science data -see below, at a rate very much lower than the full telemetry bandwidth. This is presently baselined to be the photometer detectors on and at 300 mK i.e. the cooler will have been recycled previous to entering STANDBY. All other sub-systems will be switched off.

4.6.6 Observe Mode (OBSV) Mode

There are two basic sub-modes for the observe mode Photometer and Spectrometer. The details of the OBSERVATIONS to be carried out in OBSERVE mode are given in section 4.7.

4.6.7 Cooler Recycle (CREC) Mode

The ^{3}He cooler requires recycling every 46 hours (TBC). During this time the instrument will be switched off except for vital housekeeping and cooler functions (TBC).

4.6.8 SAFE Mode

The instrument will be switched to SAFE mode in the event of any anomalous situation occurring whilst in autonomous operation. This will be with the DPU on having been rebooted from a restricted set of software stored in ROM.

4.7 OBSERVING MODES

The spacecraft will be pointed in a specific direction or, for mapping, will either slew slowly over a given region of the sky, or execute a raster pattern by movements of the telescope. The instrument will take scientifically meaningful data and use the full telemetry bandwidth. It is assumed that any calibrations required will also be done in the observe mode (TBC).

4.7.1 Photometer Observing Modes

The photometer can carry out essentially three kinds of observation: chopping, jiggling, and scanning, and it is envisaged that these will form the basis of three Astronomical Observation Templates (AOTs) to allow astronomers to specify their observations. The three kinds of observation are implemented as 6 (TBC) observing modes, named POFs (Photometer Observatory Functions), which are briefly described below. Provision is also made for additional POFs for peak-up and special engineering modes.

4.7.1.1 Observation: Point Source Photometry

POF1 Chop without jiggling:
This mode is for point source observations with reliable telescope pointing. The SPIRE Beam Steering Mechanism is used to chop between two positions on the sky

at a frequency of typically 2 Hz. The telescope may optionally be nodded with a nod period of typically three minutes.

POF2 Seven-point jiggle map:
This mode is for point source observations for which the telescope pointing or the source co-ordinates are not deemed sufficiently accurate. The SPIRE BSM chops and also executes a seven-point map around the nominal position. Nodding is optional.

4.7.1.2 Observation: Jiggle Map

POF3 n-point jiggle map:
This mode is designed for mapping of extended sources. It is similar to POF2 except that the nominal value of n is 64 rather than 7. It produces a fully sampled map of a 4 x 4 arcminute area.

POF4 Raster map:
This is the same as POF3 except that maps of large regions can be built up by using the telescope rastering capability.

4.7.1.3 Observation: Scan Map

POF5 Scan map without chopping:
This mode is used for mapping areas much larger than the SPIRE field of view. The SPIRE BSM is inactive, and the spacecraft is scanned continuously across the sky to modulate the detector signals.

POF6 Scan map with chopping:
This mode is the same as POF5 except that the SPIRE BSM implements chopping. It allows for the possibility of excess 1/f noise by permitting signal modulation at frequencies higher that POF5.

4.7.1.4 Others

POF7 Photometer peak-up (TBD):
This mode allows the necessary pointing offsets to be determined in order to allow implementation of POF1 rather than POF2. The observation itself is the same as POF3. On completion, the SPIRE DPU computes the offsets between the telescope pointed position and the source peak emission, and sends this information to the spacecraft, which can then implement the necessary pointing corrections.

POF8 Operate photometer calibrator:
The SPIRE photometer internal calibrator is energised with a pre-determined sequence and the corresponding detector signals are recorded.

POF9 Special engineering/commissioning modes (TBD).

4.7.2 Spectrometer Observing Modes

There are two kinds of spectrometer observation: point source and fully sampled map. The latter is carried out by repeating the former at a number of separate pointing using the SPIRE BSM (or, alternatively the spacecraft in RASTER Pointing mode). These are implemented as two Spectrometer Observatory Functions (SOFs):

SOF1: Point source spectrum
SOF2: Fully sampled spectral map

In all cases, the telescope pointing and/or Beam Steering Mirror position are kept fixed while the FTS mirror is scanned a predetermined number of times to generate interferograms from which the source spectrum can be derived.

4.7.3 Other Modes

4.7.3.1 Photometer Serendipity

During spacecraft slews scientifically useful information can be obtained without the necessity of using the focal plane chopper - essentially these are rapid scan maps. The chopper and spectrometer mechanisms will be switched off in this mode. Accurate pointing information will be required from the AOCS to reconstruct the slew path in the data analysis on the ground.

4.7.3.2 Photometer Parallel

When observations are being made with PACS, scientifically useful data may be obtainable from the photometer, albeit with degraded sensitivity and spatial resolution. In this mode a science data packet will be telemetered alongside the standard housekeeping data. The chopper and spectrometer mechanisms will be switched off in this mode. The feasibility and scientific desirability of this mode is TBD.

4.7.4 Real-Time Commanding

During ground contact it may be necessary to command the instrument in real time and analyse the resultant data on the ground in near real time for instrument testing and debugging purposes. In this case the full telemetry bandwidth will be required for the duration of the instrument test in question. It is not anticipated that this will occur frequently.

4.7.5 Commissioning/calibration Mode

During the commissioning and performance verification phases of mission operations, many housekeeping and other health check parameters will be unknown or poorly defined. This mode allows the limits on selected health check parameters to be ignored by whatever real time monitoring systems are in place on the spacecraft/instrument.

4.7.6 FPU operations at Ambient Temperature

TBD. It is anticipated that functional checks will be possible for mechanisms and housekeeping lines. The detectors will not function at ambient temperature. Limited verification of the readout electronics may be possible.

4.7.7 FPU Orientation

During ground tests the FTS mechanism can only operate when the FPU is on its side. In addition, there is a restriction on the orientation of the ^{3}He cooler during recycling.

4.8 INSTRUMENT REQUIREMENTS AND PERFORMANCE SPECIFICATION

4.8.1 Scientific Requirements

The scientific performance requirements for SPIRE are summarised in the *SPIRE Scientific Requirements Document* as follows:

Requirement SRD-R 1: The photometer should be capable of diffraction-limited extragalactic blind surveys of at least 60 sq. deg. of the sky, to 1-σ detection limit of 3 mJy in all bands with an observing time of six months or less.

Requirement SRD-R 2: The photometer should be capable of a galactic survey covering 1 deg. sq. to a 1-σ depth of 3 mJy at 250 μm within an observing time of one month or less.

Requirement SRD-R 3: Maximising the mapping speed at which confusion limit is reached over a large area of sky is the primary science driver. This means maximising sensitivity and field-of-view (FOV) but NOT at the expense of spatial resolution.

Requirement SRD-R 4: The photometer observing modes should provide a mechanism for telemetering undifferenced samples to the ground.

Requirement SRD-R 5: The photometer should have an observing mode that permits accurate measurement of the point spread function.

Requirement SRD-R 6: Optical field distortion should be less than 10% across the photometer field of view.

Requirement SRD-R 7: The photometer field of view shall be at least 4 x 4 arcminutes, with a goal of 4 x 8 arcminutes.

Requirement SRD-R 8: For 2Fλ feedhorns, crosstalk shall be less than 1% (goal 0.5%) for adjacent detectors and 0.1% or less (goal 0.05%) for all non-adjacent detectors in the same array; for 0.5Fλ pixels, the requirement is 5% (goal 2%) to adjacent detectors and 0.1% (goal 0.05%) to all others. (Note: This requirement is under review).

Requirement SRD-R 9: The maximum available chop throw shall be at least 4 arcminutes; the minimum shall 10 arcseconds or less.

Requirement SRD-R 10: The rms detector NEP variation across any photometer array should be less than 20%.

Requirement SRD-R 11: The photometer dynamic range for astronomical signals shall be 12 bits or higher.

Requirement SRD-R 12: SPIRE absolute photometric accuracy shall be 15% or better at all wavelengths, with a goal of 10%.

Requirement SRD-R 13: The relative photometric accuracy should be 10% or better with a goal or 5%.

Requirement SRD-R 14: SPIRE photometric measurements shall be linear to 5% over a dynamic range of 4000 for astronomical signals.

Requirement SRD-R 15: For feedhorn detectors, the overlapping sets of three detectors at the three wavelengths should be co-aligned to within 2.0 arcseconds on the sky (goal is 1.0 arcsecond).

Requirement SRD-R 16: The spectrometer design shall be optimised for optimum sensitivity to point sources, but shall have an imaging capability with the largest possible field of view that can be accommodated.

Requirement SRD-R 17: The sensitivity of the FTS at any spectral resolution up to the goal value shall be limited by the photon noise from the Herschel telescope within the chosen passband.

Requirement SRD-R 18: The spectrometer dynamic range for astronomical signals shall be 12 bits or higher.

Requirement SRD-R 19: The FTS absolute accuracy shall be 15% or better at all wavelengths, with a goal of 10%.

Requirement SRD-R 20: The FTS shall be capable of making spectrophotometric measurements with a resolution of 2 cm^{-1}, with a goal of 4 cm^{-1}.

Requirement SRD-R 21: The width of the FTS instrument response function shall be uniform to within 10% across the field of view.

Requirement SRD-R 22: The maximum spectral resolution of the FTS shall be at least 0.4 cm^{-1} with a goal of 0.04 cm^{-1}.

Requirement SRD-R 23: The SPIRE photometer shall have an observing mode capable of implementing a 64-point jiggle map to produce a fully sampled image of a 4 x 4 arcminute region.

Requirement SRD-R 24: The photometer observing modes shall include provision for 5-point or 7-point jiggle maps for accurate point source photometry.

Requirement SRD-R 25: The photometer shall have a "peak-up" observing mode capable of being implemented using the beam steering mirror.

4.1.2 Instrument Performance Estimates

4.1.2.1 Assumptions

The sensitivity of SPIRE has been estimated under the assumptions listed in Table 4.1.

Table 4.1: Assumptions for SPIRE Performance Estimation

Telescope temperature (K)	80		
Telescope emissivity	0.04		
Telescope used diameter (m) (1)	3.29		
No. of observable hours per 24-hr period	21		
Photometer			
Bands (µm)	250	350	500
Numbers of detectors	139	88	43
Beam FWHM (arcsec.)	17	24	35
Bolometer DQE (2)	0.6	0.7	0.7
Throughput	λ^2		
Bolometer yield	0.8		
Feed-horn/cavity efficiency (3)	0.7		
Field of view (arcmin.) Scan mapping	4 x 8		
Field mapping	4 x 4		
Overall instrument transmission	0.3		
Filter widths ($\lambda/\Delta\lambda$)	3.3		
Observing efficiency (slewing, setting up, etc.)	0.9		
Chopping efficiency factor	0.45		
Reduction in telescope background by cold stop (4)	0.8		
FTS spectrometer			
Bands (µm)	200-300	300-670	
Numbers of detectors	37	19	
Bolometer DQE	0.6	0.7	
Feed-horn/cavity efficiency	0.70		
Field of view diameter (arcmin.)	2.6		
Max. spectral resolution (cm^{-1})	0.04		
Overall instrument transmission	0.15		
Signal modulation efficiency	0.5		
Observing efficiency	0.8		
Electrical filter efficiency	0.8		

Notes:

1. The telescope secondary mirror is the pupil stop for the system, so that the outer edges of the primary mirror are not seen by the detectors. This is important to make sure that radiation from highly emissive elements beyond the primary reflector does not contribute stray light.
2. The bolometer DQE (Detective Quantum Efficiency) is defined as : $[NEP_{ph}/ NEP_{Total}]^2$, where NEP_{ph} is the photon noise NEP due to the absorbed radiant power and NEP_{Total} is the overall NEP including the contribution from the bolometer noise.
3. This is the overall absorption efficiency of the combination of feed-horn, cavity and bolometer element.
4. A fraction of the feedhorn throughput falls outside the solid angle defined by the photometer 2-K cold stop and is thus terminated on a cold (non-emitting) surface rather than on the 4% emissive 80-K telescope. This reduces the background power on the detector.

The background power levels on the SPIRE detectors dominated by the telescope emission), and the corresponding photon noise limited NEP values are given in Table 4.2.

Table 4.2: Background Power and Photon Noise Levels

		Photometer			**FTS band (mm)**	
		250	350m	500	200-300	300-670
Background	pW	3.9	3.2	2.0	6.0	11
Background-limited NEP	W $Hz^{-1/2}$ x 10^{-17}	8.1	6.1	4.5	10	11
Total NEP (inc. detector)	W $Hz^{-1/2}$ x 10^{-17}	10	7.3	5.4	12	14

The estimated sensitivity levels for SPIRE are summarised in Table 4.3. The figures quoted are the nominal values, with an overall uncertaintyof of around 50% to take into account uncertainties in instrument parameters, particularly feedhorn efficiency, detector DQE, and overall transmission efficiency. The pixel size will be increasingly mis-matched to the diffraction spot size. The trade-off between wavelength coverage and sensitivity of the long-wavelength FTS band must be studied in detail. At the moment, we estimate an effective loss of efficiency of a factor of two at 670mm, and scale linearly for wavelengths between 400 and 670 mm. Performance beyond 400 mm may have to be compromised to maintain the desired sensitivity below 400 mm.

Table 4.3: SPIRE Estimated Sensitivity

Photometry					
λ	µm		250	350	500
ΔS(5-σ; 1-hr)	mJy	Point source (7-point)	2.5	2.6	2.9
		4’ x 4’ jiggle map	8.8	8.7	9.1
		4’ x 8’ scan map	7.3	7.2	7.5
Time (days) to map 1 deg.^{2} to 3 mJy		1^{o} x 1^{o} scan map	1.8	1.7	1.9

Line spectroscopy **Ds = 0.04 cm^{-1}**					
λ	µm		200	400	670
ΔS (5-σ; 1-hr)	W m^{-2} x 10^{-17}	Point source	3.4	3.9	7.8
		2.6’ map	9.0	10	21

Low-resolution spectrophotometry **Ds = 1 cm^{-1}**					
λ	µm		200	400	670
ΔS (5-σ; 1-hr)	mJy	Point source	110	130	260
		2.6’ map	300	350	700

Note: For the FTS, limiting flux density is inversely proportional to spectral resolution (Δσ). Limiting line flux is independent of spectral resolution (for an unresolved line).

These estimated sensitivity levels are comparable to the figures in the SPIRE proposal.

5 INTERFACE WITH SATELLITE

Spacecraft resource allocations are based on present knowledge.

5.1 IDENTIFICATION AND LABELLING

Each individual instrument unit is allocated two unique identification codes:

- a *project code* which is the normal reference used for routine identification in correspondence and technical descriptive material.
- a *spacecraft code* finalised by the spacecraft contractor in accordance with the computerised configuration control system to be implemented, and used in particular for connector and harness identification purposes. All of these have now been given a working designation anyway as work has progressed. The *project code* shall form part of the spacecraft code. (See IID-A section 5.1)

The project codes allocated to this instrument are:

Project code	Instrument unit	Location	Temperature
FSDPU	FS Digital Processing Unit	On SVM	Warm
FSFCU	FS FPU Control Unit	On SVM	Warm
FSDCU	FS Detector Control Unit	On SVM	Warm
FSJFS	FS JFETs(Spectrometer)	See section 5.3	Cryogenic
FSJFP	FS JFETs(Photometer)	See section 5.3	Cryogenic
FSFPU	FS Focal Plane Unit	See section 5.3	Cryogenic

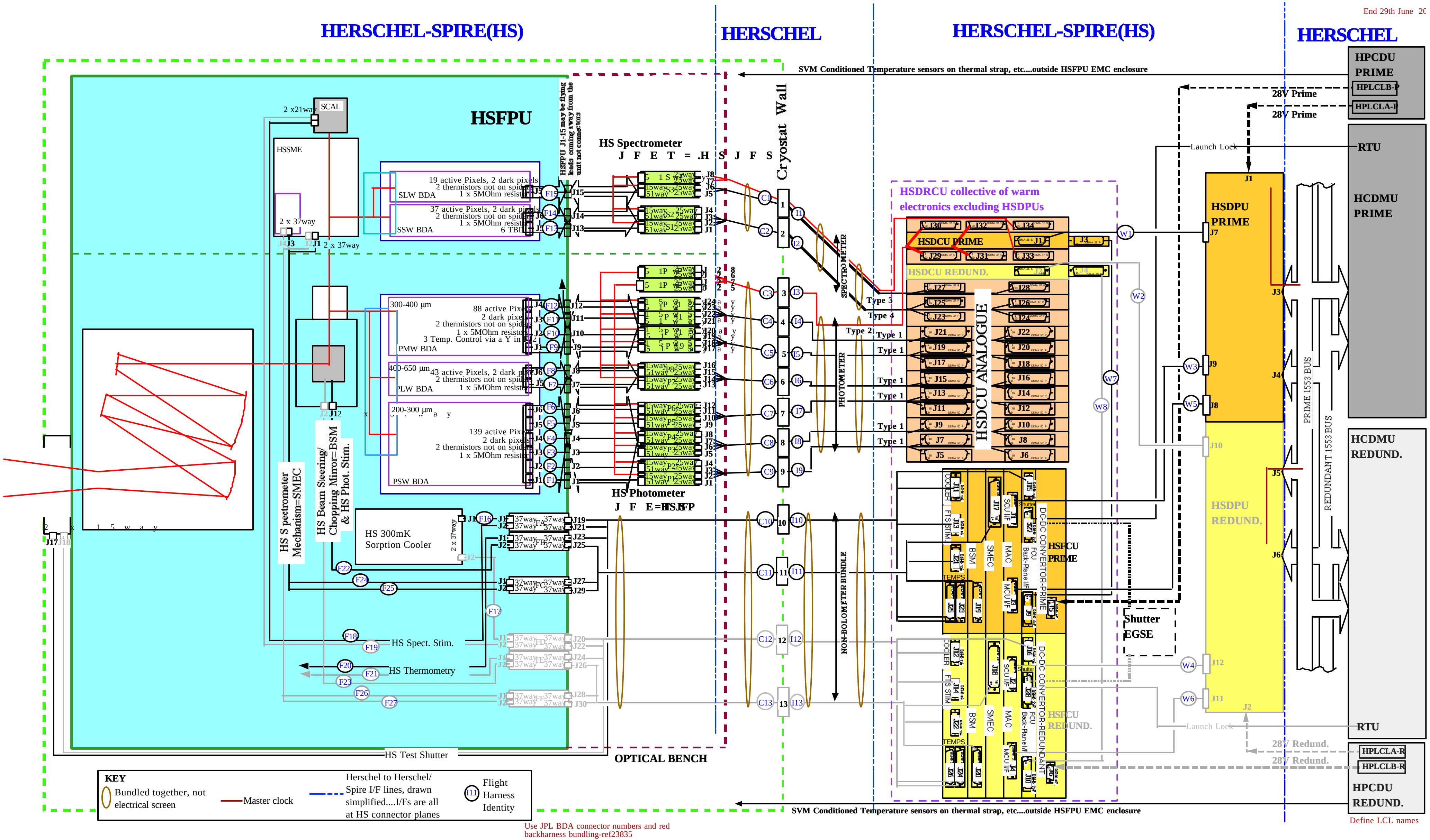
The FSFCU is a physical unit containing two functions, the FSSCU and the FSMCU meaning the FS Sub-System Control Unit and the FS Mechanisms' Control Unit respectively.

