Herschel/Planck

INSTRUMENT INTERFACE DOCUMENT

PART B

INSTRUMENT "SPIRE"

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TABLE OF CONTENTS

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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 HERSCHEL by Herschel. Changes maked by change bars (including editorial changes).
2-1	13/02/2001	Unpublished version	According to SCI/PT/MM-11440 And DCN .. Includes HP-SP-RAL-ECR-005, 06, 07, 12, 14. ECR 9 and 10 not agreed.
2.2	01/06/2002	PDR version	According to agreed changes published in Minutes of convergence meeting HP-ASPI-MN-1346
2.3 draft 4	02/07/2003	Before IHDR version	According to changes by SPIRE CR & all comments as here under (*)

(*) This issue of SPIRE IIDB takes into account or includes (or not) the following SPIRE CR and/or the ASED/ESA/SPIRE comments:

- HR-SP-RAL-ECR-032 : Removal of shutter

- HR-SP-RAL-ECR-049 : JFET 3D views (fig 5.4-3 & 5.4-4)

- HR-SP-RAL-ECR-048 : dimension & mass of units, table in §5.5

- HR-SP-RAL-ECR-009 v6 (not existing) : B.COLLAUDIN proposal, mail dated 20/03/03, file IID-B 2.3 section 5.7 THERMAL INTERFACES.doc according B.COLLAUDIN ECR009v7 proposal mail dated 02/07/03 and SPIRE IF telecon minutes H-P-ASP-MN-3310

- HR-SP-RAL-ECR-030 v2 : Temperature sensors table § 5.7.5.1 only, not applied for table § 5.7.5.3

- HR-SP-RAL-ECR-030 v3 : Temperature sensors table § 5.7.5.3 ASED HF proposal dated 07/03 (more reduced table from ASP BC proposal mail H-P-LT-3035 dated 23/04 not applied and to be discussed)

- HR-SP-RAL-ECR-050: SPIRE optical beam illustration fig 5.8-1

- HR-SP-RAL-ECR-046: Include HSDPU 1553B interface circuit §5.10.4.1

- HR-SP-RAL-ECR-029 v3: new harness definition, partially applied by SPIRE Harness definition document SPIRE-RAL-PRJ-000608 issue 1.1 (to become issue 1.2) added in annex 3, excluding internal overshield

- HR-SP-RAL-ECR-039v1 : : external overshield applied but internal overshield not applied, even if some harness and grounding corresponding figures are used for information only in sections 5.10.1 & 5.10.2

- HR-SP-RAL-ECR-033 : Update of various figures. Applied if not superseded by other CR (like CR 49, 29)

- HR-SP-RAL-ECR-040 v2: as ECR40 version v2 provided by SPIRE, the last ICD pack issue 6 is used as annex 1 (SPIRE-RAL-DWG-001409 issue 6)

- HR-SP-RAL-ECR-041 v1: not applied. Section 7.2.1: text proposed by ASPI mail GL dated 21/11/02 is applied in this draft

- HR-SP-RAL-ECR-044 v1: text of SPIRE CR added in section 5.6.1 as proposal only

- HR-SP-RAL-ECR-052 v1: Spire Herschel DPU 28V Power I/F pin-out error: will be in annex 3 (next issue 1.2 ?)

- Comments from Carsten Scharmberg (mail 15/05/03) on draft 2: applied (excluding table §5.7.5.3 for +/- 0.001K according ASED answer)

- Comments from John Delderfield (mail 14/05/03) for draft2 of sections 2 and 4 only: applied

- Comments from John Delderfield (mail 05/06/03) new figure 5.4-6: applied

- New drawings from ASED (Horst Faas) figures 5.3-1 & 5.3-2 : applied

- Comments from ASED Horst Faas mail 28/05/03 : applied

- Comments from ASED Armin Hauser § 5.7 mail 06/06/03 : partially applied (see ECR009v7 proposal)

- Comments from John Delderfield (mail 26/06/03) "IID-B comments for meeting 26june.doc"): partially applied

- Comments from fax ASED HP-ASED-FX-0586-02 dated 26/09/2002 "Response to ASPI CR 0174, IIDB evolution from issue 2.0 to 2.2" HP-ASED-FX-0586-02: partially applied

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 is the result of a specific instrument's design activity. defines In its 'interface' section (chapter 5) are defined 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 Product Assurance Requirements for Herschel/Planck Scientific Instruments Ref. SCI-PT-RQ-04410

AD 3 Herschel/Planck Operations Interface Requirements Document OIRD Ref. SCI-PT-RS-07360.

AD 4 Herschel ~~Or Planck~~ Science-operations Implementation Requirements Document - SIRD Ref. SCI- PT-03646

AD 5 Herschel/Planck Packet Structure Interface Control Document - PSICD Ref SCI-PT-ICD-07527

AD 6 Telescope specification / Herschel: SCI- PT-RS-04671_5_0

AD 7 Alignment Plan ~~Concept~~ / Herschel: Ref. HP-2-ASED-TN-0002 (Annex of AD1)

AD 8 Software standard "ECSS E 40 B ~~/ PSS-05-02~~"

~~**AD 9** Guide to applying ESA Software Standards to small projects : Ref. ESA-BSCC(96)2~~

2.2 REFERENCE DOCUMENTS

RD 1 SPIRE Instrument ~~design description ….~~ Requirements Document (IRD) SPIRE-RAL-PRJ-000034

RD 2 SPIRE Instrument ~~specification~~ Design Description SPIRE-RAL-PRJ-000620

RD 3 SPIRE Data ICD, SPIRE-RAL-PRJ-001078 (covers both telemetry and command data)

RD 4 SPIRE Management Plan ~~, (SPIRE-RAL-PRJ-000029)~~

RD 5 SPIRE ~~Instrument Development Plan~~ Science Requirements Document (SRD) SPIRE-UCF-PRJ-000064

RD 6 SPIRE Instrument AIV Plan, SPIRE-RAL-DOC ~~oc-PRJ~~-000410

RD 7 SPIRE Product Assurance Plan SPIRE-RAL-PRJ-000017.

RD 8 ~~HFI-LFI interface requirements~~ SPIRE Block Diagram SPIRE-RAL-DWG-000646

RD 9 SPIRE product tree

RD 10 Instrument WBS (inside RD4)

RD 11 Instrument Science Implementation plan

RD 12 ~~Instrument harness description~~ cancelled

~~Or :RD 12 SPIRE Grounding and Screening Philosophy SPIRE-RAL-PRJ-000624 TBC~~

RD 13 ~~Instrument reduced thermal model~~SPIRE CRYOGENIC INTERFACE THERMAL MATHEMATICAL MODEL (ITMM) SPIRE-RAL-PRJ-000728

RD 14   Instrument reduced FRM Model

RD 15 ~~Caldwell, M., Richards, A., Swinyard, B., Straylight Analysis - PHOT, SPIRE-RAL-NOT-000144~~ Spire Straylight References SPIRE-RAL-NOT-001124 .

RD 16   Swinyard. B , Power profiles for SPIRE operating modes, RAL-NOT-000068.

RD 17   SPIRE Operating Modes, SPIRE RAL-PRJ-000320

RD 18   SPIRE Thermal Configuration Control Document, SPIRE-RAL-PRJ-000560

RD 19   Herschel SPIRE Harness Definition, SPIRE-RAL-PRJ-000608

RD 20   Spire requirements on Cryostat Apertures SPIRE-RAL-NOT-01242

RD 21   Matching SPIRE - HOB Decentre and tilt amplitudes to the Photometer pupil alignment budget SPIRE-RAL-NOT-000754

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
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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3.2 RESPONSIBILITIES

INSTITUTE	RESPONSIBILITIES
ATC, Edinburgh	Beam steering mechanism
CEA, Grenoble	^{3}He cooler
CEA, SAp, Paris	Detector Readout and Control Unit (DRCU); ICC DAPSAS Centre;
DESPA, Paris	FTS expertise and design support
GSFC, Maryland	FTS Expertise and design support;
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
University of Wales, Cardiff	Focal plane array testing; filters, dichroics, beam dividers
RAL, Oxfordshire	Project management and Project Office, System and Thermal Engineering; AIV and ground calibration facilities; ICC Operations Centre
Stockholm Observatory	Instrument simulator; DRCU Simulator
University of Padua	Provision of ICC Operations Staff
University of Saskatchewan	~~Shutter~~ OGSE Fourier Spectrometer + Science Support

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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.
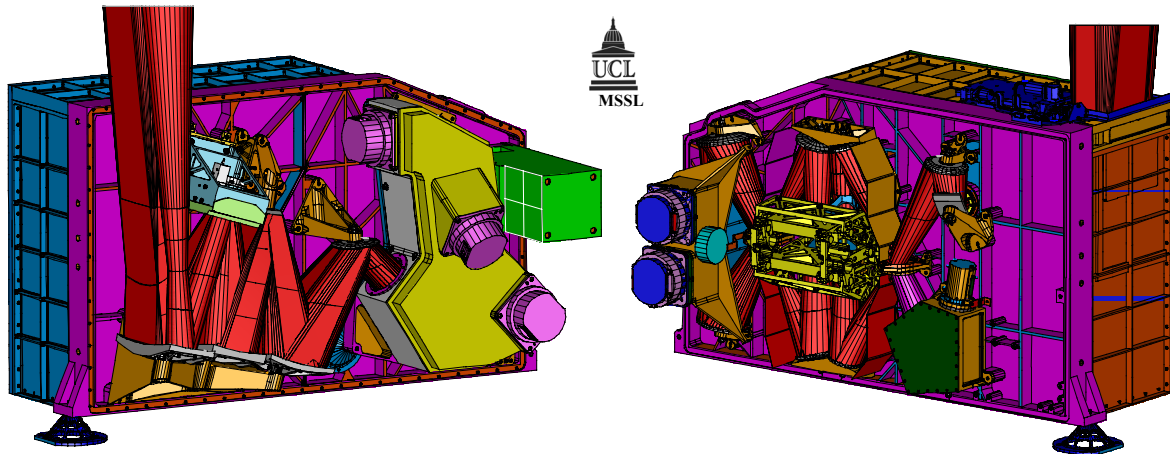
Figure 4.1 ~~Spire in Herschel~~Two halves of Spire: photometer shown on left, spectrometer on the right"

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.

~~HSFB~~P~~H~~   JFET box for the photometer detectors
SJFP   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~~H   JFET box for the spectrometer detectors
SJFS   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, and 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 refrige~~i~~rator operation. It conditions secondary power both for itself and for the DCU.

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~~ SPIRE electronics boxes.