[Documentation may refer to a DRCU or Detector Readout and Control Unit. This is no longer a single unit and the term refers collectively to the FSDCU plus the FSFCU.]

There are three groups of harnesses at instrument interface level, FSWxx, FSIxx and FSCxx where xx represents a number. The FSWxx are Warm harnesses between Warm FS units on the SVM. The FSIxx are Intermediate harness external to the cryostat between the vacuum connectors and the FS Warm Units. The FSCxx are cryogenic harness internal to the cryostat between the vacuum connectors and the FS Cryogenic units.

5.2 INTERFACE LOCATIONS

All of the above is best visualised as a block diagram, see figure 5.2.1. The Herschel to Herschel-**Spire** electrical interfaces are in several "planes" shown by dashed blue lines, the categories between each line being labelled along the top.
Note that, to be precise, these electrical interfaces are at the connector planes.



Spire Block Diagram Figure 5.2.1

5.2.1 MECHANICAL COORDINATE SYSTEM

The unit specific x,y,z origin definitions are shown in the External Configuration Drawings. (see section 5.4)

5.3 LOCATION AND ALIGNMENT

Figures 5.3-1 and 5.3-2 show the concept of the location of the three Herschel Focal Plane Units (FPUs) for HIFI, PACS and **Spire** on the Optical Bench (OB) inside the cryostat. The **Spire** FPU has two closeby JFET racks. This accommodation may be subject to detailed evolution.

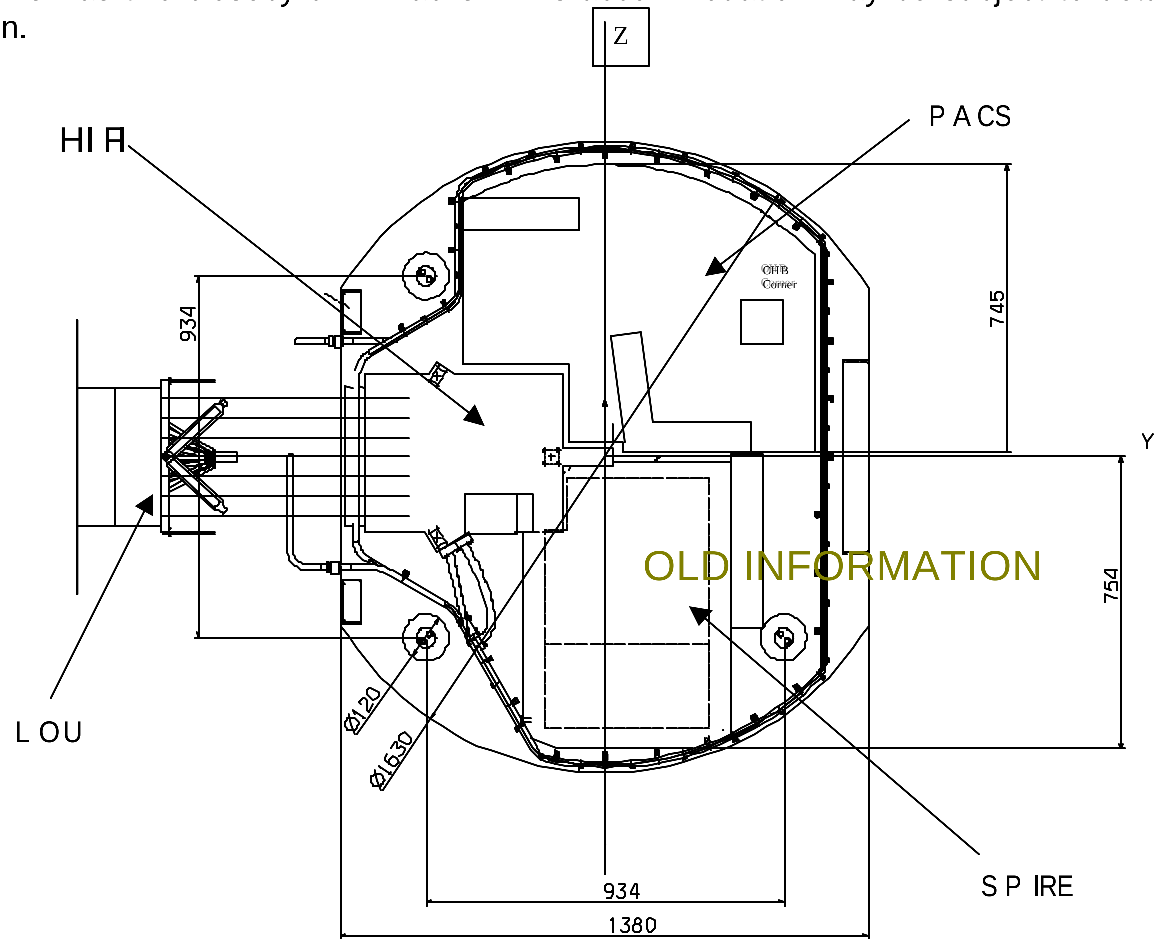


Figure 5.3-1: The Herschel Focal Plane, top view towards -X

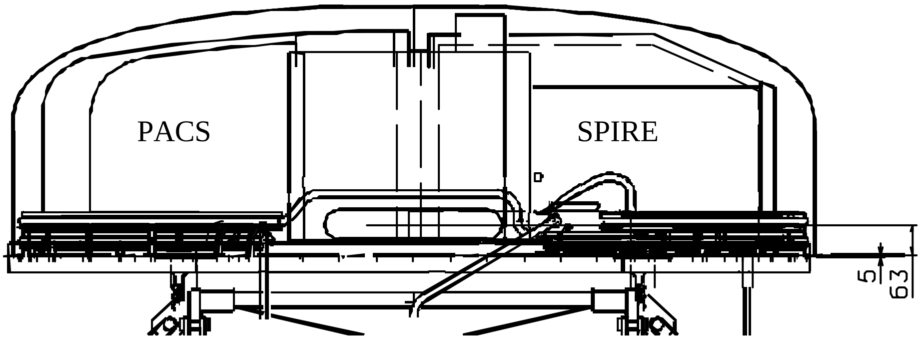


Figure 5.3-2: The Herschel Focal Plane, side view towards +Y

5.3.1 Instrument Location

The locations of the **Spire** units are as listed in section 5.1. **Spire** has no units supported on the outside of the Herschel cryostat or on the Planck Module. There are no critical alignment requirements on the **Spire** JFET boxes.

5.3.1.1 Location of units on the SVM

There are no specific requirements for the location of **Spire** units on the SVM, except that the DRCU needs optimised harness routing towards the **Spire** quadrant of cryostat 100way connectors. ESA is asked to advise the **Spire** Instrument consortium of harness and unit position definitions and 100way type at the earliest date, for comment and for them be recorded herein. The length of the instrument provided harness between the two units of the DRCU, the FSDCU and the FSFCU is critical and shall not exceed tbd.

5.3.2 Instrument Alignment on the HOB

Spire has no critical alignment and/or alignment stability requirements except for those of the FSFPU.

The FSFPU has an externally viewable alignment cube as shown on its ICD. Both the cube's angular alignment and the position of the FSFPU box' feet w.r.t. its internal optics will have been established at instrument level to a defined tolerance before delivery to ESA.

The mechanical process of mounting **Spire** on the HOB so that it is aligned to the Herschel telescope (when both are at operating temperature) is worked through in AD (tbd). This defines an error budget for how well the alignment has to be achieved, as well as how stable it then has to remain.

5.4 EXTERNAL CONFIGURATION DRAWINGS

These are included for information only. They are all controlled **Spire** drawings at their latest issue.

5.4.1 FSFPU

Figure 5.4-1 shows drawings for the FSFPU and FSJFS/JFP inside the cryostat and their relationship to the Herschel focal plane, to the cryostat radiation shield and to the diameter of the HOB. The location of both of the JFET racks will need to be optimised to provide short cable lengths to the detectors in the FPU (the reason for their existence) and good routing from their opposite faces for the cryoharness feeds.

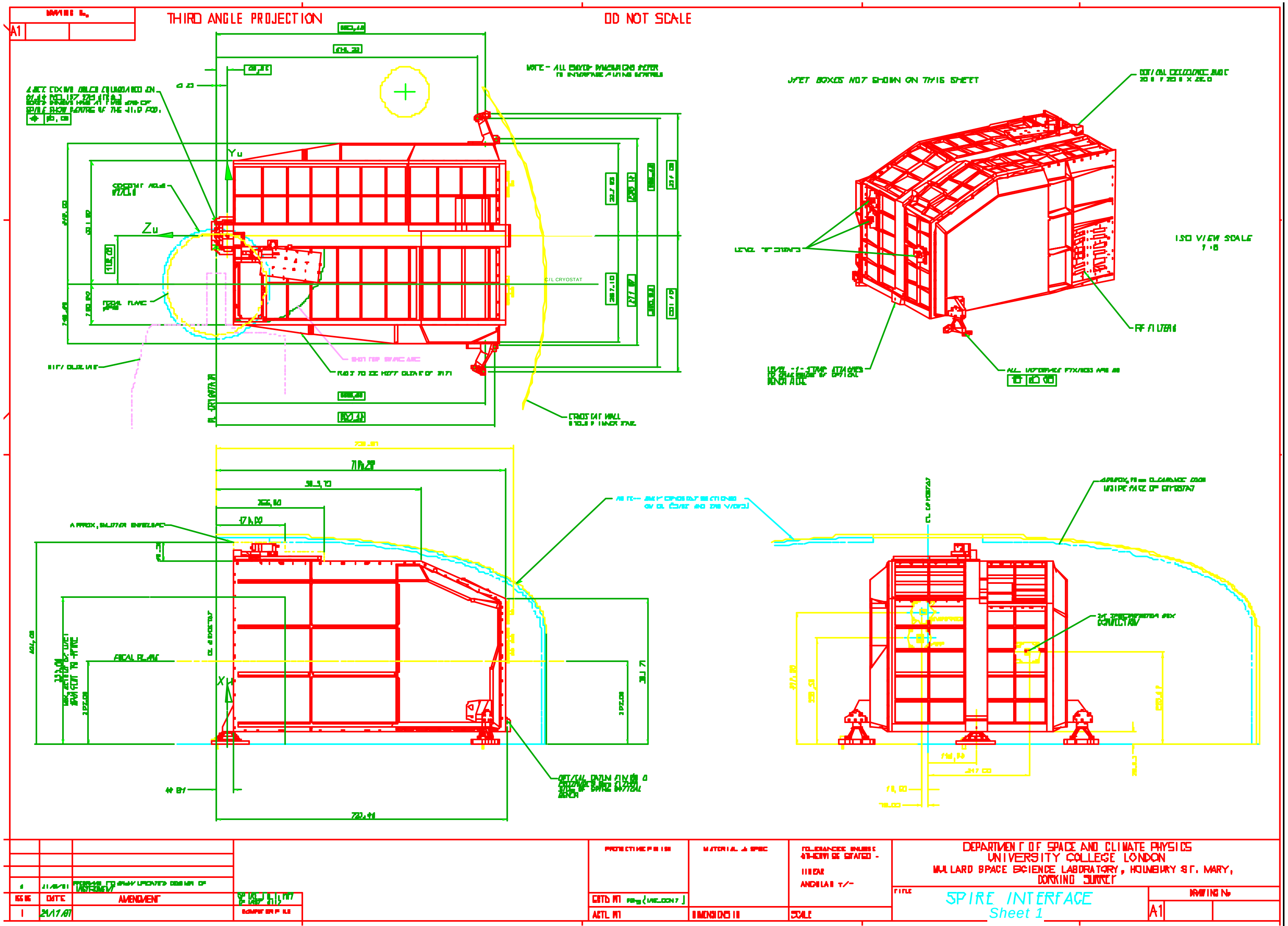


Figure 5.4-1a: **Spire** Focal Plane Unit…..sheet 1

Spire cold harness routing added but NOT agreed.

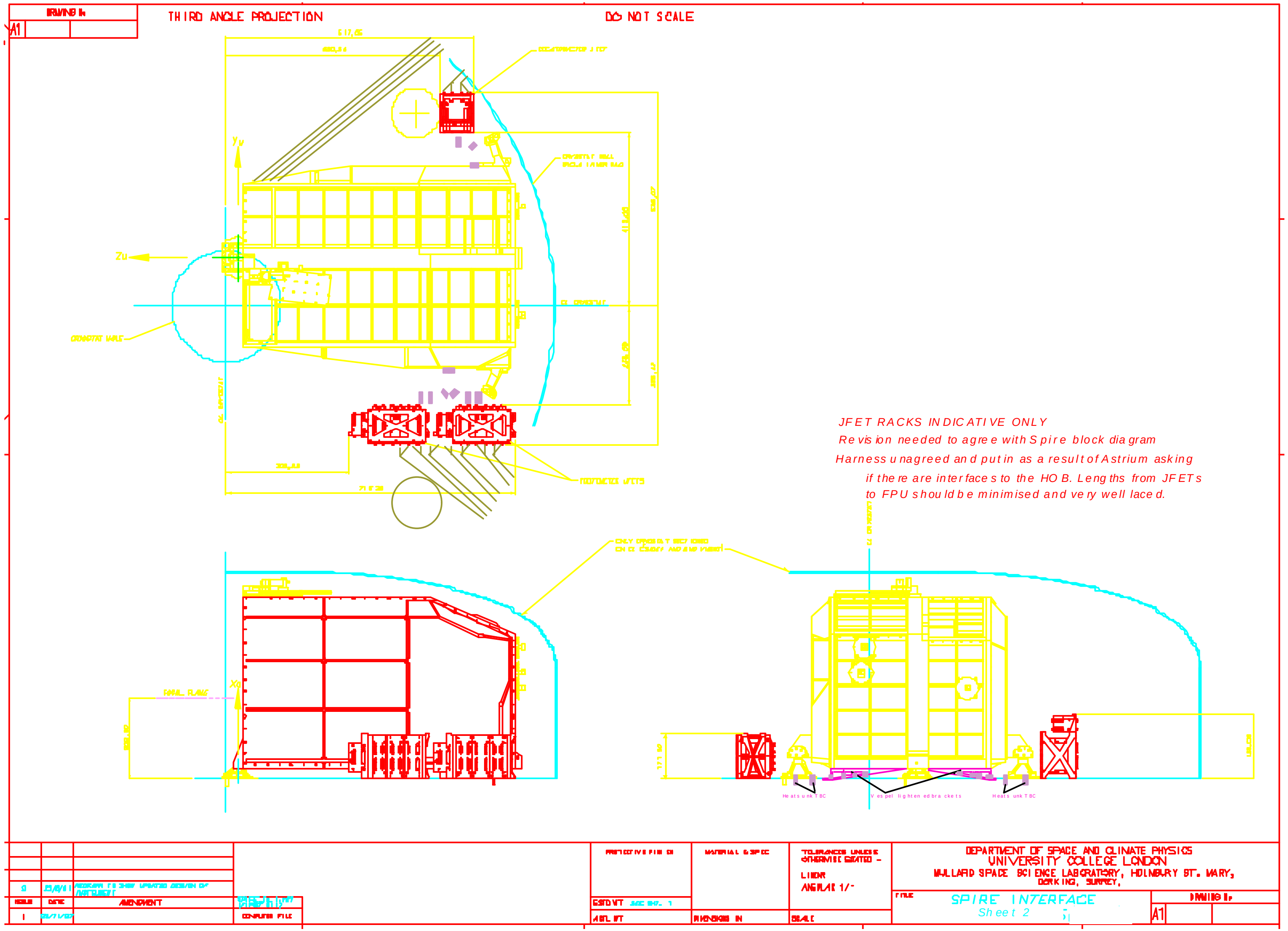


Figure 5.4-1b: **Spire** Focal Plane Unit….sheet 2. The position and size of the JFET boxes is indicative only.

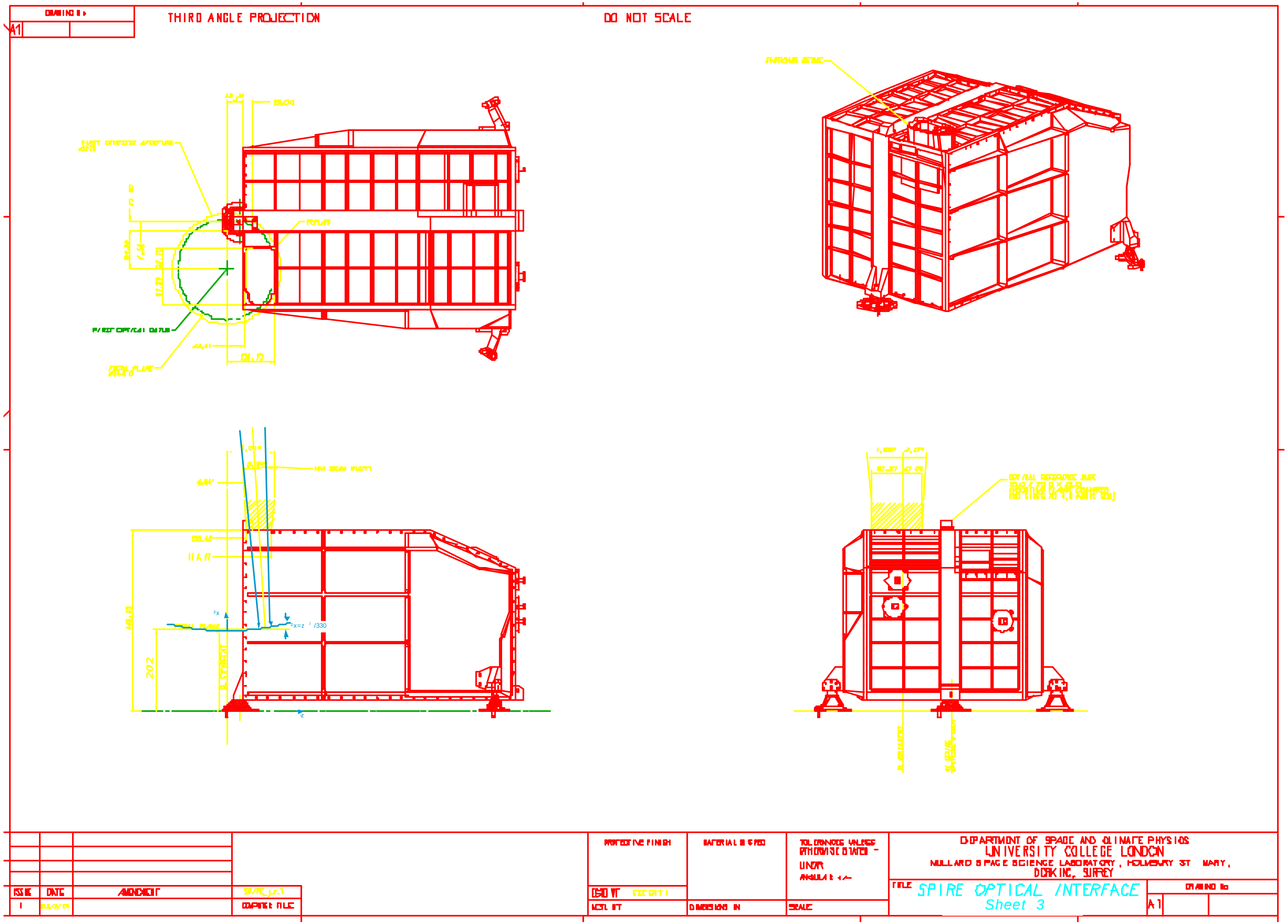


Figure 5.4-1c: **Spire** Focal Plane Unit….sheet 3

5.4.2 FSJFS

Figure 5.4-3 shows the external configuration drawing for the **Spire** Spectrometer JFET rack (TBW).

5.4.3 FSJFP

Figure 5.4-4 shows the external configuration drawing for the **Spire** Photometer JFET rack (TBW).

5.4.4 SVM Mounted Units.

Figure 5.4-5 provides the layout of the SPIRE units on the SVM

Figure 5.4-5 **Spire** SVM mounted units and the SPIRE warm interconnect harness

5.4.4.1 FSDPU

Figure 5.4-6 shows the external configuration drawing for the **Spire** Digital Processing Unit (TBW).

5.4.4.2 FSDCU

Figure 5.4-7 shows the external configuration drawing for the **Spire** Detector Control Unit (TBW).

5.4.4.3 FSFCU

Figure 5.4-8 shows the external configuration drawing for the **Spire** FPU Control Unit(TBW).

5.5 SIZES AND MASS PROPERTIES

The mass budget is identified as a critical issue and is currently under evaluation, with the aim to gain the margins adequate for this stage of the design phase (i.e. 15-20%). An increase of the allocation is not agreed with ESA nor Alcatel.

The table below shows for each unit its size, nominal mass (i.e. current estimate, excluding margins) and the allocated mass. With a total mass allocation of 90kg, the current overall margin for SPIRE is 5%.

Sizes are given in section 5.4.

Project Code	**Instrument unit**	**Dimensions [mm]**	**Nominal Mass [kg]**	**Allocated Mass [kg]**
FSFPU	Cold Focal Plane Unit	s. envelope figure 5.4-1	46.1	48.5
FSJFS/P	JFET Boxes	s. envelope figure 5.4-1	6.4	7.5
	Total Optical Bench units		52.5	56.0
FSFCU/ FSDCU	DRCU	180 x 480 x 200 (TBC)	23	
FSDPU	DPU	240 x 274 x 200 (TBC)	7.0	
FSW1-8	Harness		2.0	
	Total SVM units		32.0	34.0
Total			84.5	90.0

* Dimensions are given as Length x width x height. Length and Width define the fixation baseline

5.6 MECHANICAL INTERFACES

5.6.1 Inside cryostat

The Focal Plane Unit, the FSFPU, has 3 supporting feet to the Optical Bench. The details of this mechanical interface will be such as to allow the unit alignment and alignment-stability requirements to be fulfilled.

The **Spire** JFET racks will also mechanically interface directly to the Optical Bench.

To fulfil **Spire**'s grounding requirements, the FSFPU and both JFET racks need to be electrically isolated from the Optical Bench at their mechanical mounting points. The same applies to the bolometer system harness screens.

5.6.1.1 Microvibration

Spire's mechanisms (SMEC and BSM), not just the bolometer system itself, are sensitive to µ-vibrations. The maximum permissible input acceleration input by Herschel to the FPU HOB interface is 10µg peak, a level which is TBC and probably will be amended to a function that depends on frequency.

This needs further detailed analysis and the level is not agreed with ESA nor Alcatel.

5.6.1.2 Thermal Straps

The mechanical I/F geometry, fixing torque, etc. for each of these straps is as baselined in the IIDA. See section 5.4 for positions on **Spire** and section 5.7 for more details. The thermal straps will be steadied by non-metallic **Spire** A-frames on the outside of the FPU, designed to minimise the forces the straps can apply to thermal leadthroughs, but not be Ohmic shorts.

5.6.2 Outside Cryostat

NA

5.6.3 On SVM

The three units mounted on the SVM will each have 6 or 8 attachment points for fixation to the equipment platform, as shown in their External Configuration Drawings. Interface flatnesses, fasteners and tightening torques are all defined on these drawings.

The **Spire** warm harness will attach to the SVM via TBD ESA provided holddown ties.

5.6.4 On Planck Payload Module

NA

5.6.5 Cooler valves and piping

NA

5.7 THERMAL INTERFACES

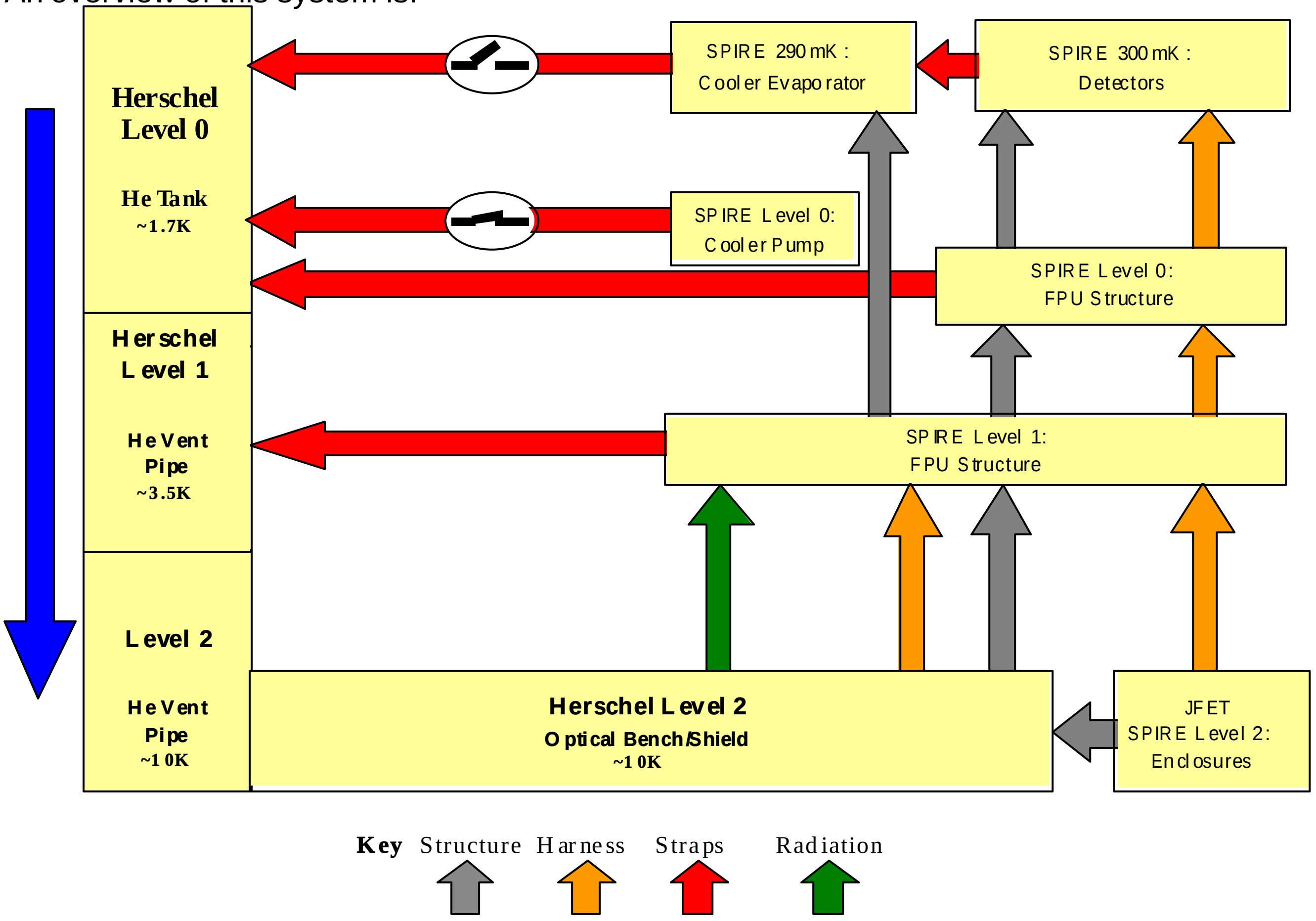
The cryogenic interfaces are the most important category of interfaces for **Spire** 's success, and the most complicated. They would provide the most gain to science performance from being somewhat improved.

5.7.1 Inside cryostat

The various instrument stages require straps to 3 different temperatures. The cryostat shall provide:

Level 0:	He tank for temperatures at the < 2 K
Level 1:	He vent-line at < 6 K
Level 2:	He vent-line at about <15 K which may be achieved by conduction to the HOB.

An overview of this system is:



5.7.1.1 Thermal Straps for ^{3}He Cooler

Operation of the **Spire** ^{3}He cooler requires that it is recycled by heating the sorption pump to ~40-K whilst the evaporator is kept at 1.7-K, thus condensing the ^{3}He into the evaporator. The temperature of the evaporator during condensation is critical to the overall efficiency of the cooler.

At the end of the condensation phase the heat switch on the sorption pump is turned ON and the switch on the evaporator is turned OFF. Then there is a substantial peak power from the sorption pump to the cryostat as it re-cools via the strap. This peak power and associated energy will not have any significant impact on the cryostat LHe tank. However it will have a significant temporary impact on the thermal gradient along the strap.

There are two straps from the cooler to separate points on the LHe tank, one for the sorption pump and one for the evaporator. In this way, during normal operation, the temperature of the evaporator strap will remain at $T_{bath}+\Delta T$ (as small as possible), leading to a good condensation efficiency and less ^{3}He lost during the cooldown from 1.7 K to 0.3 K. The sorption pump will still operate properly even if the "hot" end of its strap rises momentarily to as much as 10 K.

The **Spire** FPU provides two Level 0 thermal strap interfaces to the ^{3}He cooler. It also provides a third, separate, Level 0 strap interface for its 1.8K optical box structures which are interconnected internally so as to have just one instrument external I/F.

5.7.1.2 Requirements on Strap I/F temperatures

Spire interfaces require to be adequately cooled by HERSHEL Level 0 straps. The straps shall have at least the following conductances seen at the **Spire** I/F plane, and act towards a sink at 1.7Kelvin:

Strap	Conductance	Nominal Heatflow
Enclosure	0.05 Watts/Kelvin	1 to 3mW
Cooler Pump	0.05 Watts/Kelvin	0.25 to 1.8mW
Cooler Evaporator	0.1Watts/Kelvin	0.25 to 0.6mW

where the reason for including the heatflow is that it will change the temperature of the warm ends and hence the straps' conductivity.

The Level 1 FSFPU strap shall have a conductance of >0.05Watts/Kelvin. In this case the sink is to an HE boil-off pipe, so the cooling delivered to the **Spire** interface is not guaranteed by the strap conductance alone. At a worst case load of 18.25mWatts, which is a value **Spire** is presently trying not to need, this strap's equilibrium interface temperature shall remain <5Kelvin. With the specified conductance value, this corresponds to the nominal 3.5Kelvin level 1 boil-off pipe being raised to 4.63K

We ought to note that instrument performance would benefit if these were improved.

No FSJFS or FSJFP straps are listed because the present design uses direct mounting conduction to the HOB, so they are not fitted, TBC.

5.7.1.3 Worst case temperatures

The cryogenic units must withstand the full thermal environment given in the IIDA, including repeated max. 72hr. 80°C bakeouts and indefinite 60°C soak.

5.7.2 Outside Cryostat

NA

5.7.3 On SVM

The table below shows the required operating temperatures at the interface of the instrument unit with a mounting platform or parts thereof:

Project code	Operating		Start-up	Switch-off	Non-operating	
	Min. ^{0}C	Max. ^{0}C	^{0}C	^{0}C	Min. ^{0}C	Max. ^{0}C
FSDPU	- 15	+ 45	- 30	+ 50	- 35	+ 80
FSFCU	- 15	+ 45	- 30	+ 50	- 35	+ 80
FSDCU	- 15	+ 45	- 30	+ 50	- 35	+ 80

Note:
Acceptance temperature range is from 5 ^{0} C below min. to 5 ^{0}C above max. operating temp.
Qualification temperature range is from 10 ^{0} C below min. to10 ^{0} C above max. operating temp.

During nominal operation in-flight, the SVM units will not move at more than 3K/hour.

Spire units will use the SVM as a thermal I/F, without formal isolation, to help stabilise the temperature of unpowered sections and absorb dissipated heat when powered by conduction. The units have an alochromed aluminium general surface finish. If it is found that other arrangements are needed, such as low temperature limit thermostatted heaters, these shall be external and Herschel furnished. If details are determined on timescales that can be accommodated, **Spire** will build in minimal necessary mounting arrangements for such systems, TBC.

5.7.4 On Planck Payload Module

NA

5.7.5 Temperature channels

5.7.5.1 Instrument Temperature Sensors

The table below shows the measurement of instrument cryogenic temperatures. These data are available in DPU packets (unless otherwise indicated) via whichever is powered of the prime and redundant sides of the **Spire** electronics.

Each side uses different, electrically isolated sensors and will therefore have subtlety differing electrical to temperature calibrations. Note that the accuracy columns that follow refer to the performance of the complete system including cryoharness and electronics, not the sensors alone. "Resolutions" and "Accuracy" will need to be further defined as they are actually temperature dependant.

Regarding Cernox sensors, the logic is that type CX-1030 is used for the 300 mK stage, CX-1050 for accurate measurement at <10 Kelvin and CX-1070 for monitoring the temperature during cooldown.