4.5 SOFTWARE DESCRIPTION

The SPIRE OBS will carry out the following functions:

- Read and log housekeeping data and packetise the data that these produce.

- 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.~~Commands ~~conforming to AD5~~ defined in RD5 and conforming to AD5 will be sent via a HERSCHEL 1553 bus to the active HSDPU. The Spire OBS in the HSDPU will verify and then interpret these commands. Many will result in a sequence of internal digital commands which are then sent with appropriate timings to the HSDCU and/or the HSFCU.

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.

For latest information, refer to RD ~~6~~17.

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).

For latest information, refer to RD 617.

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.

4.8.2 Instrument Performance Estimates

4.8.2.1 Assumptions

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

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 Field mapping	4 x 8 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		

Table 4.1: Assumptions for SPIRE Performance Estimation

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.

		Photometer			FTS band (μm)	
		250	350	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

Table 4.2: Background Power and Photon Noise Levels

The estimated sensitivity levels for SPIRE are summarised in Table 4.3. The figures quoted are the nominal values, with an overall uncertaintyof 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
$\Delta S(5\text{-}\sigma; 1\text{-hr})$ 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° x 1° scan map		1.8	1.7	1.9

Line spectroscopy $\Delta\sigma = 0.04$ 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 $\Delta\sigma = 1$ 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 ($\Delta\sigma$). 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
HSDPU	Digital Processing Unit	On SVM	Warm
HSFCU	FPU Control Unit	On SVM	Warm
HSDCU	Detector Control Unit	On SVM	Warm
HSJFS	JFETs (Spectrometer)	See section 5.3	Cryogenic
HSJFP	JFETs (Photometer)	See section 5.3	Cryogenic
HSFPU	Focal Plane Unit	See section 5.3	Cryogenic
HSWIH	Warm interconnect harness	See section 5.10	Warm

The HSFCU is a physical unit containing three~~two~~ functions, the HSSCU and the HSMCU meaning the HS Sub-System Control Unit and the HS Mechanisms' Control Unit respectively, plus the HSPSU that provides secondary power to all parts of the Spire DRCU.~~.~~

[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 HSDCU plus the HSFCU.]

There are four groups of harnesses at instrument interface level,

–   HSWxx,

–   HSIxx

–   HSSxx

–   HSCxx

where xx represents a number.

The HSWxx are Warm harnesses between Warm HS units on the SVM.

HSSxx are the SVM ~~(copper)~~ cryoharnesses between the SVM connector brackets and the HS Warm Units.

The HSIxx are intermediate cryoharnesses, which are external to the cryostat, and are situated between the vacuum connectors and the connector bracket on the SVM.

The HSCxx are cryogenic cryoharnesses located inside the cryostat, between the vacuum connectors and the HS Cryogenic units.

The HSIxx, HSSxx and HSCxx are all considered to be "Cryoharness" and are not provided by the Spire instrument.

The two F harnesses (FPU sub-system F harness) between JFETs and FPU (HSFPU-HSJFP and HSFPU-HSJFS) are provided by SPIRE with the instrument units.

"ESA's contractor will also provide any safing plugs needed (TBD) for the cryoharness"

5.2 INTERFACE LOCATIONS

All of the above may be visualised by means of the block diagram, shown in figure 5.2.1 (see RD 8). 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. This diagram is for information only, and shall not represent any requirement on the spacecraft.

Note that, to be precise, these electrical interfaces are at the connector planes.

Overshield on cryoharness must not be taken into account as CR 39 doesn't have positive answer from ESA. If CR 39 is formally rejected by ESA, all figures and tables including or refering to this overshield shall be reissued.

Following the teleconference of clarification about the SPIRE overshielding (2003-05-20 - HP-2-ASED-MN-390), and according to the instruction of ESA, it has been agreed to apply partially the SPIRE ECR 39v1 :

▪ include the additional external overshield (between SVM warm units and Connector Bracket (CB), and between the CB to CVV external wall),

▪ not include the internal (inside CVV) overshield, and keep the connection by wires from the CB to the FPU ground. The configuration of which is still under discussion, see HP-2-ASED-MN-390 dated 27/5/03 as distributed by ASED.

So in this present document and in this section 5, Internal Overshield corresponding to SPIRE ECR 39v1 must not be taken into account, and all figures and tables including or referring to this internal overshield shall be reissued.

Figure 5.2.1 : Spire Block Diagram – version 5.34.4

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 nearby JFET racks. ~~This accommodation may be subject to detailed evolution.~~
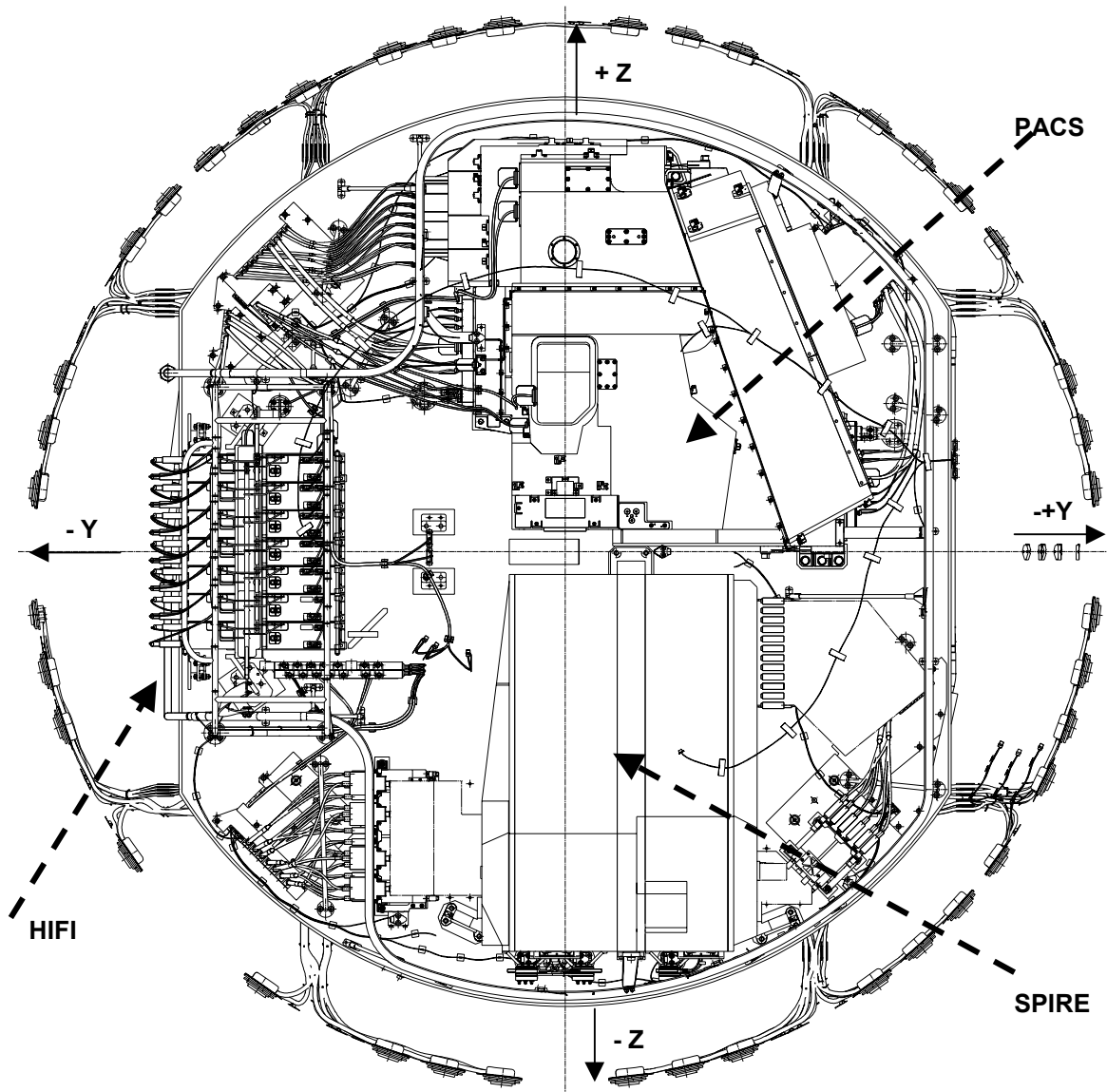
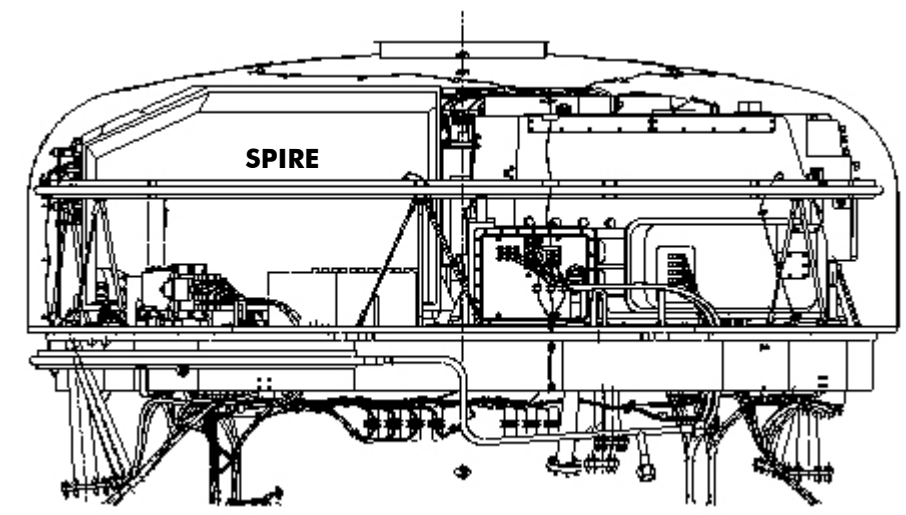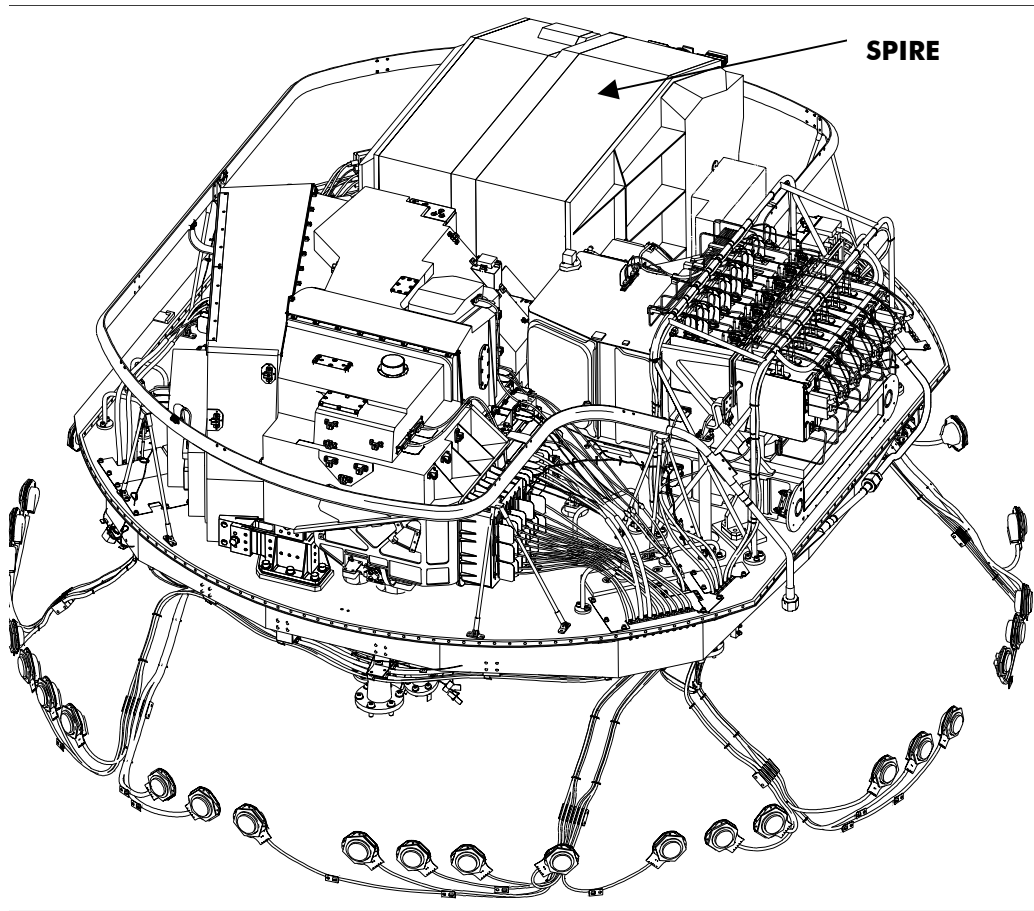**Figure 5.3-1: The Herschel Focal Plane, top view towards -X**