Location IN HSFPU	Acronym	Sensor Type	Temp. Range	Resol-ution TBC	Acc. TBC
200-300 µm PSW BDA	T_PSW_1	NTD Ge Thermistor*	0.2 K>5 K	TBD	TBD
200-300 µm PSW BDA	T_PSW_2	NTD Ge Thermistor	0.2 K>5 K	TBD	TBD
300-400 µm PMW BDA	T_PMW_1	NTD Ge Thermistor	0.2 K>5 K	TBD	TBD
300-400 µm PMW BDA	T_PMW_2	NTD Ge Thermistor	0.2 K>5 K	TBD	TBD
400-650 µm PLW BDA	T_PLW_1	NTD Ge Thermistor	0.2 K>5 K	TBD	TBD
400-650 µm PLW BDA	T_PLW_2	NTD Ge Thermistor	0.2 K>5 K	TBD	TBD
SSW BDA	T_SSW_1	NTD Ge Thermistor	0.2 K>5 K	TBD	TBD
SSW BDA	T_SSW_2	NTD Ge Thermistor	0.2 K>5 K	TBD	TBD
SLW BDA	T_SLW_1	NTD Ge Thermistor	0.2 K>5 K	TBD	TBD
SLW BDA	T_SLW_2	NTD Ge Thermistor	0.2 K>5 K	TBD	TBD
300mK Thermal Cntrl_1	TBD	NTD Ge Thermistor	0.2 K>5 K	0.05mK	0.2mK
300mK Thermal Cntrl_2	TBD	NTD Ge Thermistor	0.2 K>5 K	0.05mK	0.2mK
300mK Thermal Cntrl_3	TBD	NTD Ge Thermistor	0.2 K>5 K	0.05mK	0.2mK
Photometer/Spectrometer Level 0 box	TBD	CX-1030	1K>10K	2mK	2mK
BSM/SOB I/F	TBD	CX-1030	3K>300K	50mK	100mK
Optical Sub-bench	TBD	CX-1030	1K>10K	2mK	2mK
Input Baffle	TBD	CX-1030	3k>20K	10mK	10mK
SMEC Mechanism	TBD	CX-1030	3k>20K	10mK	10mK
SMEC/SOB Interface	TBD	CX-1030	3K>100K	25mK	50mK
SPEC Calibrator Source	TBD	CX-1030	3K>80K	5mK	5mK
SPEC Calibrator Chassis	TBD	CX-1030	3K>80K	5mK	5mK
Cooler Pump	TBD	CX-1030	1K>50K	10mK	10mK
Cooler Evap.	TBD	CX-1030	0.2 K>5 K	1mK	1mK
Cooler Shunt.	TBD	CX-1030	0.2 K>5 K	1mK	1mK
Cooler Pump heat switch	TBD	CX-1030	1K>50K	10mK	10mK
Cooler Evap. heat switch	TBD	CX-1030	1K>50K	10mK	10mK
BSM Mechanism	TBD	CX-1030	3k>20K	10mK	10mK
Spect JFET chassis	TBD	CX-1030	3K>100K	25mK	50mK
Phot JFET chassis.	TBD	CX-1030	3K>100K	25mK	50mK

*NTD Ge Thermistor is equivalent to a detector element, but it is not mounted on an isolating web.

5.7.5.2 Shutter Temperature Sensors

Handled by EGSE, not FCU/DPU, and therefore included here only for completeness. Not available for flight.

Location IN FSFPU	Acronym	Sensor Type	Temp. Range	Resol-ution	Acc.
Shutter Vane-A	TBD	CX-1070, TBC	3K>80K	5mK	10mK
Shutter Vane -B *	TBD	CX-1070, TBC	3K>80K	5mK	10mK
Shutter Actuator-A *	TBD	CX-1070, TBC	3K>120K	25mK	500mK
Shutter Actuator-B *	TBD	CX-1070, TBC	3K>120K	25mK	500mK

5.7.5.3 Satellite Temperature sensors

In addition to the **Spire** conditioned temperature channels, **Spire** requires that Herschel itself shall monitor the temperatures of certain locations on the cryostat and SVM. These are given in the table below.

Location	Sensor Type	Temp. Range	Acronym	Resol-ution*	Acc.
Level 0 Strap A to cooler	ESA TBD	1.5K to 90°C	TBD	10-500mK	TBD
Level 0 Strap B to cooler	ESA TBD	1.5K to 90°C	TBD	10-500mK	TBD
Level 0 Strap to HFSFPU 1.8k boxes	ESA TBD	1.5K to 90°C	TBD	10-500mK	TBD
Level 1 strap to FSFPU	ESA TBD	1.5K to 90°C	TBD	10-500mK	TBD
FSJFS mounting temperature	ESA TBD	1.5K to 90°C	TBD	10-500mK	TBD
FSJFP mounting temperature	ESA TBD	1.5K to 90°C	TBD	10-500mK	TBD
HOB at FSFPU centre foot	ESA TBD	1.5K to 90°C	TBD	10-500mK	TBD
HOB at FSFPU +Y foot	ESA TBD	1.5K to 90°C	TBD	10-500mK	TBD
HOB at FSFPU -Y foot	ESA TBD	1.5K to 90°C	TBD	10-500mK	TBD
Centre SPIRE SVM panel.	ESA TBD	-80 to 90°C	TBD	0.4K	1K

*Lower values applies at bottom end of range. When hot, accuracy requirement is much less stringent.

The precise number an location of these sensors shall be confirmed after thermal modelling.

Herschel shall check temperatures are within range, and for instance not empower SVM units outside of their rated operating ranges.

5.8 OPTICAL INTERFACES

Spire's only optical interface is that toleranced in section 5.3.2. The instrument's optical design is now frozen and well analysed, see AD xxxx.

For information, figures 5.8-1, 5.8-2, 5.8-3,5.8-4 and 5.8-5 show the **Spire** optical beam envelope at various places through the path from the telescope focal plane to the hole in the Herschel primary mirror. No structure or other material is allowed within the envelope defined by these “footprints.

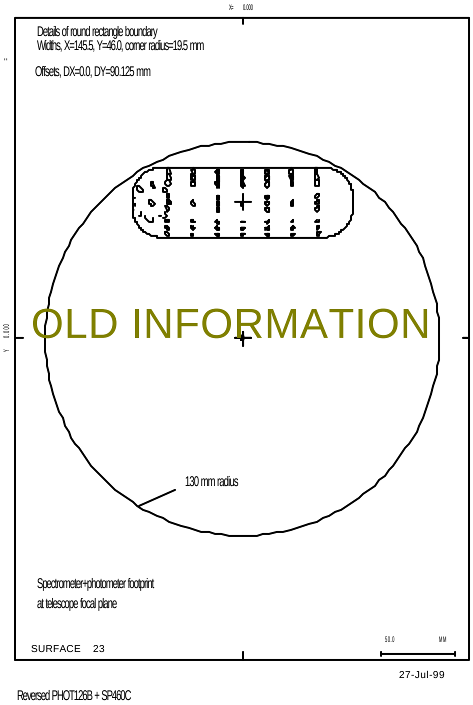


Figure 5.8-1 **Spire** optical beam envelope.
at the telescope focal plane.

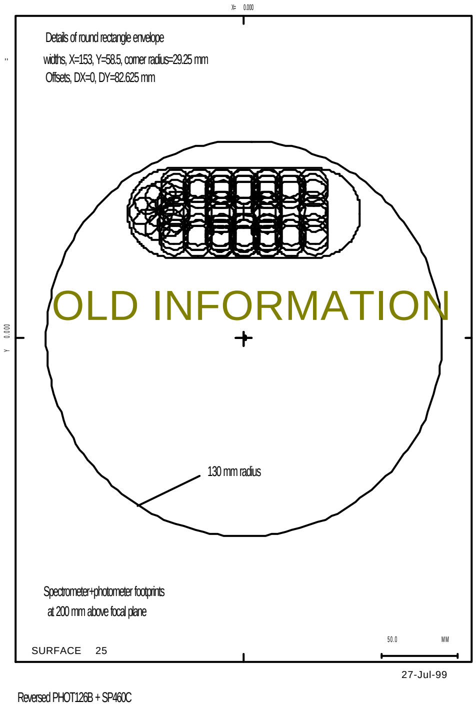


Figure 5.8-3 **Spire** optical beam envelope at 200 mm above telescope focal plane.

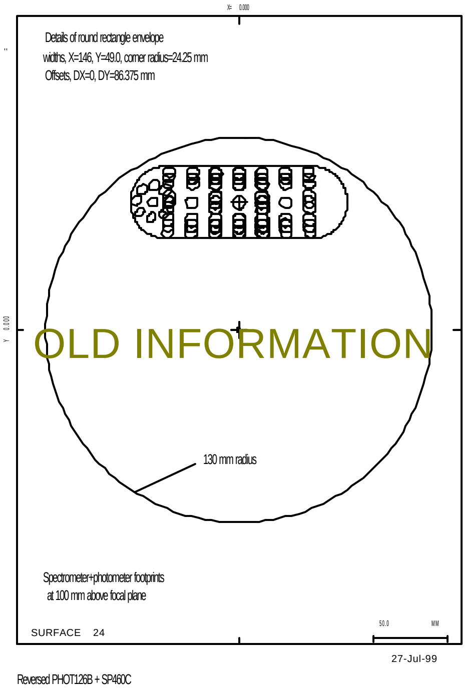


Figure 5.8-2 **Spire** optical beam envelope at 100 mm above telescope focal plane.

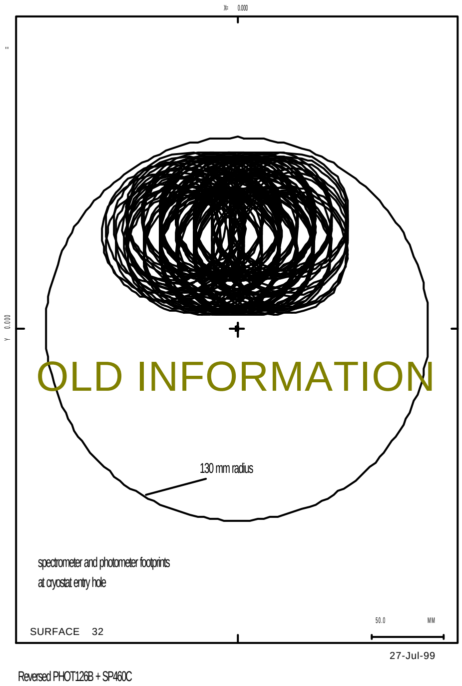


Figure 5.8-4 **Spire** optical beam envelope at the exit hole from the Herschel cryostat.

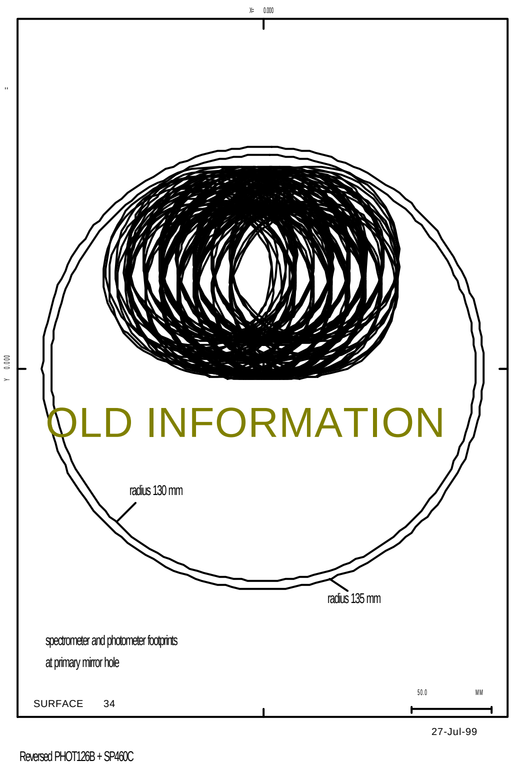


Figure 5.8-5 **Spire** optical beam envelope at the hole in the Herschel telescope primary mirror

Note that the spectrometer's used beam lies next to that of the photometer although more off-axis, and that optically both are illuminated simultaneously although they then view different places on the sky; beam switching is not used.

The above diagrams will shortly be updated, but the implications are already accounted for.

5.8.1 Straylight

The instrument straylight model and its conclusions for alignment etc. are described in RD (tbd).

5.9 POWER

The thermal design and thermal model is currently under evalutation at system level by ESA project. The values given in 5.9.1 to 5.9.3 reflect the current status and as such are for illustration.

5.9.1 Inside cryostat

The following table is for the configuration presented at IIDR. It is noted that fast adjustment of cryostat boil-off rate to match load is unrealistic, and also the IID-A has yet to apportion heat load properly across the instruments and their various modes.

PARAMETER	Heat Load Estimate (mW)			
	PHOT	SPEC	STNDBY	OFF
Level 2 Summary				
HEAT LOAD ON SPIRE L2:	**49.5**	**14.1**	**49.5**	**0.0**
ESTIMATED HEAT LEAK FROM SPIRE L2 TO L1:	12.58	7.46	12.88	6.25
ESTIMATED HEAT LOAD ON Herschel L2:	36.95	6.66	36.65	-6.24
IID-A MAXIMUM AVERAGE HEAT LOAD BUDGET TO Herschel L2:	50	50	50	50
Level 1 Summary				
ESTIMATED HEAT LOAD ON SPIRE L1:	16.68	15.86	12.89	6.25
ESTIMATED HEAT LEAK FROM SPIRE L1 TO L0:	4.22	3.79	3.51	1.92
ESTIMATED HEAT LOAD ON Herschel L1 STRAP:	12.46	12.07	9.37	4.34
IID-A MAXIMUM AVERAGE HEAT LOAD BUDGET TO Herschel L1:	25	25	25	25
L0 Summary				
ESTIMATED HEAT LOAD ON SPIRE L0:	4.419	3.993	3.513	1.923
ESTIMATED HEAT LEAK FROM SPIRE L0 TO 300mK STAGE:	0.024	0.024	0	0
ESTIMATED HEAT LOAD ON Herschel L0 STRAPS:	4.405	3.980	3.524	1.928
IID-A MAXIMUM AVERAGE HEAT LOAD BUDGET TO Herschel L0:	10	10	10	10

Excludes conducted and dissipative heatloads from cryoharness connecting to 300 K level.
Includes dissipation of ^{3}He refrigerator when operating (Averaging the load during operation and recycling – recycle mode dissipates 90 mW (TBC) for 2 out of every 48 hours). The parasitic loads from 4 to 2 K through the structure and heat switches amount to 1 mW (TBC).

5.9.2 Outside Cryostat

NA

5.9.3 On SVM

The table shows the heat dissipation of the units mounted on the SVM in Watts. Note that by comparison power passed through to the Cryoharness and FSFPU is negligible, so these dissipations are also the value of power supplied:

Project Code	Instrument Unit	Power Dissipation average [W] per box
FSDPU	**DPU**	**24**
FSFCU+FSDCU	**DRCU**	**71.3**
FSWIR	**Harness**	**0**
TOTAL		**95.3**

These apply to all modes, and the baseline is to only empower either prime or redundant in **Spire**. The instrument appears to the S/C as simply cold redundant.

5.9.4 On Planck Payload Module

NA

5.9.5 Power versus Instrument Operating Modes

The table below shows the status of the instrument subsystems in the various instrument modes.

Unit	Subsystem	Recycle	Off	On	Standby/ Parallel/ Serendipity	Observe	
						PHOT	**SPEC**
FSFPU	Detector Bias	OFF	OFF	OFF	ON	ON	ON
	Photometer Cal Source	OFF	OFF	OFF	OFF	X	OFF
	Spect Cal Source	OFF	OFF	OFF	OFF	OFF	ON
	Cooler	ON	OFF	OFF	ON	ON	ON
	BSM	OFF	OFF	OFF	ON	ON	ON
	FTS Mechanism	OFF	OFF	OFF	OFF	OFF	ON
FSFTB	JFET amplifiers	ON	OFF	OFF	ON	ON	ON
FSFCU + FSDCU	Read-out electronics & Mechanism drive Electronics	ON	OFF	OFF	ON	ON	ON
FSDPU	Digital Processing Unit	ON	OFF	ON	ON	ON	ON

ON =	Operational;
OFF =	Inactive;
X =	Either ON or OFF depending on instrument configuration.

5.9.6 Supply Voltages

5.9.6.1 Load on main-bus

The total power load **Spire** places on the 28V main-bus is defined In the **Spire** Budgets' Document. The following is an extracted summary:

Operating mode	Average BOL (beginning of life) [W]	Average EOL (end of life) [W]	Peak [W]
Observe	95.3 W	TBD	TBD
Parallel	95.3 W	TBD	TBD
Serendipity	95.3 W	TBD	TBD
Standby	95.3 W	TBD	TBD
Cooler Recycle	95.3 W	TBD	TBD
On	24 W	TBD	TBD
Off	0	0	0

Project Code	Instrument Unit	Load per LCL [W]
FSDPU	DPU	24
FSFCU+FSDCU	DRCU	71.3
TOTAL		95.3

5.9.6.2 Power Nominal Turn-on.

Having checked that **Spire** is all unpowered, the HPCDU shall empower an FSDPU(P or R).
This DPU checks that its health and sends a status packet on the active 1553 bus.
If status is OK, HCDMU causes HPCDU to turn on corresponding FSFCU (P or R).
Note that turning on the FSFCU has the automatic subsidiary effect of turning on the non-redundant DCU, but this unit is not seen directly via a S/C interface.

5.9.6.3 Interface circuits

The FSDPU and the FSFCU receive both prime and redundant 28V feeds. The configuration is shown in figure 5.2.1, and the connectors are DPU J1-2 and FCU J5-6.

Their S/C power interfaces circuits shall be designed not to generate unwanted interaction with LCL switching limiters.

The HPCDU shall telemeter LCL current to better than 0.30mA resolution.

5.9.6.4 LCL fault conditions

Powering both FCUs simultaneously is not a condition that the S/C shall allow, even in the event of a single point LCL faiilure.

Both DPUs may be powered but only under LCL fault conditions. To permit this, other design features must be present. The unwanted although powered DPU shall be kept inactive by not commanding the inactive unit, and neither HCDMU sdhall turn on the corresponding FSFCU. To permit commanding the DPUs to work like this, each FSDPU use a different 1553 bus address.