Figure 5.3-2: The Herschel Focal Plane general and, 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 HSDCU and HSFCU need 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 HSDCU and the HSFCU is critical. As a goal, the location of these two units on the SVM should enable this length to be kept below 0.8m.

5.3.2 Instrument Alignment on the HOB

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

The HSFPU has an externally viewable alignment cube as shown on its ICD. Both the cube's angular alignment and the position of the HSFPU 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 ~~RD 7~~AD7. 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 readibility only. ~~They are all controlled Spire drawings at their latest issue.~~

The fully configured detailed interface drawings are provided in annex 1.

5.4.1 HSFPU

An overview of the HSFPU is provided below in Figure 5.4-1. More detailed drawings of the SPIRE focal plane and JFET units, showing their relationship to the Herschel focal plane, the cryostat radiation shield and the diameter of the HOB, can be found in Annex 1. ~~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.~~
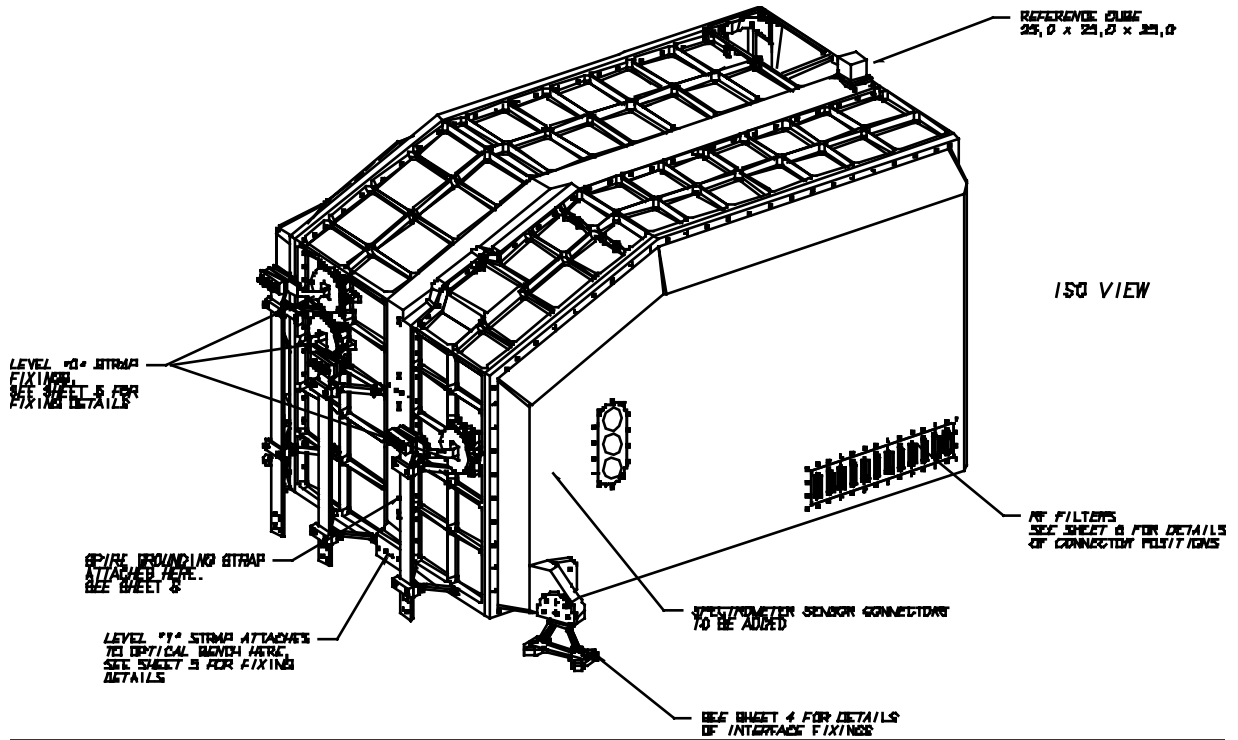
Figure 5.4-1 : HSFPU overall view

5.4.2 HSJFS

Figure 5.4-3 provides an isometric view of the Spire Spectrometer JFET rack. More detailed drawings can be found in Annex 1.
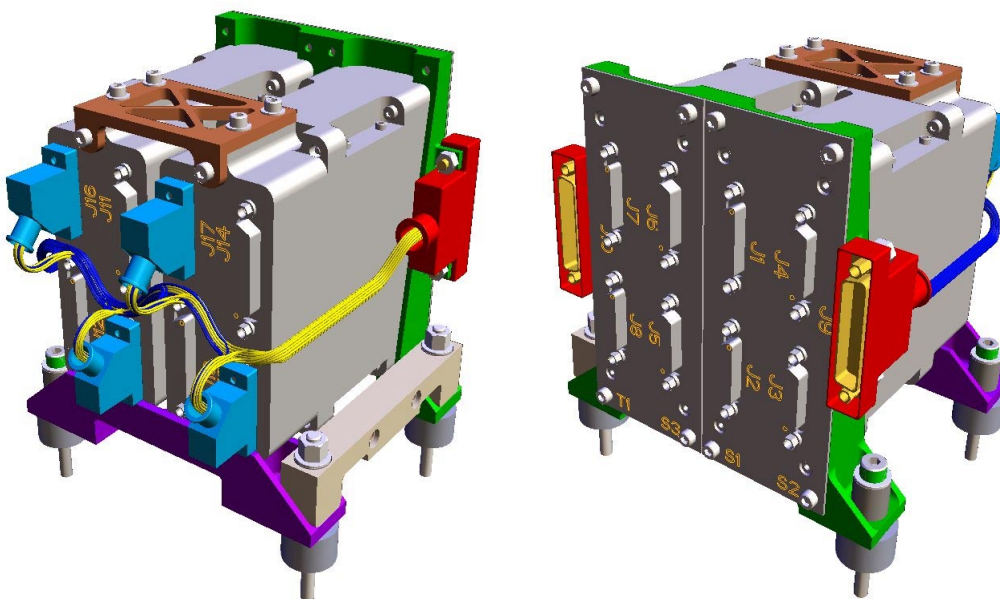
Figure 5.4-3 : SPIRE Spectrometer JFET rack external configuration

5.4.3 HSJFP

Figure 5.4-4 provides an isometric view of the Spire Photometer JFET rack. More detailed drawings can be found in Annex 1.
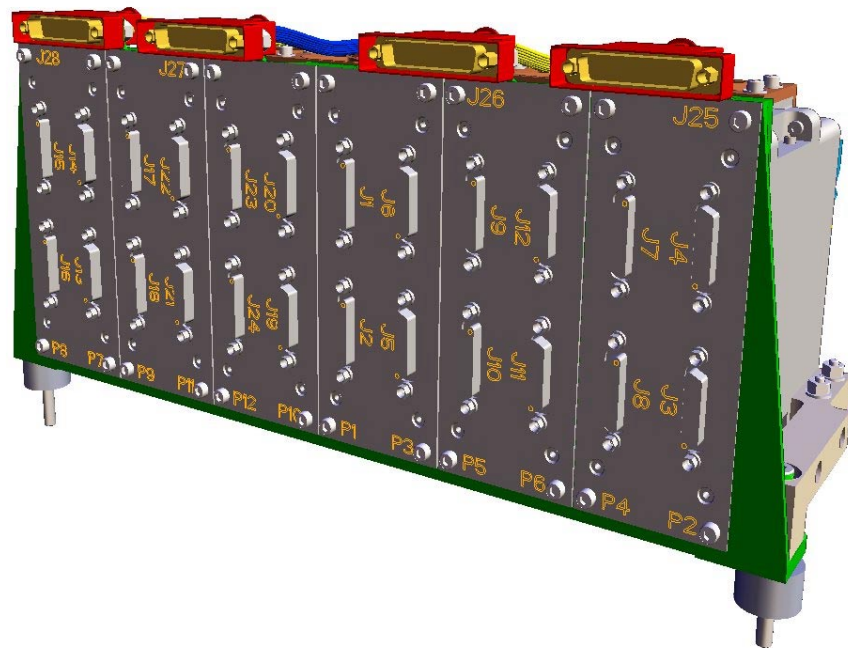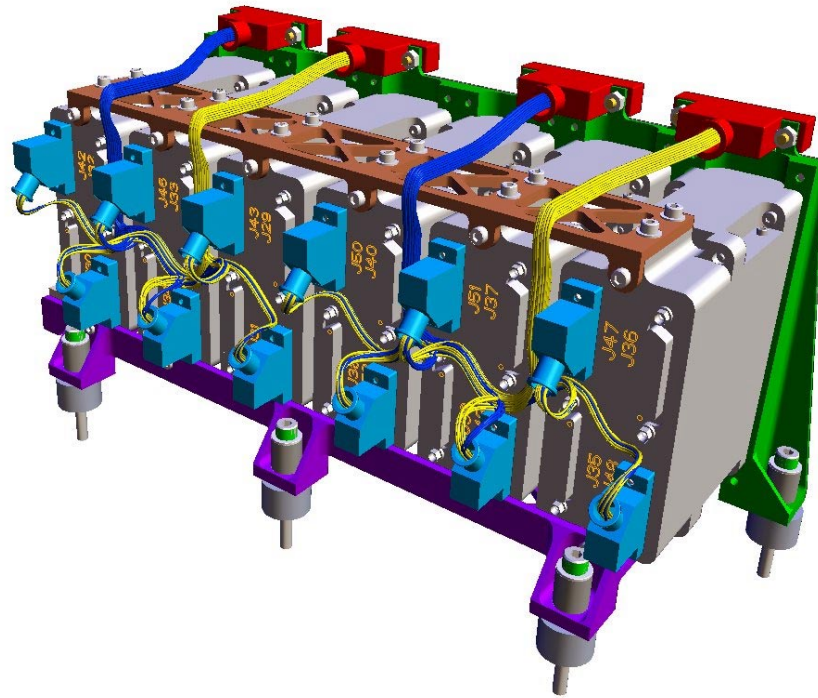
Figure 5.4-4 : SPIRE Photometer JFET rack external configuration