The Herschel platform shall monitor that LCL's are behaving correctly. With certain timing restrictions, it shall regularly check that an "off" LCL is passing less than a minimum current, and that an "on" LCL is passing a current between a minimum and a maximum that depends on circuit. It shall re-check this before and after implementing a command to change an LCL's state. The formal status of the functionality of LCLs [working, stuck on, stuck open-circuit, dubious, etc.] shall be stored somewhere in the Herschel commanding system (probably on the ground?) to stop any attempt to switch a failed LCL without specific over-ride .

An open-circuit LCL is not a particularly difficult case to consider as it would just preclude the use of one side of **Spire**.

5.9.6.4.1 FSDPU Power Input Circuit Configuration

TBD

5.9.6.4.2 FSFCU Power Input Circuit Configuration

TBD

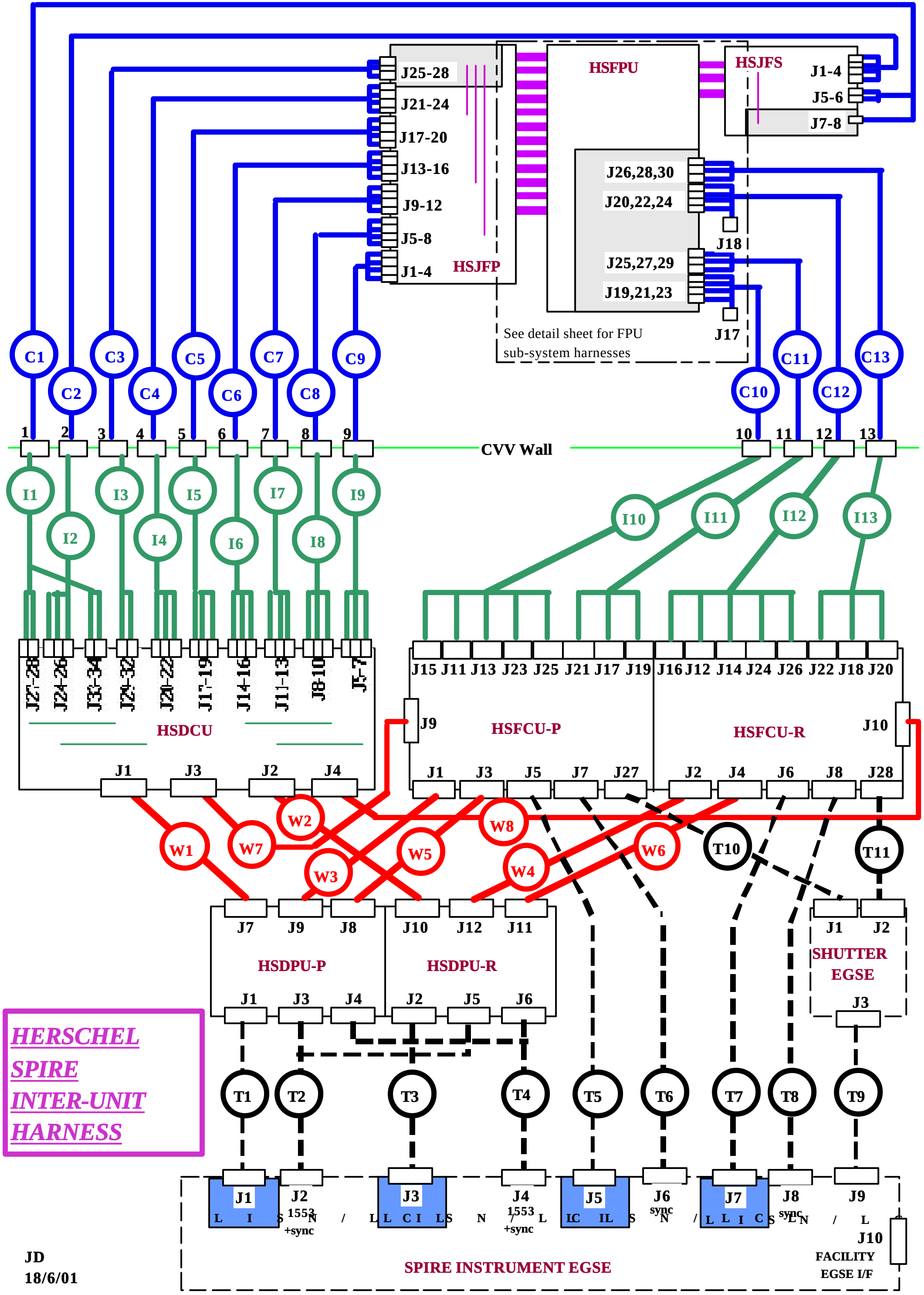
5.9.7 Keep Alive Line (KAL)

Because **Spire** should not be switched-on/off frequently, a KAL will not be implemented.

5.10 CONNECTORS, HARNESS, GROUNDING, BONDING

5.10.1 Harness and Connectors

The figure below gives an overview of the **Spire** harness layout.



Note that the Cryo-harness, i.e.series C and I, are ESA provided and not **Spire** flight H/W, whilst the T series apply only for instrument test and are not **Spire** flight items.

The specifications for the cryo harness, series C and I, are given in the tables below.

Internal Harness

Name	100 Way Connector	FPU Connector	Description	Number of Conductors	Number of Shields	Type	Max. Impedance Requirements			Max.Current per Conductor	Average	Duty Cycle			Max. Volts
							R (Ω)	C(pF)	L(H)			t	T	(t x T)	
C1	CVV 1	JFS J5	Bolometer signals from JFS	48	4	TT	200	1000	0.08	1nA		50%	33%	17%	0.1
			Overshield		1	80%									
	CVV 1	JFS J6	Bolometer signals from JFS	48	4	TT	200	1000	0.08	1nA		50%	33%	17%	0.1
			Overshield		1	80%									
	CVV 1	JFS J7	Spectrometer Bias & JFET Power	12	1	4 x TT	1000/100	1000	0.08	5mA/1μA		50%	33%	17%	10
			Spectrometer Bias & JFET Power	12	1	4 x TT	1000/100	1000	0.08	5mA/1μA		50%	33%	17%	10
			JFET Heaters + TC Bias	12	1	4 x TT	1000/100	1000	0.08	5mA/1μA	1mA/1μA	50%	33%	17%	10
	CVV 1	JFS J8	Spectrometer Bias & JFET Power	12	1	4 x TT	1000/100	1000	0.08	5mA/1μA		0%	33%	0%	10
			Spectrometer Bias & JFET Power	12	1	4 x TT	1000/100	1000	0.08	5mA/1μA		0%	33%	0%	10
			JFET Heaters + TC Bias	12	1	4 x TT	1000/200	1000	0.08	5mA/1μA	1mA/1μA	0%	33%	0%	10
			Overshield		1	80%									
C2	CVV 2	JFS J1	Bolometer signals from JFS	48	4	TT	200	1000	0.08	1nA		50%	33%	17%	0.1
			Overshield		1	80%									
	CVV 2	JFS J2	Bolometer signals from JFS	48	4	TT	200	1000	0.08	1nA		50%	33%	17%	0.1
			Overshield		1	80%									
	CVV 2	JFS J3	Bolometer signals from JFS	48	4	TT	200	1000	0.08	1nA		50%	33%	17%	0.1
			Overshield		1	80%									
	CVV 2	JFS J4	Bolometer signals from JFS	48	4	TT	200	1000	0.08	1nA		50%	33%	17%	0.1
			Overshield		1	80%									
		Shield	RF Overshield insulated form CVV wall		1	80%	NA	NA	NA	NA		NA	NA	NA	NA
C3	CVV 3	JFS J25	Bolometer bias, JFET Power, Heater	48	4	TT	1000/200/100	1000	0.08	1mA/5mA/6mA		50%	33%	17%	0.1
			Overshield		1	80%									
	CVV 3	JFS J26	Bolometer bias, JFET Power, Heater	36	3	TT	1000/200/100	1000	0.08	1mA/5mA/6mA		50%	33%	17%	0.1
			Overshield		1	80%									
	CVV 3	JFS J27	Bolometer bias, JFET Power, Heater	48	4	TT	1000/200/100	1000	0.08	1mA/5mA/6mA		50%	33%	17%	0.1
			Overshield		1	0.8									
	CVV 3	JFS J28	Bolometer bias, JFET Power, Heater	36	3	TT	1000/200/100	1000	0.08	1mA/5mA/6mA		50%	33%	17%	0.1
			Overshield		1	0.8									
		Shield	RF Overshield insulated form CVV wall		1	80%	NA	NA	NA	NA		NA	NA	NA	NA
C4	CVV 4	JFP J21	Bolometer signals from JFP	48	4	TT	200	1000	0.08	1nA		50%	33%	17%	0.1
			Overshield		1	80%									
		JFP J22	Bolometer signals from JFP	48	4	TT	200	1000	0.08	1nA		50%	33%	17%	0.1
			Overshield		1	80%									
		JFP J23	Bolometer signals from JFP	48	4	TT	200	1000	0.08	1nA		50%	33%	17%	0.1
			Overshield		1	80%									
		JFP J24	Bolometer signals from JFP	48	4	TT	200	1000	0.08	1nA		50%	33%	17%	0.1
			Overshield		1	80%									
		Shield	RF Overshield insulated form CVV wall		1	80%	NA	NA	NA	NA		NA	NA	NA	NA
C5	CVV 5	JFP J17	Bolometer signals from JFP	48	4	TT	200	1000	0.08	1nA		50%	33%	17%	0.1
			Overshield		1	80%									
		JFP J18	Bolometer signals from JFP	48	4	TT	200	1000	0.08	1nA		50%	33%	17%	0.1
			Overshield		1	80%									
		JFP J19	Bolometer signals from JFP	48	4	TT	200	1000	0.08	1nA		50%	33%	17%	0.1
			Overshield		1	80%									
		JFP J20	Bolometer signals from JFP	48	4	TT	200	1000	0.08	1nA		50%	33%	17%	0.1
			Overshield		1	80%									
		Shield	RF Overshield insulated form CVV wall		1	80%	NA	NA	NA	NA		NA	NA	NA	NA
C6	CVV 6	JFP J13	Bolometer signals from JFP	48	4	TT	200	1000	0.08	1nA		50%	33%	17%	0.1
			Overshield		1	80%									
		JFP J14	Bolometer signals from JFP	48	4	TT	200	1000	0.08	1nA		50%	33%	17%	0.1
			Overshield		1	80%									
		JFP J15	Bolometer signals from JFP	48	4	TT	200	1000	0.08	1nA		50%	33%	17%	0.1
			Overshield		1	80%									
		JFP J16	Bolometer signals from JFP	48	4	TT	200	1000	0.08	1nA		50%	33%	17%	0.1
			Overshield		1	80%									
		Shield	RF Overshield insulated form CVV wall		1	80%	NA	NA	NA	NA		NA	NA	NA	NA
C7	CVV 7	JFP J9	Bolometer signals from JFP	48	4	TT	200	1000	0.08	1nA		50%	33%	17%	0.1
			Overshield		1	80%									
		JFP J10	Bolometer signals from JFP	48	4	TT	200	1000	0.08	1nA		50%	33%	17%	0.1
			Overshield		1	80%									
		JFP J11	Bolometer signals from JFP	48	4	TT	200	1000	0.08	1nA		50%	33%	17%	0.1
			Overshield		1	80%									
		JFP J12	Bolometer signals from JFP	48	4	TT	200	1000	0.08	1nA		50%	33%	17%	0.1
			Overshield		1	80%									
		Shield	RF Overshield insulated form CVV wall		1	80%	NA	NA	NA	NA		NA	NA	NA	NA

Name	100 Way Connector	FPU Connector	Description	Number of Conductors	Number of Shields	Type	Max. Impedance Requirements			Max.Current per Conductor	Average	Duty Cycle			Max. Volts
							R (Ω)	C(pF)	L(H)			t	T	(t x T)	
C8	CVV 8	JFP J5	Bolometer signals from JFP	48	4	TT	200	1000	0.08	1nA		50%	33%	17%	0.1
			Overshield		1	80%									
		JFP J6	Bolometer signals from JFP	48	4	TT	200	1000	0.08	1nA		50%	33%	17%	0.1
			Overshield		1	80%									
		JFP J7	Bolometer signals from JFP	48	4	TT	200	1000	0.08	1nA		50%	33%	17%	0.1
			Overshield		1	80%									
		JFP J8	Bolometer signals from JFP	48	4	TT	200	1000	0.08	1nA		50%	33%	17%	0.1
			Overshield		1	80%									
		Shield	RF Overshield insulated form CVV wall		1	80%	NA	NA	NA	NA		NA	NA	NA	NA
C9	CVV 9	JFP J1	Bolometer signals from JFP	48	4	TT	200	1000	0.08	1nA		50%	33%	17%	0.1
			Overshield		1	80%									
		JFP J2	Bolometer signals from JFP	48	4	TT	200	1000	0.08	1nA		50%	33%	17%	0.1
			Overshield		1	80%									
		JFP J3	Bolometer signals from JFP	48	4	TT	200	1000	0.08	1nA		50%	33%	17%	0.1
			Overshield		1	80%									
		JFP J4	Bolometer signals from JFP	48	4	TT	200	1000	0.08	1nA		50%	33%	17%	0.1
			Overshield		1	80%									
C10	CVV 10	Shield	RF Overshield insulated form CVV wall		1	80%	NA	NA	NA	NA		NA	NA	NA	NA
			Vane drive, solenoid and heater	4	1	STQ	10			100mA		NA	NA	NA	10
			Vane thermistor bias and readout	4	1	STQ	1000			1 mA		NA	NA	NA	
		FCU J11	Cooler heaters	4	0	TQ	10			25 mA		6%	1/3	2%	
			Sorption pump heat switch heaters	4	0	TQ	50			1.5mA		100%	1/3	33%	
			Evaporator heat switch heaters	4	0	TQ	50			1.5mA		100%	####	33%	
		FCU J13	FTS Stimulaor (S-Cal)	4	0	TQ	30			9 mA		50%	33%	17%	
		FCU J23	FPU Thermometry A	32	8	STQ	1000			1nA	1nA	100%	33%	33%	
		FCU J25	FPU Thermometry B	28	7	STQ	1000			1nA	1nA	100%	33%	33%	
C11	CVV 11	FCU J 21	FPU Thermometry C	12	3	STQ	1000			1nA	1nA	100%	33%	33%	
		FCU J 17	SMEC Drive Coil	4	2	STP	5			100mA	8 mA	50%	33%	17%	
			SMEC Drive coil Voltage	2	1	STP	500			1 mA	1 mA	50%	33%	17%	
			SMEC LVDT	6	3	STP	500			10mA	10mA	50%	33%	17%	
			SMEC Launch Latch	2	1	STP	10			35mA	0	0%	0%	0%	
			SMEC Launch Latch Confirm	2	1	STP	100			1 mA	0	0%	0%	0%	
			SMEC Thermometry											0%	
		FCU	SMEC Moire sensor	19	9	STP/STT	1000								
		FCU J19	BSM Chop and Jiggle Sensors	6	2	STT	1000			10mA	10mA	50%	33%	17%	0.4
			BSM Chop and Jiggle Bias	4	2	STP	100			1 mA	1 mA	50%	33%	17%	0.4
			P-Cal Temperature	4	1	STQ	1000			2.5nA	2.5nA	100%	33%	33%	
C12	CVV 12	FCU J16	Shutter (position and latch sense)	4	1	STQ	1000	1500	0	5 mA	0	NA	NA	NA	0
			Vane drive, solenoid and heater	4	1	STQ	10	0	0	100mA	0	NA	NA	NA	10
			Vane thermistor bias and readout	4	1	STQ	1000	0	0	1 mA	0	NA	NA	NA	0
		FCU J12	Cooler heaters	4	0	TQ	10	0	0	25 mA	0	6%	33%	2%	0
			Sorption pump heat switch heaters	4	0	TQ	50	0	0	1.5mA	0	100%	33%	33%	0
			Evaporator heat switch heaters	4	0	TQ	50	0	0	1.5mA	0	100%	33%	33%	0
		FCU J14	FTS Stimulaor (S-Cal)	4	0	TQ	30	0	0	9 mA	0	50%	33%	17%	0
		FCU J24	FPU Thermometry A	32	8	STQ	1000	0	0	1nA	1nA	100%	33%	33%	0
		FCU J26	FPU Thermometry B	28	7	STQ	1000	0	0	1nA	1nA	100%	33%	33%	0
C13	CVV13	FCU J 22	FPU Thermometry C	12	3	STQ	1000	0	0	1nA	1nA	100%	33%	33%	0
		FCU J 18	SMEC Drive Coil	4	2	STP	5	0	0	100mA	8 mA	50%	33%	17%	0
			SMEC Drive coil Voltage	2	1	STP	500	0	0	1 mA	1 mA	50%	33%	17%	0
			SMEC LVDT	6	3	STP	500	0	0	10mA	10mA	50%	33%	17%	0
			SMEC Launch Latch	2	1	STP	10	0	0	35mA	0	0%	0%	0%	0
			SMEC Launch Latch Confirm	2	1	STP	100	0	0	1 mA	0	0%	0%	0%	0
			SMEC Thermometry	0	0	0	0	0	0	0	0	0%	0%	0%	0
		FCU	SMEC Moire sensor	19	9	STP/STT	1000								
		FCU J20	BSM Chop and Jiggle Sensors	6	2	STT	1000	0	0	10mA	10mA	50%	33%	17%	0.4
			BSM Chop and Jiggle Bias	4	2	STP	100	0	0	1 mA	1 mA	50%	33%	17%	0.4
			P-Cal Temperature	4	1	STQ	1000	0	0	2.5nA	2.5nA	100%	33%	33%	0
			Total	1974	268										