The location of both of the JFET racks is 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.

5.4.4 SVM Mounted Units.

Drawings of the layout of the SPIRE Warm Units on the SVM are provided in the corresponding section of the IIDA.

The following sub-sections provide an overview of the warm units, whereas detailed interface drawings can be found in Annex 1.

5.4.4.1   HSDPU

Figure 5.4-6 shows an isometric view of the Spire Digital Processing Unit More detailed drawings can be found in Annex 1.
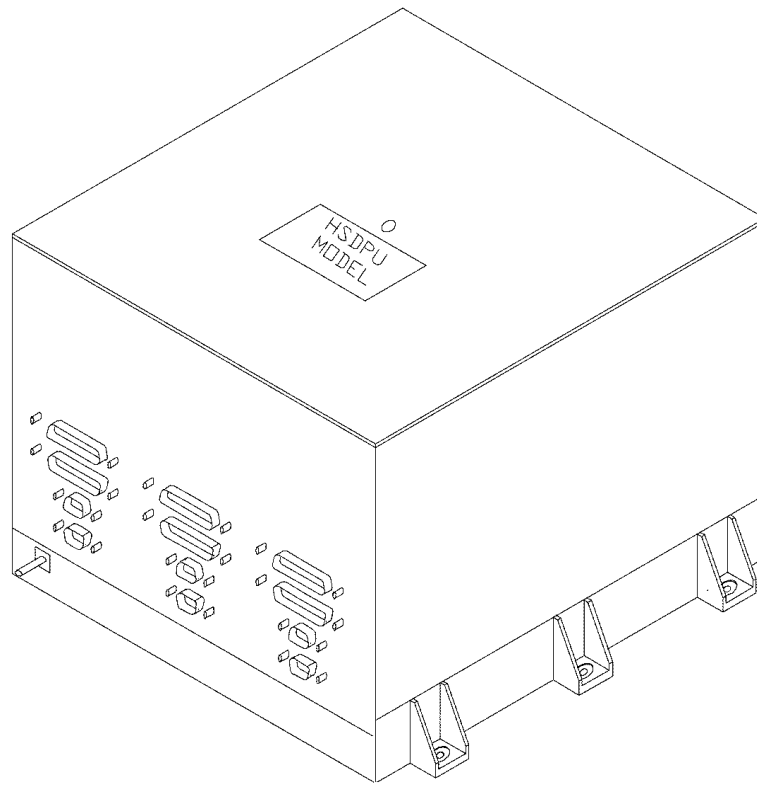
Figure 5.4-6 Isometric view of the DPU

5.4.4.2   HSDCU

Figure 5.4-7 shows an isometric view of the Spire Detector Control Unit. More detailed drawings can be found in Annex 1.
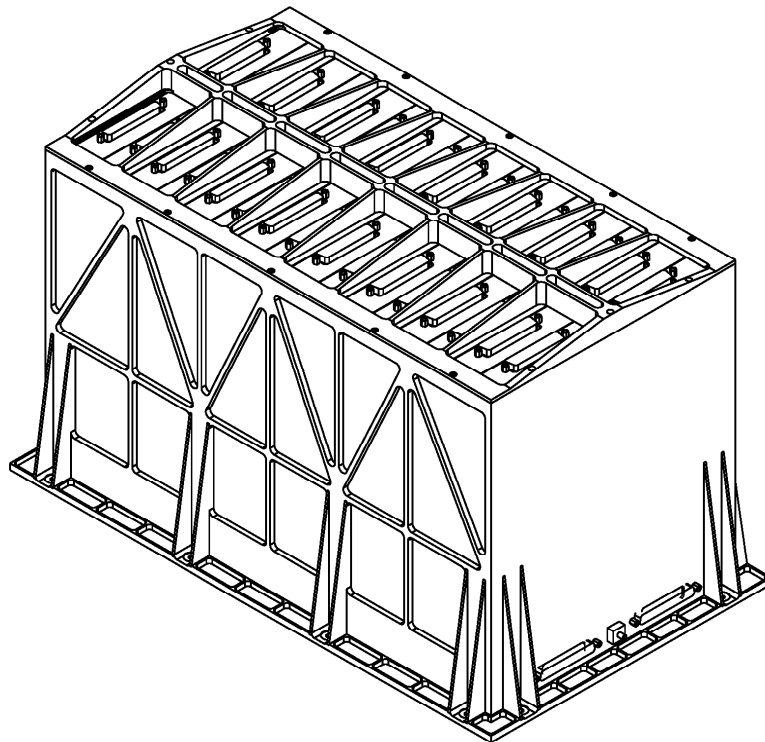
Figure 5.4-7 : HSDCU external configuration

5.4.4.3   HSFCU

Figure 5.4-8 shows an isometric view of the Spire FPU Control Unit.
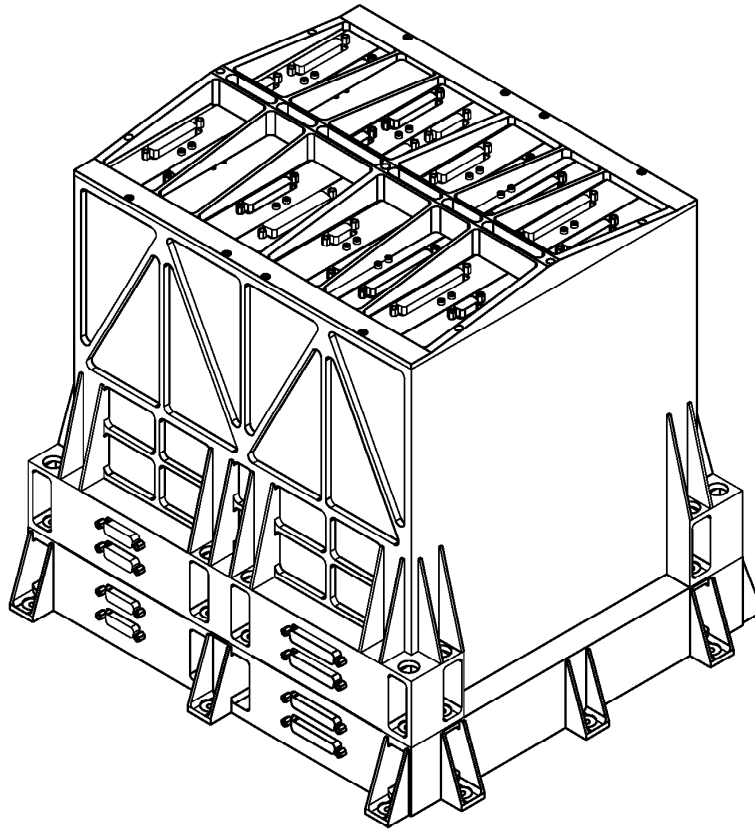
Figure 5.4-8 : HSFCU external configuration

5.5 SIZES AND MASS PROPERTIES

The mass budget is a mission critical item and no possibility is foreseen to negotiate any higher values for the allocated totals shown in bold in the following table:

Note: SPIRE CR 48 v1 applied to this table

Project Code	Instrument Unit	Dimenions (mm) incl~~uding~~. feet~~, & Drawing References.~~	Nominal Mass without margins (kg)	Allocated Mass (kg)
~~F~~**HS**FPU	HS Focal Plane Unit (*)	Non-rectangular~~, see section 5.4. drawing refs. : 5264 / 300 sheets 1,2 … 6.~~	44.81~~45.5~~	47.2~~46.3~~
~~F~~**HS**JFP	HS JFET Rack Photometer	124.6 x118.2 x 274.5 ~~270.5 x 104 x 114 TBC~~ ~~6 JFET Assembly – KE2896 – 30/11/01.~~	2.51~~3.0~~	2.8~~3.3~~
~~F~~**HS**JFS	HS JFET Rack Spectrometer	114.2 x 114 x 112.5 ~~108.5 x 91 x 104 TBC~~ ~~2 JFET Assembly – KE2897 – 30/11/01.~~	0.89~~1.2~~	1.0~~1.4~~
		Total SPIRE OB Units	**48.21**~~49.7~~	**51.0**
~~F~~**HS**FCU	HS FPU Control Unit ~~Digital Processing Unit~~	325 x 370 x 335 ~~374 X 409.1 X 330~~ ~~SPIR-MX-5200 000 A – 12/01/02.~~	15.28~~14.3~~	15.0

FHSDCU	HS Detector Control Unit	490 x 285 x 305 ~~494 X 289 X 305~~ ~~SPIR-MX-5100-000 A – 11/01/02.~~	15.68~~15.4~~	15.5
FHSDPU	HS Digital Processing Unit	274 x 274 x 194 ~~274 X 258 X 194~~ ~~HER S003/02 – 10/02/02.~~	6.6(**)2~~7.0~~	7.0
FHSW1-8	HS Warm Inter-unit Harness	To Alenia layout	1.5	1.5
		Total SPIRE SVM Units	**39.08**~~38.2~~	**39.0**
		SPIRE Instrument Total	**87.29**~~87.9~~	**90.0**

(*): HSFPU includes attached flying leads and any FPU thermal strap supports.

(**): 7.18 against 6.6 given for HSDPU during IHDR (total becomes 39.64 and 87.84), TBC by SPIRE by a further CR

The drawings for all these items are in annex 1, in SPIRE-RAL-DWG-001409 issue 6~~4~~

Dimensions are given in the order ~~as~~ XxYxZ, and XYZ axis are defined on each unit drawing in annex 1 ~~Length x Width x Height, the first two applying parallel to the mounting surface~~.
Dimensions including mounting feet, excluding connectors.

5.6   MECHANICAL INTERFACES

Note: Electrical and thermal characteristics conferred by these mechanical interfaces are covered in the appropriate sections, not here.

5.6.1 Inside cryostat

The Focal Plane Unit, the HSFPU, 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.

Proposal of SPIRE ECR 44:

Details to Spire JFET Mechanical interface:

- HOB Interface surfaces shall be controlled over at least a radius of 9mm about each JFET foot mounting point.

- To avoid compromising the Kapton insulation on the feet, the HOB surface in these zones shall be

unscratched and smoother than 0.8 micron mean peak/trough surface roughness This finish only needs

to be confirmed by visual comparison with finish gauges and not by formal stylus inspection.

- The HOB JFET M4 mounting holes shall provide 2D depth self-locking threads with relief at least

equivalent to a 0.5mm 45deg. chamfer at their outer ends.

Note that the JFET I/F drawings in annex 1 now specify the nominal diameter of all the feet to be 16mm. The smoothness and C/sunk or bore are necessary to maintain electrical insulation.

5.6.1.1   Microvibrations

Spire's mechanisms (SMEC and BSM) are sensitive to m-vibrations between 0.03 Hz and 300 Hz, with the potential effect of displacing the SMEC suspended mirrors from their optical positions. The bolometers, as they

are accommodated, probably have a similar susceptibility to HOB-driven microvibrations. This is potentially due to harness flexure /capacitance changes, rather than to movements of the detector elements themselves.

Spire needs knowledge of the level of the microvibration-induced forces on the HSFPU at its HOB interface, in order to ensure they can be mitigated. The expected levels of input acceleration are to be provided by ESA/Alcatel, over the frequency range between 30 Hz and 300 Hz.

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 provided A-frames on the outside of the FPU, designed to minimise the forces the straps can apply to thermal lead-throughs, but not be Ohmic shorts. Separate supports are needed to minimise cross-coupling between the two sorption cooler straps.~~

SPIRE requires the following thermal straps:

- 3 Level-0 thermal straps

- 2 Level-1 thermal straps

- 2 Level-3 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 HERSCHEL to Spire interfaces for the L0 straps are at three standardized points just above the HOB plate. For information, inside SPIRE, these thermal straps will be steadied by non-metallic Spire provided A-frames on the outside of the FPU, designed to minimise the forces the straps can apply to thermal lead-throughs, but not be Ohmic shorts. Separate supports are needed to minimise cross-coupling between the two sorption cooler straps.

5.6.2 Outside Cryostat

NA

5.6.3 On SVM

The three units mounted on the SVM will each have 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 be attached to the SVM via TBD ESA provided hold-down 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 improved.

5.7.1 Inside the cryostat

Note: All this section 5.7.1 corresponds to ECR009v7 ASP proposal dated 02/07/03, to be agreed and updated

5.7.1.1 Description of the thermal interfaces

Spire uses 4 thermal stages to run 300mK detectors inside a ^{4}HEII cryostat,. These link into levels provided by the Herschel cryostat. An overview of the **Spire** system is as follows, drawn with the heat switches associated with its 300mK cooler set as for an observing mode.
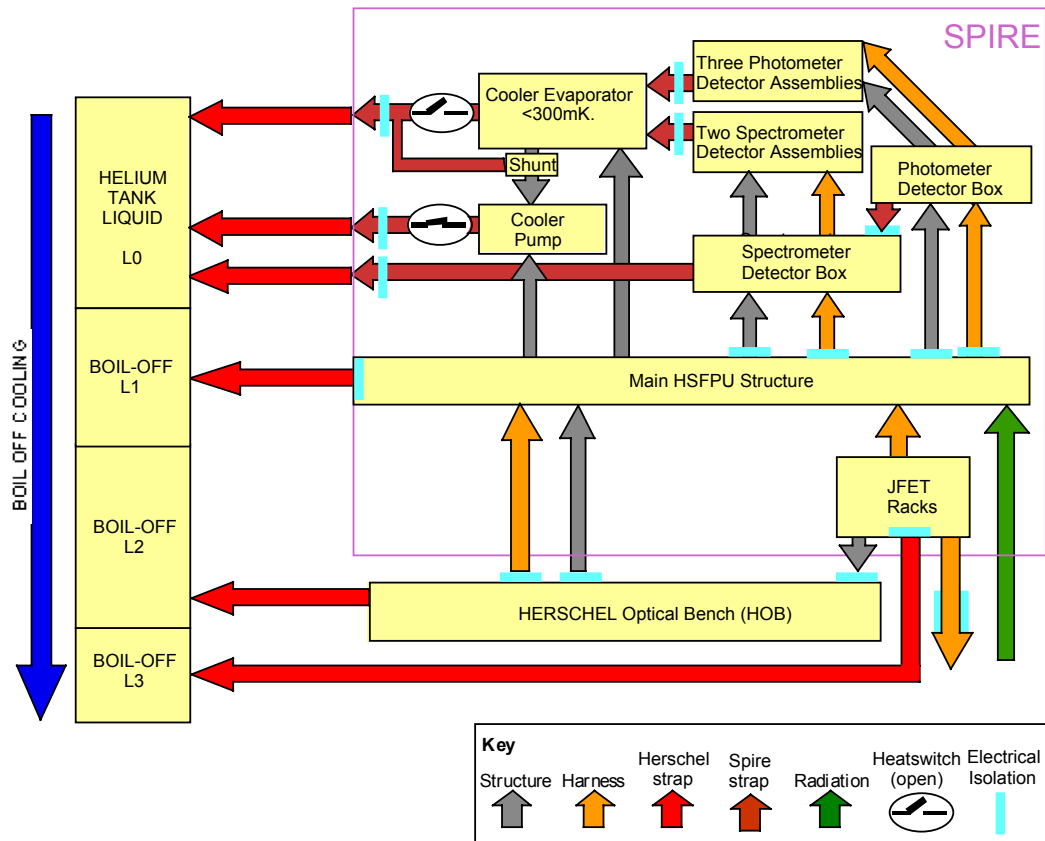
Figure 5.7.1: SPIRE system overview

Electrical insulation is not shown here for electrical purposes but rather because where high thermal conduction is needed it adds to the design challenge. The radiative loads on Spire, shown in green, potentially come from warm baffles "seen" off-axis up the optical beam aperture. The arrow for external harness loads on the JFETs is not joined to anything specific as this depends on design decisions taken by Astrium.

Spire has two detector optical box structures, one housing the photometer detectors and one the spectrometer's. They mount on thermally isolating mounts inside the HSFPU and, to minimise the heat leak to

IIDB SPIRE

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DATE :	02-07-2003
ISSUE :	2.3 DRAFT 4 **PAGE**: 5-15

the 300mK detectors themselves, link to the lowest available temperature, the L0 cryostat liquid sink. The spectrometer box has an external L0 interface and the photometer is then linked from it internally to the HSFPU, so together they only require one external I/F strap to L0.

As shown above, there are two other L0 interfaces associated with the 300mK sorption cooler which will be described below.

Not shown in the above overview are the small thermal loads on the **Spire** side of the I/F on the three L0 straps, due to their necessary mechanical support to the FPU.

The main HSFPU mountings to the HOB are also designed to be thermally isolating, so that the HSFPU can run at L1 whilst the HOB itself is at L2. The HOB tends to warm the HSFPU, which is why the structure and harness heat flow arrows are as shown.

When operational, JFET racks have a comparatively high dissipation. Fortunately, within reason, it is actually advantageous to run them a little warm. They therefore attach further up the boil-off line sequence to L3. Note that **Spire** plans to only power one rack at a time, either spectrometer or photometer and, depending on which is the more thermally demanding mode to operate in, their order on the L3 pipe is significant. Due to gas flow, the earlier can heat the later (with a heat path back into the FPU) but not visa versa.

To provide the required overall thermal balance boundary, the cryostat's inner instrument shield forms an enclosure at level 2, and the effective temperature seen from the surface of the HSFPU, integrated over an outward hemisphere, needs to be well specified.

5.7.1.2   Description of Operation and Interfaces for the 3He Cooler

The **Spire** [3]He cooler is closed and does not have a lifetime limit as cryogen boils away. However it cannot cool continuously but rather it needs to be re-generated regularly. This energy cycle is a small but significant contribution to the total dissipation within the Herschel cryostat.

When operational, Spire runs a 48 hour [3]He cooler cycle, 46 hours with **Spire**'s detectors cooled to "300mK" and 2 hours recycling.

Achieving the 46 hours lifetime requires both low parasitic flows inside the cooler and that **Spire** only places a limited load on the cooler's 300mK cold-tip, typically so these sum to less than 29 µWatts (this is not an external I/f and is only stated here for information). At this loading the cooler provides <300mK at its cold-tip. However achieving all these factors depends strongly on the environmental temperatures provided by the Herschel cryostat at all the four levels.

The two L0 straps associated with the cooler carry low heat flows during the 46 hours cooled to "300mK", and so this is not the mode which sizes the requirements on them. Only the pump heat switch is ON (closed) and the load approximates to the thermal strays + 50 times the heat lift at 300mK, the latter power being determined by thermodynamics. However the requirements on these two L0 straps during the 2 hours recycling are much more demanding, and need to be considered all the way from the cooler to the [4]HEII bath before apportioning **Spire**/Herschel interface values partway along their length.

During the first, i.e. the condensation, phase of recycling, the evaporator heat switch is closed and the pump's switch opened. The sorption pump is heated to 40-45K. Condensation occurs in the evaporator. Almost all the cooler's He charge needs to be condensed so **Spire** can meet the holdtime for its subsequent 46 hours at 300mK. The temperature of the evaporator at the end of condensation is critical. Again this is a parameter internal to **Spire**, even being internal to one of its subsystems, but modelling without margins shows that it needs to be <2K. With some heat flow along a strap, the challenge of achieving this so far from the main Herschel cryogen is non-trivial given it implies a heat switch I/F temperature of 1.85K, again an internal **Spire** interface..