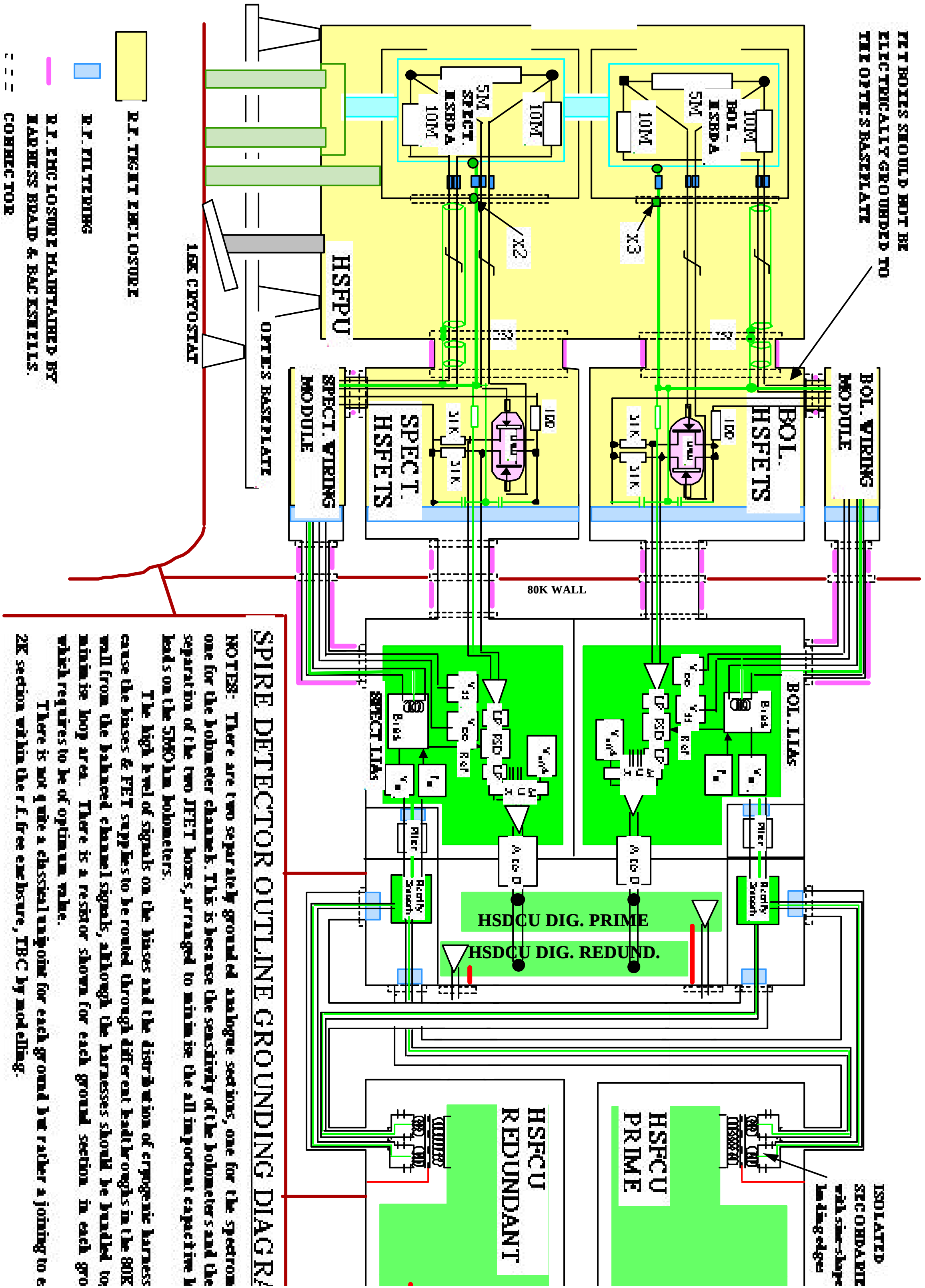
External Harness

Name	100 Way Connector	SVM Connector	Description	Number of Conductors	Number of Shields	Type	Max. Impedance			Max.Current per Conductor	Average	Duty Cycle			Max. Volts
							R (Ω)	C(pF)	L(H)			t	T	(t x T)	
I1	CVV 1	DCU J27	12 ch. SLW Bolometer (1-12)	24	12	STP	200	1000	0.12	1nA		50%	33%	17%	0.1
			Ground Wire	1	0	S	1000	1000		1 μA		50%	33%	17%	0.1
	CVV 1	DCU J28	12 ch. SLW Bolometer (13-24)	24	12	STP	200	1000	0.08	1nA		50%	33%	17%	0.1
			Ground Wire	1	0	S	1000	1000		1 μA		50%	33%	17%	0.1
	CVV 1	DCU J33	Spectrometer Bias (SLW & SSW) 1°	8	4	STP	1000	1000	0.08	1 μA		50%	33%	17%	0.1
			Temp. Control Bias 1°	2	1	STP	1000	1000	0.08	1 μA		50%	33%	17%	1
			JFET Power 1°	6	3	STP	100	1000	0.08	5mA		50%	33%	17%	10
			Heaters (SLW and SSW) 1°	6	3	STP	100	1000	0.08	5mA		50%	33%	17%	0.1
			Ground wires 1°	4	0	S	1000	1000		1 μA		50%	33%	17%	0.1
	CVV 1	DCU J34	Spectrometer Bias (SLW & SSW) (Red.)	8	4	STP	1000	1000	0.08	1 μA		50%	33%	17%	0.1
			Temp. Control Bias (Red.)	2	1	STP	1000	1000	0.08	1 μA		50%	33%	17%	1
			JFET Power (Red.)	6	3	STP	100	1000	0.08	5mA		50%	33%	17%	10
			Heaters (SLW and SSW) (Red.)	6	3	STP	100	1000	0.08	5mA		50%	33%	17%	0.1
			Ground wires (Red.)	4	0	S	1000	1000		1 μA		50%	33%	17%	0.1
		Shield	RF Overshield insulated form CVV wall		1	80%	NA	NA	NA	NA		NA	NA	NA	NA
I2	CVV 2	DCU J23	12 ch. SSW Bolometer (1-12)	24	12	STP	200	1500	0.08	1nA		50%	33%	17%	0.1
			Ground Wire	1	0	S	1000	1500		1 μA		50%	33%	17%	0.1
	CVV 2	DCU J24	12 ch. SSW Bolometer (13-24)	24	12	STP	200	1500	0.08	1nA		50%	33%	17%	0.1
			Ground Wire	1	0	S	1000	1500		1 μA		50%	33%	17%	0.1
	CVV 2	DCU J25	12 ch. SSW Bolometer (25-36)	24	12	STP	200	1500	0.08	1nA		50%	33%	17%	0.1
			Ground Wires	4	0	S	1000	1500		1 μA		50%	33%	17%	0.1
	CVV 2	DCU J26	12 ch. SSW Bolometer (37-44)	24	12	STP	200	1500	0.08	1nA		50%	33%	17%	0.1
			Ground Wires	4	0	S	1000	1500		1 μA		50%	33%	17%	0.1
		Shield	RF Overshield insulated form CVV wall		1	80%	NA	NA	NA	NA		NA	NA	NA	NA
I3	CVV 3	DCU J29	PSW JFET Power	12	6	STP	100	1500	0.08	5mA		50%	33%	17%	0.1
			PSW Bias	6	3	STP	1000	1500	0.08	1 μA		50%	33%	17%	0.1
			Heaters	12	6	STP	100	1500	0.08	5mA		50%	33%	17%	0.1
			Ground Wire	1	0	S	1000	1500	0.08	1 μA		50%	33%	17%	0.1
	CVV 3	DCU J31	PMW/PLW JFET Power	12	6	STP	100	1500	0.08	5mA		50%	33%	17%	0.1
			PMW/PLW Bias	8	4	STP	1000	1500	0.08	1 μA		50%	33%	17%	0.1
			Temp. Control Bias	2	1	STP	1000	1500	0.08	1 μA		50%	33%	17%	1
			Ground Wire	1	0	S	1000	1500	0.08	1.00E-06		50%	33%	17%	0.1
	CVV 3	DCU J30	PSW JFET Power	12	6	STP	100	1500	0.08	5mA		50%	33%	17%	0.1
			PSW Bias	6	3	STP	1000	1500	0.08	1 μA		50%	33%	17%	0.1
			Heaters	12	6	STP	100	1500	0.08	5mA		50%	33%	17%	0.1
			Ground Wire	1	0	S	1000	1500	0.08	1 μA		50%	33%	17%	0.1
	CVV 3	DCU J32	PMW/PLW JFET Power	12	6	STP	100	1500	0.08	5mA		50%	33%	17%	0.1
			PMW/PLW Bias	8	4	STP	1000	1500	0.08	1 μA		50%	33%	17%	0.1
			Temp. Control Bias	2	1	STP	1000	1500	0.08	1 μA		50%	33%	17%	1
			Ground Wire	1	0	S	1000	1500	0.08	1 μA		50%	33%	17%	0.1
		Shield	RF Overshield insulated form CVV wall		1	80%	NA	NA	NA	NA		NA	NA	NA	NA
I4	CVV 4	DCU J20	16 ch. PMW (1-16)	32	16	STP	100	1500	0.12	1nA		50%	33%	17%	0.1
			Ground Wire	2	0	S	1000	1500	0.08	1 μA		50%	33%	17%	0.1
		DCU J21	16 ch. PMW (17-32)	32	16	STP	100	1500	0.12	1nA		50%	33%	17%	0.1
			Ground Wire	2	0	S	1000	1500	0.08	1 μA		50%	33%	17%	0.1
		DCU J22	16 ch. PMW (33-48)	32	16	STP	100	1500	0.12	1nA		50%	33%	17%	0.1
			Ground Wire	2	0	S	1000	1500	0.08	1 μA		50%	33%	17%	0.1
		Shield	RF Overshield insulated form CVV wall		1	80%	NA	NA	NA	NA		NA	NA	NA	NA
I5	CVV 5	DCU J17	16 ch. PMW (1-16)	32	16	STP	100	1500	0.12	1nA		50%	33%	17%	0.1
			Ground Wire	2	0	S	1000	1500	0.08	1 μA		50%	33%	17%	0.1
		DCU J18	16 ch. PMW (17-32)	32	16	STP	100	1500	0.12	1nA		50%	33%	17%	0.1
			Ground Wire	2	0	S	1000	1500	0.08	1 μA		50%	33%	17%	0.1
		DCU J19	16 ch. PMW (33-48)	32	16	STP	100	1500	0.12	1nA		50%	33%	17%	0.1
			Ground Wire	2	0	S	1000	1500	0.08	1 μA		50%	33%	17%	0.1
		Shield	RF Overshield insulated form CVV wall		1	80%	NA	NA	NA	NA		NA	NA	NA	NA
I6	CVV 6	DCU J14	16 ch. PMW (1-16)	32	16	STP	100	1500	0.12	1nA		50%	33%	17%	0.1
			Ground Wire	2	0	S	1000	1500	0.08	1 μA		50%	33%	17%	0.1
		DCU J15	16 ch. PMW (17-32)	32	16	STP	100	1500	0.12	1nA		50%	33%	17%	0.1
			Ground Wire	2	0	S	1000	1500	0.08	1 μA		50%	33%	17%	0.1
		DCU J16	16 ch. PMW (33-48)	32	16	STP	100	1500	0.12	1nA		50%	33%	17%	0.1
			Ground Wire	2	0	S	1000	1500	0.08	1 μA		50%	33%	17%	0.1
		Shield	RF Overshield insulated form CVV wall		1	80%	NA	NA	NA	NA		NA	NA	NA	NA

Name	100 Way Connector	SVM Connector	Description	Number of Conductors	Number of Shields	Type	Max. Impedance			Max.Current per Conductor	Average	Duty Cycle			Max. Volts
							R (Ω)	C(pF)	L(H)			t	T	(t x T)	
I7	CVV 7	DCU J11	16 ch. PMW (1-16)	32	16	STP	100	1500	0.12	1nA		50%	33%	17%	0.1
			Ground Wire	2	0	S	1000	1500	0.08	1 μA		50%	33%	17%	0.1
		DCU J12	16 ch. PMW (17-32)	32	16	STP	100	1500	0.12	1nA		50%	33%	17%	0.1
			Ground Wire	2	0	S	1000	1500	0.08	1 μA		50%	33%	17%	0.1
		DCU J13	16 ch. PMW (33-48)	32	16	STP	100	1500	0.12	1nA		50%	33%	17%	0.1
			Ground Wire	2	0	S	1000	1500	0.08	1 μA		50%	33%	17%	0.1
		Shield	RF Overshield insulated form CVV wall		1	80%	NA	NA	NA	NA		NA	NA	NA	NA
I8	CVV 8	DCU J8	16 ch. PMW (1-16)	32	16	STP	100	1500	0.12	1nA		50%	33%	17%	0.1
			Ground Wire	2	0	S	1000	1500	0.08	1 μA		50%	33%	17%	0.1
		DCU J9	16 ch. PMW (17-32)	32	16	STP	100	1500	0.12	1nA		50%	33%	17%	0.1
			Ground Wire	2	0	S	1000	1500	0.08	1 μA		50%	33%	17%	0.1
		DCU J10	16 ch. PMW (33-48)	32	16	STP	100	1500	0.12	1nA		50%	33%	17%	0.1
			Ground Wire	2	0	S	1000	1500	0.08	1 μA		50%	33%	17%	0.1
		Shield	RF Overshield insulated form CVV wall		1	80%	NA	NA	NA	NA		NA	NA	NA	NA
I9	CVV 9	DCU 5	16 ch. PMW (1-16)	32	16	STP	100	1500	0.12	1nA		50%	33%	17%	0.1
			Ground Wire	2	0	S	1000	1500	0.08	1 μA		50%	33%	17%	0.1
		DCU J6	16 ch. PMW (17-32)	32	16	STP	100	1500	0.12	1nA		50%	33%	17%	0.1
			Ground Wire	2	0	S	1000	1500	0.08	1 μA		50%	33%	17%	0.1
		DCU J7	16 ch. PMW (33-48)	32	16	STP	100	1500	0.12	1nA		50%	33%	17%	0.1
			Ground Wire	2	0	S	1000	1500	0.08	1 μA		50%	33%	17%	0.1
I10	CVV 10	FPU	Shutter (position and latch sense)	4	1	STQ	1000	1500		5 mA		NA	NA	NA	
			Vane drive, solenoid and heater	4	1	STQ	10			100mA		NA	NA	NA	10
			Vane thermistor bias and readout	4	1	STQ	1000			1 μA		NA	NA	NA	
		FPU	Cooler heaters	4	0	TQ	10			25mA		6%	1/3	2%	
			Sorption pump heat switch heaters	4	0	TQ	50			1.5mA		100%	1/3	33%	
			Evaporator heat switch heaters	4	0	TQ	50			1.5mA		100%	33.30%	33%	
		FPU	FTS Stimulaor (S-Cal)	4	0	TQ	30			9 mA		50%	33%	17%	
		FPU	FPU Thermometry A	32	8	STQ	1000			1nA	1nA	100%	33%	33%	
		FPU	FPU Thermometry B	28	7	STQ	1000			1nA	1nA	100%	33%	33%	
I11	CVV 11	FPU	FPU Thermometry C	12	3	STQ	1000			1nA	1nA	100%	33%	33%	
		FPU	SMEC Drive Coil	4	2	STP	5			100mA	8 mA	50%	33%	17%	
			SMEC Drive coil Voltage	2	1	STP	500			1 μA	1 μA	50%	33%	17%	
			SMEC LVDT	6	3	STP	500			10μA	10μA	50%	33%	17%	
			SMEC Launch Latch	2	1	STP	10			35mA	0	0%	0%	0%	
			SMEC Launch Latch Confirm	2	1	STP	100			1 mA	0	0%	0%	0%	
			SMEC Thermometry												
		FPU	SMEC Moire sensor	19	9	STP/STT	1000								
		FPU	BSM Chop and Jiggle Sensors	6	2	STT	1000			10μA	10μA	50%	33%	17%	0.4
			BSM Chop and Jiggle Bias	4	2	STP	100			1 mA	1 mA	50%	33%	17%	0.4
			P-Cal Temperature	4	1	STQ	1000			2.5nA	2.5nA	100%	33%	33%	
I12	CVV 12	FPU	Shutter (position and latch sense)	4	1	STQ	1000	1500	0	5 mA	0	NA	NA	NA	0
			Vane drive, solenoid and heater	4	1	STQ	10	0	0	100mA	0	NA	NA	NA	10
			Vane thermistor bias and readout	4	1	STQ	1000	0	0	1 mA	0	NA	NA	NA	0
		FPU	Cooler heaters	4	0	TQ	10	0	0	25mA	0	0.0625	0.3333	0.0208	0
			Sorption pump heat switch heaters	4	0	TQ	50	0	0	1.5mA	0	1	0.3333	0.3333	0
			Evaporator heat switch heaters	4	0	TQ	50	0	0	1.5mA	0	1	0.333	0.333	0
		FPU	FTS Stimulaor (S-Cal)	4	0	TQ	30	0	0	9 mA	0	0.5	0.33	0.165	0
		FPU	FPU Thermometry A	32	8	STQ	1000	0	0	1nA	1nA	1	0.33	0.33	0
		FPU	FPU Thermometry B	28	7	STQ	1000	0	0	1nA	1nA	1	0.33	0.33	0
I13	CVV 13	FPU	FPU Thermometry C	12	3	STQ	1000	0	0	1nA	1nA	1	0.33	0.33	0
		FPU	SMEC Drive Coil	4	2	STP	5	0	0	100mA	8 mA	0.5	0.33	0.165	0
			SMEC Drive coil Voltage	2	1	STP	500	0	0	1 mA	1 mA	0.5	0.33	0.165	0
			SMEC LVDT	6	3	STP	500	0	0	10mA	10mA	0.5	0.33	0.165	0
			SMEC Launch Latch	2	1	STP	10	0	0	35mA	0	0	0	0	0
			SMEC Launch Latch Confirm	2	1	STP	100	0	0	1 mA	0	0	0	0	0
			SMEC Thermometry	0	0	0	0	0	0	0	0	0	0	0	0
		FPU	SMEC Moire sensor	19	9	STP/STT	1000								
		FPU	BSM Chop and Jiggle Sensors	6	2	STT	1000	0	0	10mA	10mA	0.5	0.33	0.165	0.4
			BSM Chop and Jiggle Bias	4	2	STP	100	0	0	1 mA	1 mA	0.5	0.33	0.165	0.4
			P-Cal Temperature	4	1	STQ	1000	0	0	2.5nA	2.5nA	1	0.33	0.33	0
			Total	1226	528										

5.10.2 Grounding

The **Spire** grounding scheme as given in the figure below, will be essential to the satisfactory performance of the instrument, it being vital that interfaces do not cause energy to be dissipated in the 300mK section and particularly not in the bolometers themselves.