It is also vital during this process that the shunt extracts nearly all the heat from the hot gas travelling from the pump to the evaporator; it should typically stay below 6K. The hot gas emitted from the pump limits the power that can be applied to heat the pump and thus how quickly re-cycling can be achieved. Note that faster recycling means less integrated heat leak out from the hot pump and more efficient use of the main Herschel

cryogen. On the other hand, taking longer than 2 hours would eat into the baseline observing efficiency. The overall shunt strap actually needs a tuned conductance because it has also to go above 3K to avoid [3]He condensing on it instead of in the evaporator.

At the end of the condensation phase of the cooler's regeneration, the switch on the evaporator is turned OFF (open) and then the heat switch on the pump is turned ON (closed). There is a substantial peak power via the strap from the sorption pump as it re-cools. Although this peak may be minimised by careful slow operation of the switch, it will have a significant temporary impact on the thermal gradient along the strap. There is a suggested requirement that the pump heat switch I/F at the cooler, again a **Spire** internal interface, should not go above 10K during this heat flow pulse.

A fraction of the [3]He charge is then expended cooling both itself and the evaporator/detectors down to 300mK, which we take to be the end of recycling. This leaves an amount of [3]He available to cool the Spire 300mK section for 46 hours.

It is baseline to the operation of these coolers that the pump and evaporator have separate straps back to the [4]HeII because otherwise the heat-pulse that occurs as the pump is cooled could heat the evaporator and waste lots of the available [3]He charge.

Test results for the recycling of the flight type 6 litre coolers are now available. They still come with a warning that they have been obtained at unit level with 200mW/K strap impedances from both the straps from the cooler heat switch interfaces(which are not **Spire**/Herschel Interfaces) to the [4]HeII.
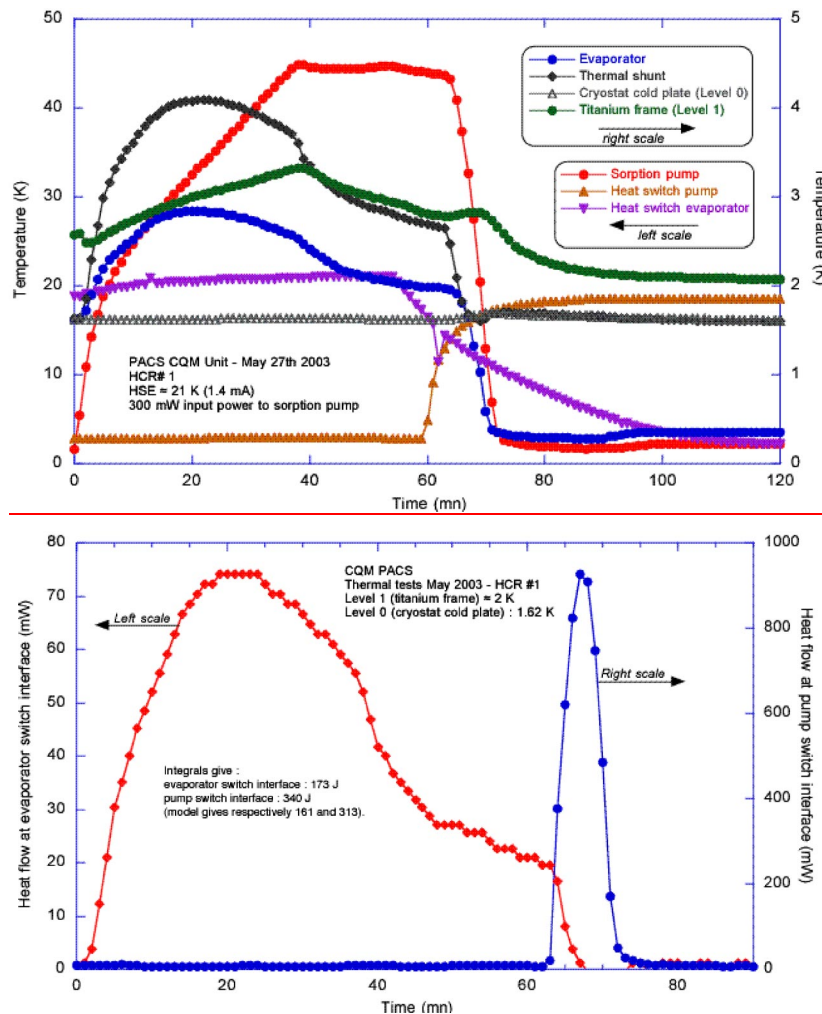
Figure 5.7.2: Measured temperature and heat-flow

There is one variation under consideration by **Spire**. The 2K evaporator requirement at the end of the condensation phase [typically 1.85K at the cooler's heat switch interface inside the instrument] is sufficiently challenging to achieve that we are considering putting the shunt on the pump's strap rather than on the evaporator's, see thermal overview drawing at the start of this section. This would avoid 15 or so mWatts from the shunt travelling down the evaporator strap at this stage in the recycling, which at present has the effect of increasing the temperature drop along it. Caveat: it's not clear yet if this alteration has other significant disadvantageous side-effects. Worst case temperatures

5.7.1.3   Thermal requirements

Two major thermal requirements for SPIRE are its sorption minimum cooler cycle time of 48h, and its cold tip temperature of < 290mK.

The table below shows the required operating temperatures and design heat flows at the thermal interfaces of the instrument unit with the cryostat or parts thereof :

SPIRE FPU thermal I/F		**in-Orbit (cycle 48h assumed)**				**Ground**								
		Operation		Recycling Cooler		Operations FM (IMT/IST)		Operations EQM		Cooler recycling		non operating		
		46h		2h		46h		46h		2h				
		Max I/F Temp.	Max Heat load	Max I/F Temp.	Max. Heat load	Max I/F Temp.	Max. Heat load	Max I/F Temp.	Max. Heat load	Max I/F Temp.	Max. Heat load	max continuous temperature	Bake out temperature (72h max)
L0	SPIRE SM Detector enclosure [814]	**2.0 K (i)**	**4 mW**	N/A	N/A	Same as in orbit						60.0 °C	80 °C
	SPIRE Cooler Pump strap [node 815]	2.0 K	1.0 mW (ii)	**10.0 K**	**350J /1560s (triangular profile ⌐⌐)**							60.0 °C	80 °C
	SPIRE Cooler Evaporator strap [node 816]	2.0 K	0 mW	**2.0 K (iii)**	**30mW for strap design (iv)**							60.0 °C	80 °C
L1	SPIRE L1 (two straps) [node 800]	**5.5 K (v)**	**15 mW**	5.5 K	15 mW	7.0 K TBC	15 mW TBC (vi)	7.0 K TBC	15 mW TBC (vi)	7.0 K TBC	15 mW TBC (vi)	60.0 °C	80 °C
L2	SPIRE L2 (Optical bench / FPU legs)	12.0 K	-	12.0 K	-	12.0 K	-	12.0 K	-	12.0 K	-		80 °C
L3	SPIRE L3 HSJFP, HSJFS	15.0 K	50 mW 25 mW	12.0 K	0.0 mW	12.0 K	50 mW 25 mW	12.0 K	50 mW 25 mW	12.0 K	-		80 °C

note   Sorption Cooler Recycling phase is composed of 2 phases in sequence

- 3He condensation (duration 3600s TBC), evaporator switch closed, pump switch open

- Pump cooling phase & evaporator cooling (duration 1560s TBC) evaporator switch open, pump switch closed

(i)   According to the current HPLM requirements the temperature of the Helium in the tank should be <1.7K, the conductance of the detector strap (helium to thermal interface) is > 0.05W/K, therefore with 4mW, the thermal interface should be < 1.78K

(ii)   the maximum average dissipation during operation includes the heat peaks during recycling

These peaks constitutes most of the average dissipation on 48h, therefore, during operation there should remain almost nothing (condensation heat on pump strap (heat switch closed), 1mW allocated, TBC)

(iii)   SPIRE requires 1.85K at the evaporator interface, to guarantee a low enough temperature at the sorption cooler evaporator, and good efficiency of the 3He condensation, to get 48h cycle time.

The requirement applies at the thermal interface during 200s at the end of condensation phase

(iv)   the evaporator strap heat profile comes from 3He condensation in the evaporator, and on the shunt located on the pumping line (140J/3600s triangular profile) + 15mW constant conduction from pump to shunt. The 2 K requirement for cooler recycling applies only for 700s (TBC) at the end of condensation, which lead to an evaporator strap design for 30mW/<2K. With 1.70K at the tank, the strap conductance should be about 100mW/K

(v)   SPIRE requires L1 temperature below 4.5K to guarantee recycle time of the sorption cooler.. Transient evaluation with typical dissipations of all instruments (operation & standby mode) gives L1 temperatures between 4 K and 5.6K, depending of the detail of the sequence of the observation. A requirement of 5.5K is kept here

(vi)   During instrument ground test (IST/IMT), the cryostat vent line is flushed with 100mg/s from the auxiliary tank, and the cover is flushed with LN2. The heat flow on L1 is dominated by the radiation trapped from the cover environment (gaps). Only the SPIRE expected flow are indicated here.

These environments are still under investigation, and it should be made clear that the cooler can be recycled.
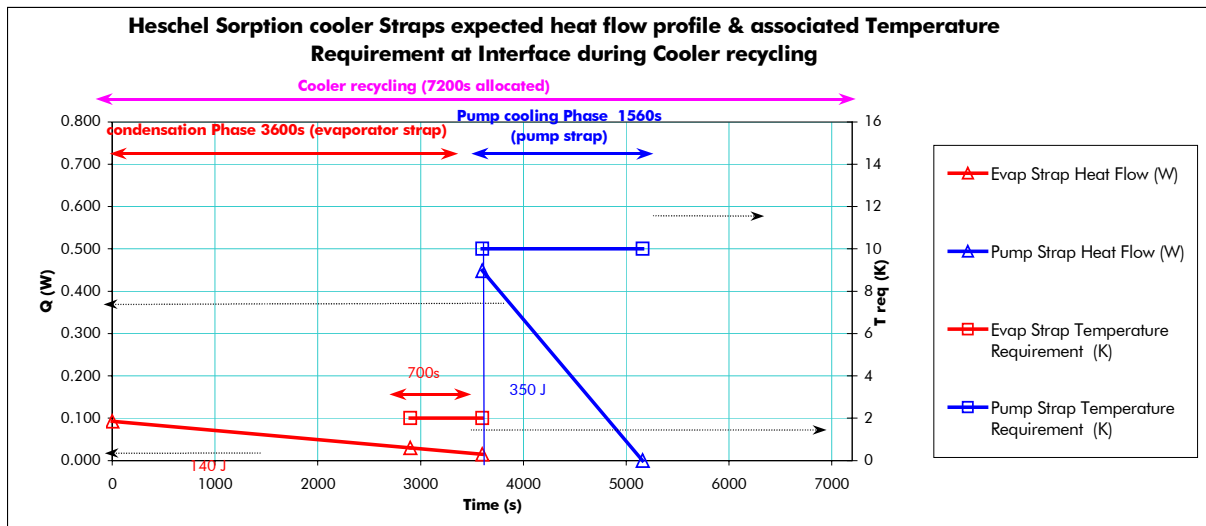
Figure 5.7.3: Expected heat profiles on evaporator and Pump strap, during recycling

5.7.1.4   Worst case temperatures

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

5.7.2 Outside the Cryostat

NA

5.7.3 On the 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. °C	Max. °C	°C	°C	Min. °C	Max. °C
HSDPU	- 15	+ 45	- 30	+ 50	- 35	+ 60
HSFCU	- 15	+ 45	- 30	+ 50	- 35	+ 60
HSDCU	- 15	+ 45	- 30	+ 50	- 35	+ 60

Note:

- Acceptance temperature range is from 5 °C below min. to 5 °C above max. operating temp.

- Qualification temperature range is from 10 °C below min. to 10 °C above max. operating temp.

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

- Spire units will be thermally joined over their base mounting I/Fs to the panel skins which will help stabilise the temperature of un-powered 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 thermostated heaters, these shall be external and Herschel furnished. If details are determined on time-scales that can be accommodated, Spire will build in minimal necessary mounting arrangements for such systems, TBC.

5.7.4 On the Planck Payload Module

NA

5.7.5 Temperature channels

5.7.5.1   Instrument Temperature Sensors

For information the table below shows the measurement of instrument cryogenic temperatures. These data are available in DPU science packets (unless otherwise indicated) via whichever is powered of the prime and redundant sides of the Spire electronics. They may also be included in some housekeeping packets.

Each Prime/Redundant 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.

Cernox sensors type CX-1030 are used for all HSFPU SPIRE conditioned housekeeping temperatures. The below table is consistent with RD19 Spire Wiring Definition.

Location IN HSFPU	Acronym	Sensor Type	Temp. Range	Resol.	Acc.
PSW BDA_1	T_PSW_1	NTD Ge Thermistor*	0.2 K>5 K	0.5mK	2mK
PSW BDA_2	T_PSW_2	NTD Ge Thermistor	0.2 K>5 K	0.5mK	2mK
PMW BDA_1	T_PMW_1	NTD Ge Thermistor	0.2 K>5 K	0.5mK	2mK
PMW BDA_2	T_PMW_2	NTD Ge Thermistor	0.2 K>5 K	0.5mK	2mK
PLW BDA_1	T_PLW_1	NTD Ge Thermistor	0.2 K>5 K	0.5mK	2mK
PLW BDA_2	T_PLW_2	NTD Ge Thermistor	0.2 K>5 K	0.5mK	2mK
SSW BDA_1	T_SSW_1	NTD Ge Thermistor	0.2 K>5 K	0.5mK	2mK
SSW BDA_2	T_SSW_2	NTD Ge Thermistor	0.2 K>5 K	0.5mK	2mK
SLW BDA_1	T_SLW_1	NTD Ge Thermistor	0.2 K>5 K	0.5mK	2mK
SLW BDA_2	T_SLW_2	NTD Ge Thermistor	0.2 K>5 K	0.5mK	2mK
300mK Plumbing Cntrl_1	PTC_Ch1 TBD	NTD Ge Thermistor	0.2 K>5 K	0.05mK	0.2mK
300mK Plumbing Cntrl_2	PTC_Ch2 TBD	NTD Ge Thermistor	0.2 K>5 K	0.05mK	0.2mK
300mK Plumbing Cntrl_3	PTC_Ch3 TBD	NTD Ge Thermistor	0.2 K>5 K	0.05mK	0.2mK
JFET temps (6off? TBD)	TBD	HeaterThermistor?	10K>120K	0.5K	1K
HSFPU EMC filtersOpt. Bench (HOB)	EMCFIL TBD	CX-1030	3K>100K	25mK	50mK
Spectrometer 2K box	T_SL0TBD	CX-1030	1K>10K	2mK	2mK
Photometer 2K box	T_PL0TBD	CX-1030	1K>10K	2mK	2mK
M3,5,7 Optical SubBench	T_SUBTBD	CX-1030	3K>100K	25mK	50mK
HSFPU Input Baffle	T_BAFTBD	CX-1030	3K>80K	5mK	5mK
BSM/SOB I/F	T_BSMSTBD	CX-1030	3K>80K	5mK	5mK
HS Spect. Stimulus Flange	T_SCSTTBD	CX-1030	1K>50K	10mK	10mK
Sorption Pump	T_CPHP TBD	CX-1030	0.2 1K>50 K	10mK	10mK
Evaporator	T_CEVTBD	CX-1030	0.2 K>5 K	1mK	1mK
Sorption Pump Heat Switch	T_CPHSTBD	CX-1030	1K>50K	10mK	10mK
Evaporator Heat Switch	T_CEHSTBD	CX-1030	1K>50K	10mK	10mK
Thermal Shunt	T_CSHTTBD	CX-1030	0.2 K>5 K	1mK	1mK
HS Spect. Stim 4%	T_SCL4TBD	CX-1030	3K>80K	5mK	5mK
HS Spect. Stim 2%	T_SCL2TBD	CX-1030	3K>80K	5mK	5mK
BSM	T_BSMMTBD	CX-1030	3K>20K	10mK	10mK
SMEC	T_FTSMTBD	CX-1030	3K>20K	10mK	10mK
SMEC/HSOB I/F	T_FTSS	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

The SPIRE shutter has been removed. Temperature sensors are therefore not required

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.

			CCU Measurement		EGSE Measurement	
Position	**Type (1)**	**Name (1)**	**Range**	**Accuracy**	**Range**	**Accuracy**
On Instrument Shield, close to SPIRE	C100	T213	3.0K - 20.0K	± 0.1K	3.0K - 20.0K	± 0.1K
L0; Cooling Strap 5; to "SPIRE SM Detector enclosure"	C100	T225	1.6K - 2.0K	± < 0.001K	1.6K - 2.0K	± < 0.001K
L0; Cooling Strap 6; to "SPIRE Cooler Pump HS"	C100	T226	2.0K - 10.0K	± 0.01K	2.0K - 10.0K	± 0.01K
L0; Cooling Strap 7; to "SPIRE Cooler Evaporator HS"	C100	T227	1.5K - 2.2K	± < 0.01K	1.5K - 2.2K	± < 0.01K
L1; on Ventline upstream strap 4 to "SPIRE Optical Bench"	C100	T235	2.0K - 10.0K	± 0.01K	2.0K - 10.0K	± 0.01K
L1; on Ventline downstream strap 4 to "SPIRE Optical Bench"	C100	T236	2.0K - 10.0K	± 0.01K	2.0K - 10.0K	± 0.01K
L3; on Ventline to JFET-Phot	C100	T246	3.0K - 20.0K	± 0.1K	3.0K - 20.0K	± 0.1K
L3; on Ventline to JFET-Spec	C100	T247	3.0K - 20.0K	± 0.1K	3.0K - 20.0K	± 0.1K
L1; on Strap 4 on SPIRE FPU side	C100	T248	2.0K - 10.0K	± 0.01K	2.0K - 10.0K	± 0.01K
On Spire JFET-Spec (Pos on Structure or L3 strap)	PT1000	T249	-	-	13K - 370K	± 1K
On Spire JFET-Spec (Pos on Structure or L3 strap)	C100	T250	3.0K - 20.0K	± 0.1K	3.0K - 20.0K	± 0.1K
On Spire JFET-Phot (Pos on Structure or L3 strap)	PT1000	T251	-	-	13K - 370K	± 1K
On Spire JFET-Phot (Pos on Structure or L3 strap)	C100	T252	3.0K - 20.0K	± 0.1K	3.0K - 20.0K	± 0.1K
OB Plate near SPIRE foot (center)	PT1000	T253	-	-	13K - 370K	± 1K
OB Plate near SPIRE foot (center)	C100	T254	3.0K - 20.0K	± 0.1K	3.0K - 20.0K	± 0.1K
OB Plate near SPIRE foot (-z+y)	PT1000	T255	-	-	13K - 370K	± 1K
OB Plate near SPIRE foot (-z+y)	C100	T256	3.0K - 20.0K	± 0.1K	3.0K - 20.0K	± 0.1K
OB Plate near SPIRE foot (-y-z)	C100	T258	3.0K - 20.0K	± 0.1K	3.0K - 20.0K	± 0.1K

(1) : Type and name for information only

Note : One temperature sensor (T257) has been removed.

The SPIRE reduced TMM (issue 2.3 , future issue 2.5 to come) is in annex 2

* Lower values for resolution and accuracy apply at bottom end of range, higher when hot and the absolute value of the requirement is much less stringent. The temperature of an item should be determined (accuracy+ resolution errors) to 2% of its absolute value in Kelvin, TBC

The precise number and 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

The cryostat and baffle structures shall be compatible with the SPIRE beam.

5.8.1 Straylight

The instrument straylight model and its conclusions related to alignment etc. are described in RD-15.

For information, Figure 5.8-1 illustrates the SPIRE optical beam envelope viewed as it passes out of the HSFPU, showing the contributions from the photometer and the spectrometer. The differing beams result from the extremes of the BSM's ¡iggle and chop displacements. The beam envelope formed is the geometric optical beam passing through the Spire cold stop. The 6mm clearance around the beam, at the level of the shutter frame, is the allowance required for beam diffraction.