SPIRE DETECTOR OUTLINE GROUNDING DIAGRA

NOTES: There are two separately grounded analogue sections, one for the spectrom one for the bolometer channels. This is because the sensitivity of the bolometers and the separation of the two JFET boxes, arranged to minimise the all important capacitive l leads on the 5MOhm bolometers.

The high level of signals on the biases and the distribution of cryogenic harness cause the biases & FET supplies to be routed through different leadthroughs in the 80K wall from the balanced channel signals, although the harnesses should be bundled to; minimise loop area. There is a resistor shown for each ground section in each gro which requires to be of optimum value.

There is not quite a classical unipoint for each ground but rather a joining to e, 2K section within the r.f. free enclosure, TBC by modelling.

The **Spire** FCU itself and the DPU use a "standard" ESA-type secondary power system, whereas the DCU/FPU and FCU supply sections shown above are an optimised system w.r.t. minimising the overall bolometer analogue ground noise. The FCU powers the DCU, keeping the latter free of conditioning noise. The FCU driven items in the FPU, see figure 5.2.1, are considered less critical and will all be Ohmically grounded in the FPU.

Ohmic isolation is baselined within all straps to the cryostat, >5MΩ and <50pF at the working temperature. Note that this isolation is within the strap system, that is a Herschel not a **Spire** element, would seemingly be common to all straps, and of the proven qualified ISO design. It should not form part of the instrument I/F itself.

5.10.3 Bonding

It is understood that Herschel bonding applies to harness shields used to maintain closed Faraday cages. Bonded interfaces shall not be used as routine current return paths.

We note that presently all Warm Electronics units rely in conductivity via their mechanical mounting feet to S/C. **Spire** would much prefer a formal S/C aluminium strap bounding tree, coupled by controlled straps to all equipments, and will therefore provide a bounding strap mounting point on each SVM mounted unit to permit this.

5.10.4 Electrical Signal Interfaces

5.10.4.1 1553 Data Buses

The 4 interfaces to the two (prime and redundant) buses between the **Spire** instrument DPUs and the CDMU shall conform to MIL-STD-1553B, with the CDMU controlling the bus.

The 4 **Spire** interfaces shall have unique bus addresses, consistent with Herschel properly controlling the use of Prime and Redundant equipments.

A long stub configuration shall be used for each of the 4 interfaces, one transformer for each stub in the bus wiring and one in the instrument I/F.

Connector use is as follows:

DPU Connector	Prime Bus	Redundant Bus
Prime DPU	J3	J4
Redundant DPU	J5	J6

5.10.4.2 Master Clock

Herschel shall supply 2 differential signal lines of 2^{17}Hz. master clock signals. They are therefore supplied unground-referenced. These are shown as brown lines in figure 5.2.1.

Electrical interface details are standard digital differential receiver, through DPU connectors J3 and 5, i.e. bundled with primary 1553 bus.

This shall be supplied to both powered and unpowered **Spire** units.

Note that Herschel arranges the OR-ing of the functions over Prime and Redundant CDMU so that **Spire** is unaffected by which one is active.

Older documentation may have references to S/C wide synchronisation of dc-dc convertors, etc., but this will NOT be implemented.

5.10.4.3 Launch confirmation

Spire has three cryogenic mechanisms: BSM; SMEC; shutter. It is baselined that each will need to be launch-locked and will feed isolated SPST micro-switch contacts to Herschel to confirm this, linking to the HCDMU's RTU inputs.

There will thus be six pairs of these contacts, 3 mechanisms X [wired via prime harness and wired via redundant cryoharness].

Herschel should check each of their states using <10V and <2mA as part of the early launch procedures.

Connectors used are FCU J26 -27, which are used in flight for this purpose but also for different functions during instrument level test.

5.11 DATA HANDLING

5.11.1 Telemetry

5.11.1.1 Telemetry rate

The instrument produced “raw” housekeeping and science data rates, given for information purposes, are as follows:

Description	Data rate (Kbps)
Housekeeping data rate (non-prime)	2.1
Housekeeping data rate (prime)	2
Science data rate: Photometer only	93.6
Science data rate: Spectrometer only	97.4
Science data rate: Parallel mode	10
Science data rate: Serendipity mode	87

Any increase in telemetry rate would have science benefits. Note that the data rate allocation of 100Kbps is a limit on the average including orbit recycling/commanding periods

5.11.1.2 Data-bus rate

For the purpose of possible (up to 5 minutes) higher instrument data-rates, the bus interconnecting the instrument and the HCDMU shall have the capability of handling a telemetry rate of > 200 kbps. This will allow for the rapid emptying of **Spire** on-board data storage units at the end of each observation, thus keeping overheads due to data transfer to a minimum.

5.11.1.3 Data Packets

Spire is capable of buffering 10 seconds of data at 100kps. In order to prevent data overflow in this **Spire** data storage, the HVDMU shall request packets from **Spire** at least as frequently as once per second(TBC).

5.11.2 S/C housekeeping

The S/C should be capable of collecting and range checking the following instrument parameters every minute. It shall provide a data packet to the ground that includes these housekeeping values, together with any range violations and any actions taken thereon.

Voltages to instrument
Currents to instrument
Power status – i.e. which **Spire** units are on i.e. FSDPU and FSDRC.
Requested temperatures in Section 5.7.5.2.

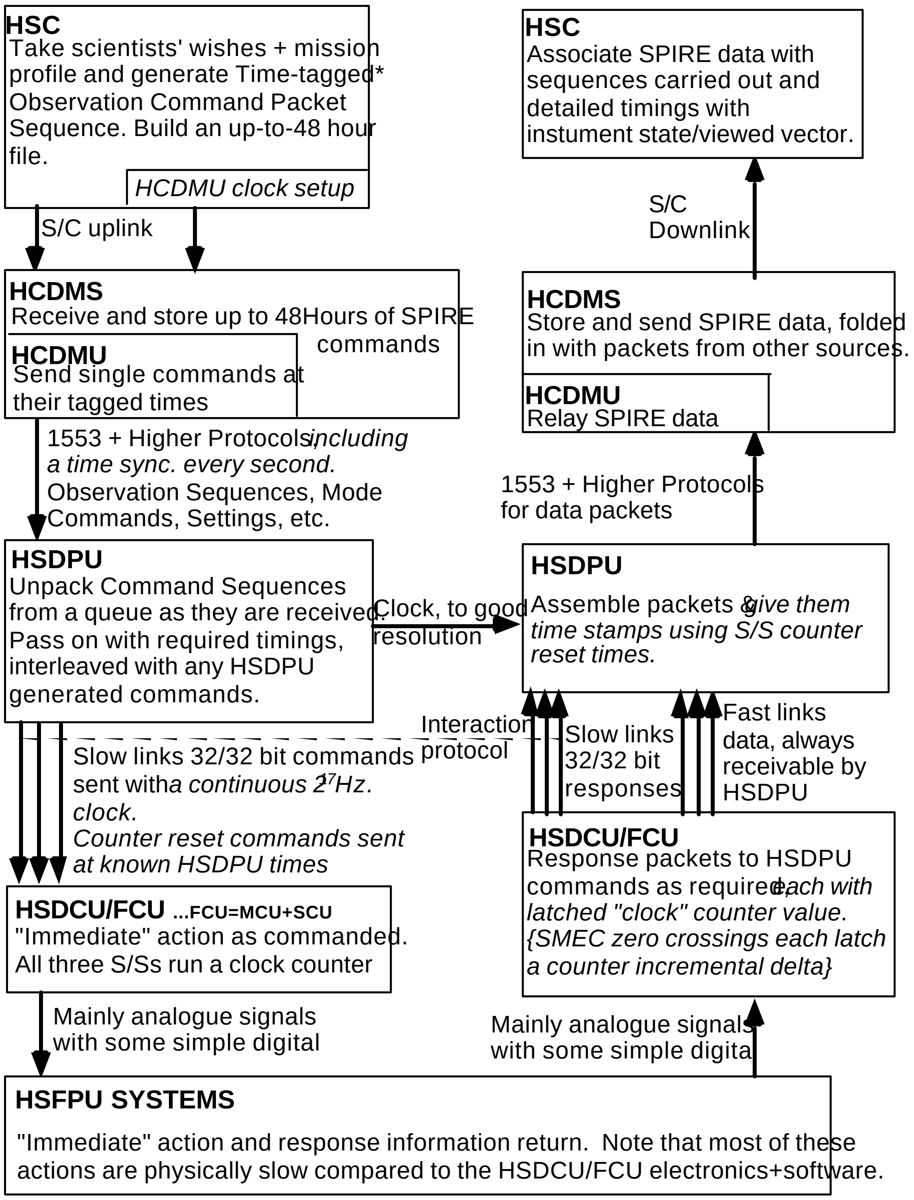
5.11.3 Timing and synchronisation signals

The S/C shall provide **Spire** with a timing synchronisation at least once per 24 hours to allow cross reference or synchronisation of the **Spire** clock to the spacecraft clock.

Spire requires to be able to deduce where Herschel is pointing to 0.1 of its smallest pixel IFOV. So when using the telescope scan mode, a “start of scan” indication will be sent be to the DPU to give a timing precision of better than 5TBC milliseconds. This is required so that the **Spire** data can be located in time and correctly ground processed to link to Herschel attitude; it is not required for the operation of the **Spire** instrument.

The **Spire** instrument typically works by its DPU unpacking S/C commands to a lower level, and sending those lower level commands to the DCU and FCU with timings that they can guarantee to keep up with. There is a minimum of handshaking on internal interfaces and, for instance, the DPU has to be ready to receive science data packets from the DPU and FCU whenever they reasonably send them. In these internal data packet headers are counter values permitting accurate datation of all values back to sequence start pulses sent from the DPU. The scheme can be viewed as:

SPIRE DATA TIMINGS



*This process uses known worst case timings for SPIRE operation + margin to ensure that the plan can be implemented and timed starts will not slip.

Note that for the above scheme to work, either the DCU/MCU/SCU need to have no input FIFOs, or the DPU need to know that they are empty and a reset will go straight through, or these units need to check for the reset pulse in hardware before feeding other packets into a FIFO. TBD.

5.11.4 Telecommand

It is assumed that the observation schedule for each 24 hour period will be uplinked during the data transfer and commanding phase (DTCP). It is further assumed that the correct receipt of all **Spire** commands is verified by the S/C during the DTCP.

The maximum rate of sending command packets from the CDMS to the **Spire** instrument is less than 10 per second.

The maximum telecommand packet length is 256 octets.

All **Spire** telecommands are defined in document AD (tbd).

5.12 ATTITUDE AND ORBIT CONTROL/POINTING

5.12.1 Attitude and orbit control

For information, **Spire** has the following **instrument** pointing modes:

- Peak up mode. The ACMS pointing ability quoted in the IID-A (3.7 arcsec APE – see also section 5.12.2) will not be good enough to prevent unacceptable signal loss when observing point sources with the photometer or spectrometer.
  The **Spire** beam steering mirror will be used to perform a cruciform raster over the observation target and the offset between the required pointing and the actual pointing of the telescope will be provided via an ACMS Data Packet from the **Spire** instrument to the S/C. The S/C will then adjust the pointing accordingly.
- Nodding mode. If the telescope temperature stability time constant proves to be short compared with a typical pointed observation with **Spire**; then the telescope must be capable of being pointed to another fixed position on the sky between 10 arcsec and 4 arcmin from the original pointing in an arbitrary direction with respect to the spacecraft axes. The settling time at each re-pointing must be less than 10 seconds
- Line scan mode. To map large areas of the sky, the telescope must be capable of being scanned up to 20 degrees at a constant rate in an arbitrary orientation with respect to the spacecraft axes. The rate of scan must be variable between 0.1 arcsec/sec and 60 arcsec per second. It is expected that the RPE will be maintained in the orthogonal direction during the scan. The S/C must be capable of reaching any scan speed up to the maximum within 20 seconds of the observation commencing.
- Raster mode. To finely sample the **Spire** FOV the instrument beam steering mirror will be used to step the FOV across the sky in an arbitrary direction. The step size will be between 1.7 (to be agreed, current value is 2) arcsec and 30 arcsec. The beam steering mirror can also be used to chop a portion of the **Spire** FOV at a rate up to 2 Hz.

The S/C is specified as being able to perform its own raster mode, i.e. stepping the FOV of the overall Herschel telescope view to follow predetermined patterns. This is acknowledged to be much less efficient than using the internal Beam Steering Mirror (BSM), but is needed as a backup in the event of **Spire** BSM failure. The spacecraft shall be capable of performing a rectangular raster with steps of between 1.7 and 30 arcsec in any arbitrary orientation with respect to the S/C axes.
To map extended regions using the spectrometer, the **Spire** instrument will use the Herschel telescope Normal Raster Mode. The instrument may perform fine sampling of each raster pointing using its internal BSM.

5.12.2 Pointing

The **Spire** instrument requires an absolute pointing error of better than 1.5 arcsec r.m.s. (TBC), and a relative pointing error of better than 0.3 arcsec r.m.s. per minute.
This is achieved by the peak up mode in case the pointing goal values are not fully achieved by the S/C.

5.12.3 On-Target Flag (OTF)

For pointed observations, within about a second of an acquisition being achieved an On-Target Flag will be provided from the platform to **Spire** as a message on the1553 bus, specifying the acquisition time to a precision of better than 0.1 second. This is required for the correct processing of the **Spire** data on the ground; it is not required for **Spire** operations.

5.13 ON-BOARD HARDWARE/SOFTWARE AND AUTONOMY FUNCTIONS

5.13.1 On-board hardware

There is a single on-board computer in each of the prime and redundant **Spire** FSDPUs. These have the only non-hardcoded on-board software used in **Spire**.

5.13.2 On-board software

It is assumed that the **Spire** warm electronics will remain powered during all operational phases. The DPU will download baseline software from ROM during power up but some additional software may be required (TBD) to be unlinked before observations commence, either patches or whole modules/objects.

No single instrument command nor any sequence of instrument commands will constitute a hazard for the instrument so the FSDPU is required to trap out any such situations. For the same reason, the FSDPU shall ensure its own correct function, at least as far as checking memory function in the background, checksummed read only areas, and an inhibitable SEU safing capability.

5.13.3 Autonomy functions

The S/C must be capable of automatic monitoring all Spacecraft Housekeeping parameters, i.e. the parameters listed in section 5.7.5.2 when the S/C is not in ground contact.

The S/C must also be capable of monitoring certain **Spire** Instrument Housekeeping parameters provided to it via “Housekeeping Data” packets from the **Spire** DPU – see 5.7.5.1.

The S/C must be capable of taking predefined action – e.g. switching off the power to the **Spire** instrument – when an error or hard limit is detected in either the **Spire** S/C Housekeeping or the **Spire** Instrument Autonomous Housekeeping parameters.

The S/C must be capable of receiving and interpreting **Spire** “Event Data” packets that will alert the S/C of errors or hard limits detected by the **Spire** DPU autonomy monitoring software. Again the S/C must be capable of taking the appropriate pre-defined action on detecting an error alert in the **Spire** Event Data.

5.13.4 Instrument Autonomy Housekeeping Packet Definition

TBD

5.13.5 Instrument Event Packet Definition

TBD

5.14 EMC

5.14.1 Conducted Emission/Susceptibility

None to be found under required test conditions

5.14.2 Radiated Emission/Susceptibility

None to be found under required test conditions

5.14.3 Frequency Plan

The original specification for **Spire** to have all its internal oscillators for signal/power synchronised to S/C sync. signals has been dropped.

The **Spire** frequency plan will be associated with the DRCU. It will show how all the DRCU frequencies are arranged to minimise noise problems in the bolometer sub-system's highly sensitive analogue sections.

5.15 TRANSPORT AND HANDLING PROVISIONS

5.15.1 Focal Plane Unit

5.15.1.1 Transport Container

The **Spire** FPU (FSFPU) will be transported in a clean hermetically sealed container to be opened only in class 100 clean conditions (TBC) with less than 50% humidity (TBC).

The maximum shock the FSFPU can sustain in any direction is (TBD). The transport container is fitted with shock recorders and internal humidity monitors. The FSFPU transport container is shown in figure TBD.

5.15.1.2 Cooling and Pumping restrictions

During cryostat warm-up or cool-down phases the rate of temperature change dT/dt shall not exceed 10 K/hour (TBC). The rate of depressurisation/pressurisation dP/dt shall not exceed 50 mBar/minute (TBC).

5.15.1.3 Mechanism positions

For reasons of possible damage caused by vibration during transport, environmental testing and launch, mechanisms shall be placed in the TBD position. This position is shown in table TBD.

5.15.1.4 Unpacking Procedure

The procedure for removing and installing the FSFPU from its transport container is given in document TBW

5.15.2 JFET/Filter Boxes

5.15.2.1 Transport Container

The **Spire** JFET/Filter Boxes (FSFTP/S) will be transported in a clean hermetically sealed container to be opened only in class 100 clean conditions (TBC) with less than 50% humidity (TBC).

The maximum shock the FSFTP/S can sustain in any direction is (TBD). The transport container is fitted with shock recorders and internal humidity monitors. The FSFTP/S transport container is shown in figure TBD.

5.15.2.2 Unpacking Procedure

The procedure for removing and installing the FSFTP/S from its transport container is given in document TBW

5.15.3 Electronics Units

5.15.3.1 Transport Container

The **Spire** warm electronics units (FSDPU; FSFCU; FSDCU, FSWIH) will be transported in clean hermetically sealed containers to be opened only in class 100000 clean conditions (TBC) with less than 75% humidity (TBC).

The maximum shock any of the warm electronics units can sustain in any direction is (TBD). The transport containers are fitted with shock recorders and internal humidity monitors. The **Spire** warm electronics transport containers are shown in figure TBD.

5.15.3.2 Unpacking Procedure

The procedures for removing and installing the **Spire** from warm electronics units their transport containers are given in document TBW

5.16 DELIVERABLE ITEMS

5.16.1 Instrument Models.

The model philosophy to be adopted for the AIV of the Herschel **Spire** instrument will be in accordance with the **Spire** Development Plan and Model Philosophy, AD (tbd).

In outline, the instrument models to be produced are:

AVM – The Avionics Model shall permit us "…to validate electronics and software for its interface with the S/C, including anything that exchanges information with, for example, the AOCS. In addition all tasks relevant to **Spire** autonomy shall be verified." This requires a DPU in at least form, fit and function plus a simulator of the DRCU and cold FPU – collectively termed the DRCU Simulator. As the schedule demands that this model will be delivered almost simultaneously with the CQM, it is planned to use the CQM DPU in the AVM.

CQM - Cryogenic Qualification Model. For both the cold FPU and the warm electronics it is assumed that this is built to flight standards, but not necessarily using flight quality electronic components. 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 will mimic as exactly as possible the thermal, electrical and mechanical properties of the flight instrument and will be capable of under going the full environmental qualification programme

PFM – Proto-Flight Model. This will be the model that is intended for flight, built to full flight standards. The PFM will therefore undergo environmental test to qualification levels for acceptance times (TBD**)** - this applies to both the warm electronics boxes and the cold FPU. A CQM qualification review will determine if in fact the PFM has needed sufficient updates that full requalification is needed in some respects.

FS – Flight Spare. The flight spare cold FPU will be made from the refurbished CQM (TBC). The flight spare warm electronics will consist of spare electronics cards/modules/harness.

5.16.2 Electrical Ground Support Equipment (EGSE)

Electrical Ground Support Equipment (EGSE) will be needed to provide **Spire** instrument level monitoring during instrument integration with the S/C and system level testing.

Deliverables:

- FPU electrical simulator, including simulation of the FSFTP/S, to enable integration of the FSDCU,FSDPU, FSFCFU and FSWIH
- TBD EGSE for integration of the FSFPU
- Quick Look Facility to enable testing of the instrument at system level. This will interface to the S/C test environment

5.16.3 Mechanical Ground Support Equipment (MGSE)

MGSE is required to ensure safe handling of all instrument components during assembly integration and test procedures.

Deliverables:

- Transport containers
- Instrument to cryostat integration jigs/equipment
- Plus TBD

5.16.4 Optical Ground Support Equipment (OGSE)

OGSE is required to carry out alignment procedures with the telescope.

Deliverables:

- Instrument optics primary alignment and alignment verification jigs/equipment
- Plus TBD

5.16.5 System Test Software

Will be based on the Quick Look Facility - computers and software that allow the monitoring in near real time of the instrument housekeeping parameters and instrument data. This is the basic facility to be used for the ICC operations monitoring for the monitoring of the instrument in-orbit. The same facility with enhanced capabilities will be used for the ground tests and in-orbit check out of the instrument.

5.16.6 Hardware for the Observatory Ground Segment

Quick Look Facility for the Mission Operations Centre for instrument in-flight commissioning. This will consist of TBD workstations etc….and must be identical to the system used for instrument system level testing.

5.16.7 Software for the Observatory Ground Segment

The software for the Quick Look Facility will be delivered to the MOC for instrument in-flight commissioning.

Plus TBD.

5.16.8 Instrument Software Simulator

TBD

5.16.9 Test Reference Data

The **Spire** instrument test reference data will be delivered in the TBD form generated during instrument and system level testing.

5.16.10 Instrument Characterisation Data

The **Spire** instrument characterisation data will be delivered in the TBD form generated during instrument and system level testing.

5.16.11 Technical Documentation

The following documents will be delivered:

- Instrument User Manual following the requirements laid down in the OIRD (AD2)

- Instrument database – this will be delivered in the TBD form generated during instrument and system level testing.
- Each instrument model will be delivered with an Acceptance Data Package consisting of TBD…a good way to end a document.

6 GROUND SUPPORT EQUIPMENT

6.1 MECHANICAL GROUND SUPPORT EQUIPMENT

TBD

6.2 ELECTRICAL GROUND SUPPORT EQUIPMENT

In agreement with all the other instruments of Herschel/Planck the SPIRE EGSE will be implemented using SCOS2000.

In order to achieve the benefits of smooth transition between different mission phases and maximum reuse of resources, this system will also be used during instrument-level testing, system level tests and in the operational phases of the mission. In particular, the interface between the EGSE and the MOC during the Commissioning and Performance Verification phases (and, for Herschel only, contingency activities during the normal operations phase) will be the same as that between the EGSE and the CCE. This interface, concerning telemetry, telecommanding, the instrument database and procedures will follow the standard defined by SCOS 2000 i.e.

Telemetry:
The SPIRE EGSE will be supplied with all telemetry packets from the satellite (or its simulator) in real time.

This telemetry interface will conform to the SCOS2000 telemetry ICD (ref: TBD).

Telecommanding:
The SPIRE EGSE will not require any commanding capability through the CCE. Instrument commanding will be implemented in the CCE in line with the methods of operation of the MOC.

Databases:
SPIRE will deliver the instrument database to the Prime Contractor through the standard SCOS2000 database interface mechanism (ref: TBD).

SPIRE expects the Prime Contractor to deliver the full satellite database through the same interface. This will allow checking of the correct implementation of the instrument database in the satellite database and allow the display and monitoring of S/C parameters during tests/operations at the system level.

Test procedures:
Test procedures, including command sequences, will be delivered in an agreed format (e.g. flow diagrams and descriptions) to the Prime Contractor who will be responsible for their implementation in the CCE.

Archive data:
It shall be possible to retrieve test data from the CCE off-line.

6.3 COMMONALITY

Taking into account that it is a fundamental design goal of the Herschel/Planck mission that commonality should be pursued to the maximum extent possible, the Herschel instrument teams have been actively engaged in investigating such possibilities.

6.3.1 EGSE

It has been agreed that a common EGSE system could be developed as a collaborative effort between instrument groups.

In addition, it has been agreed that this system would be applicable at various times during all the phases of the mission listed below:

- Subsystem Level Testing
- Instrument Level Testing
- Module and System Level Testing
- In-orbit instrument commissioning
- Performance Verification
- Routine operations

In the interests of minimising the cost and maximising the reliability of such a system through the different phases the EGSE will:

- be based on SCOS 2000 – this system will be used in the ground segment by the MOC for controlling the satellite. The cost of the system (essentially free), its proven use in similar situations for other space projects and the support provided by ESOC, contribute to a cheaper and more reliable system.

- use the same interfaces between the EGSE and other systems, in order to improve reliability through reuse throughout the mission.

- Provide a constant implementation of the
  - Man Machine Interfaces
  - Data Archiving and Distribution facilities
  - On-board Software Management
  - On-board Maintenance (e.g. Software Development Environment, Software Validation Facility)
  - Common User Language (for Test procedures and in-orbit operations)

6.3.2 INSTRUMENT CONTROL AND DATA HANDLING

All three Herschel instruments are using the same supplier (IFSI) for their on-board control and data handling hardware and software systems, which interface to the spacecraft. This has ensured commonality in the areas of;

- on-board microprocessors
- instrument internal interfaces
- On-board Programming language

- Software Development Environments
- Software Validation Facilities

In addition, the on-board software provides commonality in its non instrument-specific functions. A common instrument commanding scheme has also been agreed and will be implemented by the instrument teams.

6.3.3 OTHER AREAS

Other areas of possible commonality will be addressed by working groups set up as and when necessary. These may cover:

- Follow up on Herschel Common Science System data archive activities
- A common approach to IA/QLA systems

7 INTEGRATION, TESTING AND OPERATIONS

Information in this chapter covers all instrument-related activities after the acceptance of the instruments by ESA and handover to the Contractor.

7.1 Integration

Procedures detailing the individual integration steps will be prepared and reviewed in due time.

7.1.1 HPLM Integration

It is anticipated that the SPIRE Focal Plane Unit (FSFPU) and the SPIRE JFET box (FSFTB) will be integrated separately onto the Herschel optical bench. Electrical and RF-shield connections (TBD) will be made between the boxes after mechanical integration with the Herschel optical bench.

This applies to both the CQM and PFM units.

7.1.2 PPLM Integration

NA

7.1.3 SVM Integration

TBD

7.1.4 Herschel/Planck Integration

TBD

7.2 Testing

After completion of the integration, be it at the level of the FPLM, PPLM, SVM or Herschel/Planck, a series of verification tests will be carried-out.

Each test will be defined in detail in a test procedure to be written by the Contractor, based on instrument group inputs. It will be reviewed and approved by the Herschel/Planck project group.

7.2.1 CQM Testing

Overview

The detailed system level test procedures for the SPIRE CQM are TBW. An indication of the type of testing anticipated for the SPIRE CQM is given below:

FPU integration procedures
Optical alignment procedures
Integration with CCE
Test of checkout procedures to be done for PFM
Test of parallel operation with PACS
Functional checks using standard test procedures
Thermal balance tests under representative conditions. This will include cooler recycle and some mechanism operations.

Test switching sequences between all modes. Check length of time required to change modes – including waiting for thermal environment to stabilise.
Test thermal dissipation in each “operating mode”.
Straylight checks with GSE fitted or with final shield blanked off. This is an extreme test as the other shields will be at higher temperatures than expected in flight.
EMC test of conducted susceptibility only.

Test Environment
In order to carry out these tests the SPIRE instruments expects the CQM test environment to be as follows:

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

Detailed Sequencing

Sequence	Duration [days]	Objective	Requirements	Remarks
Instrument Test SPIRE	3			
SPIRE Functional Test	~1.5			
1		SPIRE switch on procedure, including validation of connection between EGSE and instrument, memory load and dump		SPIRE will be switched to the ON mode
2		Validate function of FSDPU		At the end of this SPIRE will be switched to REDY mode

Sequence	Duration [days]	Objective	Requirements	Remarks
3		Validate function of FSDRCU		
4		Verify function of cooler thermistors and heaters		
5		Verify function of mechanisms (Shutter (if fitted); BSM; FTS - see note)	To operate the SPIRE FTS mechanism the cryostat will need to be tilted over to 90 degrees about the Z axis.	
6		Cooler recycle	To recycle the SPIRE cooler the cryostat will need to be rotated about the Z-axis by at least 17 degrees	
7		Verify function of bolometers, detector readouts, thermal control heaters and temperature sensors		To do this properly will require either the use of the PLM GSE; the use of the SPIRE internal shutter or blanking the final shield within the cryostat
8		Verify function of Calibration sources		
9		Verify SPIRE Autonomy functions		
10		Verify SPIRE to CDMS interfaces and telemetry rates		This to include S/C switching SPIRE to SAFE mode in event of an anomaly
11		Validation of SPIRE deactivation (=shut-down) procedure		SPIRE will be switched to OFF mode
SPIRE Performance Test	~1.5			
1		Validation of SPIRE activation sequence and switch to SPIRE ready Mode		Takes SPIRE from OFF to REDY
2		Cooler recycle	Cryostat needs to be orientated correctly - see above	
3		Validation of SPIRE switching to standby mode		SPIRE switched to standby

Sequence	Duration [days]	Objective	Requirements	Remarks
4		Switch SPIRE to photometer OBSERVE		SPIRE switched to one of the photometer observe modes and placed in most straylight sensitive condition - shutter closed?
5		Cryostat background measurement	This requires GSE or blanked off shield	
6		EMI tests		Test for induced noise from whatever source in quiescent conditions
7		Conducted susceptibility		Inject EMC through supply lines
8		Test SPIRE FSFPU thermal behaviour in photometer observe mode		Run through typical photometer observing sequence in most "thermally intensive" mode - this will include operation of calibrators and BSM.
9		Switch SPIRE to spectrometer OBSERVE	Cryostat needs to be orientated correctly (see above). Test of how long it takes to switch modes.	
10		Test SPIRE FSFPU thermal behaviour in spectrometer observe mode		Run through typical spectrometer observing sequence - this will include operation of calibrators.
SPIRE AOT Test				
1		Test SPIRE photometer POFs		Details TBD - generates test data sets for interface checks with FINDAS and processing software etc
2		Test SPIRE spectrometer POFs		Ditto
SPIRE/PACS parallel Operation				

Sequence	Duration [days]	Objective	Requirements	Remarks
1		SPIRE switched to standby mode PACS as prime instrument		Details TBD
SPIRE Shutdown				
1		SPIRE switched from standby to OFF		If all tests are done contiguously then this only need happen once. If not then will need to have appropriate shut down and start up sequences at the beginning of each test period.

Table 7.2-1: Outline test sequence for the SPIRE CQM integrated in the CQM PLM.

7.2.2 PFM Testing

The PFM system level test procedures for SPIRE are TBW. It is expected that they will be for instrument and system verification and validation purposes only as the CQM testing will have addressed all fundamental operational issues. The sequencing and test environment requirements for the PFM testing will be the same, or very similar (TBC), as for the CQM testing shown in table 7.2-1.

7.3 Operations

Covered in other applicable documentation as follows:

AD 2	Herschel/Planck Operations Interface Requirements Document (OIRD)
AD 3	Herschel Science-operations Implementation Requirements Document (Herschel-SIRD)

7.4 Commonality

The SPIRE system level integration and test programme is compatible with that laid out in the IID-A chapter 7.

8 PRODUCT ASSURANCE

The instrument will comply with the ‘Product Assurance Requirements for Herschel/Planck Scientific Instruments’ (AD5).

Details are to be found in SPIRE Product Assurance Plan (RD2).

9 DEVELOPMENT AND VERIFICATION

9.1 GENERAL

These are guidelines that will be followed in constructing the instrument AIV programme:

- The instrument will be fully tested in compliance with the satellite level AIV plans as set out in the IID part A and reference documents therein.

- The AIV flow will be designed to allow the experience gained on each model to be fed into both the design and construction of the next model and into the AIV procedures to be followed for the next model.

- A cold test facility to house the instrument will be constructed that will represent as nearly as possible the conditions and interfaces within the Herschel cryostat.

- The instrument Quick Look Facility and commanding environment will be the same or accurately simulate the in-flight environment to facilitate the re-use of test command scripts and data analysis tools during in-flight operations.

- The EGSE and instrument Quick Look Facility will interface to FINDAS.

- Personnel from the ICC will be used to conduct the instrument functional checkout to allow an early experience of the instrument operations and to facilitate the transfer of expertise from the ground test team to the in-flight operations team.

- A more detailed description of the system level AIV sequence is given in reference document RD4. This document will form the basis of the *Herschel SPIRE Instrument Test Plan,* which will provide the baseline instrument test plans and detailed procedures and will be submitted to ESA for approval.

- Detailed procedures for the sub-system level AIV will be produced by all sub-system responsible groups.

- Sub-systems will undergo individual qualification or acceptance programmes before integration into the instrument.

- Sub-systems will be operationally and functionally checked at the appropriate level before integration into the instrument.

9.2 MODEL PHILOSOPHY

The model philosophy to be adopted for the AIV of the SPIRE instrument will be in accordance with the requirements of the Herschel IID part A. The instrument models to be produced are:

- AVM – Avionics Model.
- CQM - Cryogenic Qualification Model.

- PFM - Proto Flight Model.
- FS - Flight Spare.

See section 5.16.1 for more details

9.3 MECHANICAL VERIFICATION

TBD

9.4 THERMAL VERIFICATION

TBD

9.5 VERIFICATION OF SCIENTIFIC PERFORMANCE

TBD

9.6 ELECTRICAL TESTING

TBD

9.7 EMC TESTING

TBD

10 MANAGEMENT, PROGRAMME, SCHEDULE

All relevant information can be found in the SPIRE Management Plan, AD4.