The figure 5.8-1 here under takes into account the removing of SPIRE shutter
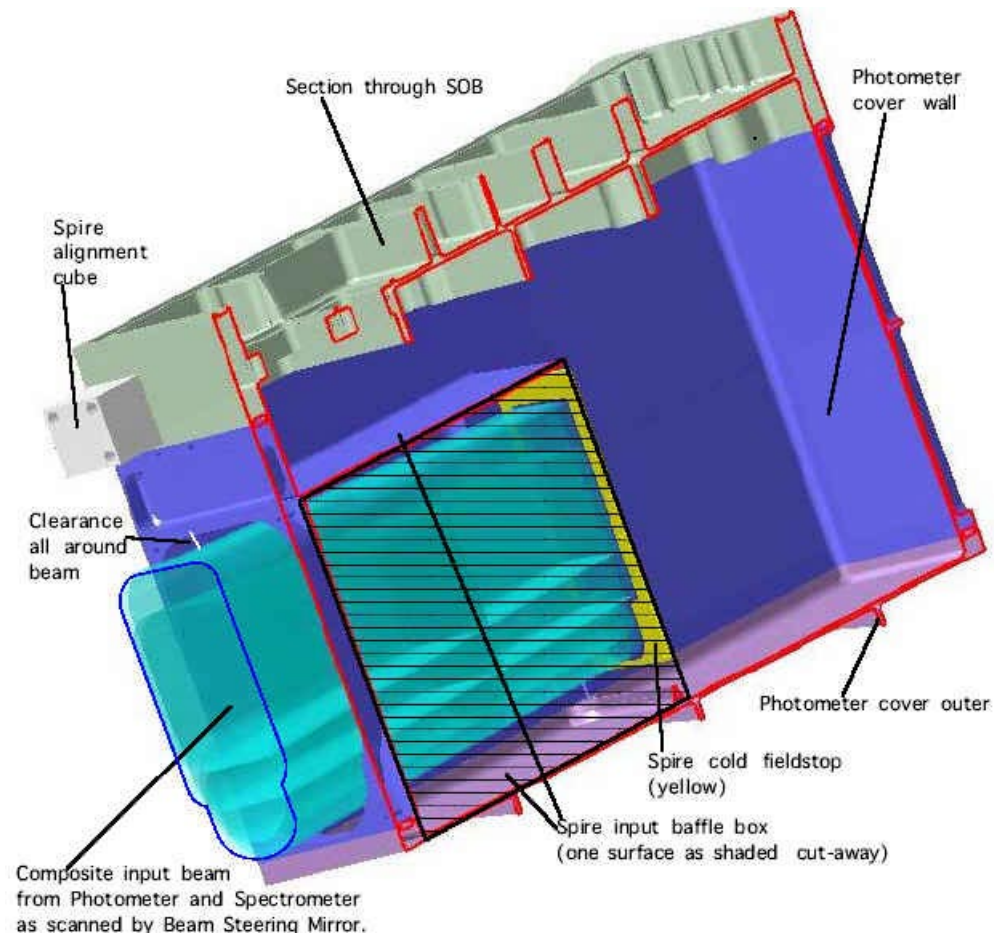
Figure 5.8-1 Spire optical beam envelope as it leaves the HSFPU

The spectrometer's almost circular used beams are the farther from HERSCHEL field centre, and lie to the side of the semi-rectangular beams of the photometer. FOV switching is not used within SPIRE to boresight the photometer and the spectrometer; both are illuminated simultaneously by the HERSCHEL telescope.

5.9   POWER

The thermal design and thermal model is still under evaluation at system level, with industry and ESA project. The values given in 5.9.1 reflect the current known status.

5.9.1 Power inside the cryostat

The SPIRE components which dissipate power inside the cryostat are described in the Table below. It should be noted that the individual component dissipations can vary according to the operational mode of the instrument, as described in section 5.9.5.

Component	Max. at component level (mW)	Mean at component level (mW)	Max in harness (mW)	Mean in harness (mW)
Photometer Cal	4	0.1		
Spectrometer Cal	5	2		
300 mK Cooler *	1.42	1.22		
BSM / Photometry	4	4		
BSM / Spectroscopy	4	1		
SMEC / Photometry	9.5	4.6		
SMEC / Spectroscopy	9.5	1.6		
JFETS / Photometry	42	42		
JFETS / Spectrometry	14.1	14.1		

* Recycling is a special case, see section 5.7.19.

5.9.2 Power outside the Cryostat

NA

5.9.3 Power on the SVM

The following table shows the heat dissipation (in Watts) of the warm electronic units mounted on the SVM. Note that the power passed through to the Cryoharness and the HSFPU is negligible, such that the dissipation values given here are the same as those corresponding to the unit power loads on the bus (Section 5.9.6.1) :

Project Code	Instrument Unit	Dissipation	Comment
HSDPU	HS Digital Processing Unit	15.3 W	
HSFCU	HS FPU Control Unit	42.9 W	Includes power cond. losses
HSDCU	HS Detector Control Unit	37.0 W	Lower in spectrometer Mode
HSWIR	HS Warm Inter-unit Harness	0.1 W	

		Total	**95.3 W**	

The above dissipations are essentially independent of observing mode, with the exception that the baseline is to power EITHER the spectrometer OR the photometer bolometer systems at any one time. The above figures are based on the higher dissipation values expected with *photometer* operation. When operating in spectrometry mode, the reduction in HSDCU power requirements and the associated reduction in conditioning losses in the HSFCU are TBD.

The baseline is to empower either prime or redundant modules of Spire. The instrument will therefore appear to the S/C as simply cold redundant.

5.9.4 Power 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	Observing	
						Photom.	**Spectro.**
HSFPU	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
HSFTB	JFET amplifiers	OFF	OFF	OFF	ON	ON	ON
HSFCU + HSDCU	Read-out electronics & mechanism drive electronics	ON	OFF	OFF	ON	ON	ON
HSDPU	Digital Processing Unit	ON	OFF	ON	ON	ON	ON

LEGEND	
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:

Reference   **HP-SPIRE-REQ-0020**

The SVM shall provide the allocated power budget as defined hereafter.
The "average" and "peak" power values correspond to "worst-case" conditions, i.e. taking into account the specified supply bus voltage range : 26V and 29V.

Spire Operating Mode	¹Max. Ave. BOL	¹Max. Ave. EOL	¹Long Peak BOL/EOL
Observing	95.3 W	95.3 W	TBD
Parallel	95.3 W	95.3 W	TBD
Serendipity	95.3 W	95.3 W	TBD
Standby	95.3 W	95.3 W	TBD
Cooler Recycle	95.3 W	95.3 W	TBD
On	15.3 W	15.3 W	TBD
Off	0 W	0 W	0

Project Code	Instrument Unit	Mean load per LCL
HSDPU	HS Digital Processing Unit	15.3 W [2]
HSFCU	HS FPU Control Unit	80.0 W [3]

1   The "average" and "peak" power values correspond to "worst-case" conditions, i.e. taking into account the specified supply bus voltage range : 26V ~ 29V. The average "with-margin", and peak "with-margin" total power loads are also to be provided. Power requirements cannot be accepted until assumed margins are clearly stated.

2   The **maximum** associated "Long Peak" load on this LCL is understood to be the mean value (above) X 1.20, i.e. 18.5 W.

3   The **maximum** associated "Long Peak" load on this LCL is understood to be the mean value (above) X 1.20, i.e. 96 W.

*

5.9.6.2 Power Nominal Turn-on.

Having checked that Spire is all unpowered, the HPCDU shall empower an HSDPU (P or R).

This DPU checks its health and sends a status packet on the active 1553 bus. If its status is OK, the HCDMU commands the HPCDU to turn on the corresponding HSFCU module (P or R).

Note that turning on the HSFCU 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

Reference **HP-SPIRE-REQ-0030**

The HSDPU and the HSFCU receive both primary and redundant 28V feeds. The configuration is shown in figure 5.2.1, and the connectors are HSDPU J1-2 and HSFCU J5-6.

*

Their S/C power interfaces circuits shall be designed not to generate unwanted interactions with LCL switching limiters. Instrument power circuits are shown in sections 5.9.6.4.1 & .2.

Reference **HP-SPIRE-REQ-0040**

The HPCDU shall telemeter the Spacecraft's LCL current to a resolution of better than 25mA or 1/256 of (trip x 1.5), whichever is the larger. The stated resolution, to be provided by the current telemetry, does imply any particular level of current measurement *accuracy*.

*

5.9.6.4 LCL fault conditions

Reference **HP-SPIRE-REQ-0050**

The S/C shall not allow simultaneous powering of both FCUs, even in the event of a single point LCL failure.

*

Reference **HP-SPIRE-REQ-0060**

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 in-active by not commanding the inactive unit, and neither HCDMU shall turn on the corresponding HSFCU. To permit commanding the DPUs to work like this, each HSDPU uses 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 HSDPU Power Input Circuit Configuration
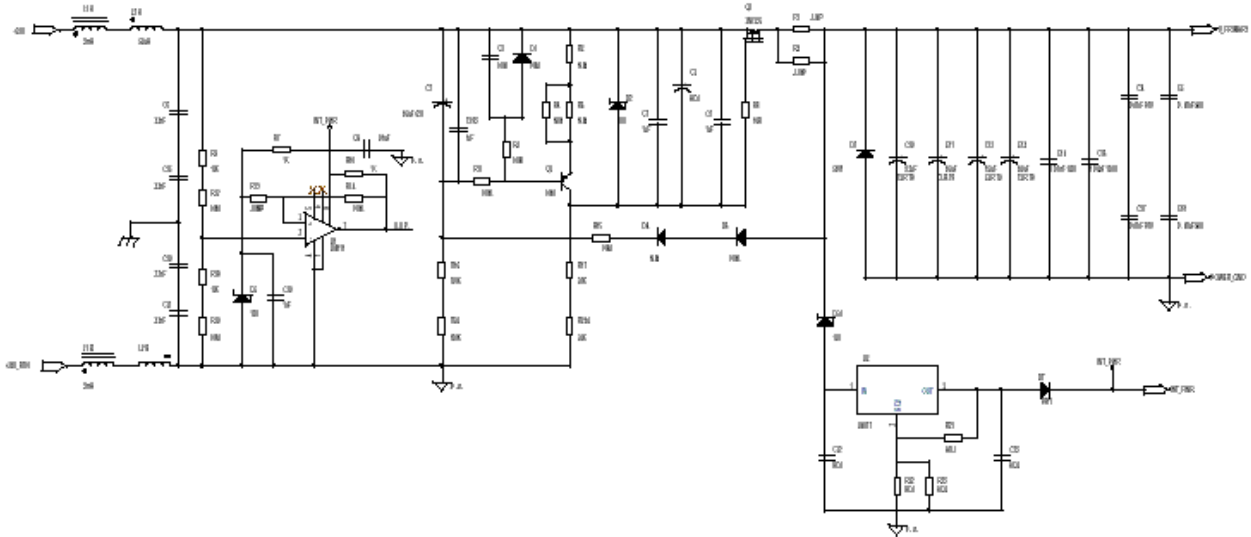
5.9.6.4.2 HSFCU Power Input Circuit Configuration

TBW

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

~~In all this section 5.10, Overshield on cryoharnessmust not be taken into account as CR 39 doesn't have positive answer from ESA. If CR 39 is formally rejected by ESA, all figures and tables including or refering to this overshield shall be reissued.~~

Following the teleconference of clarification about the SPIRE overshielding (2003-05-20 - HP-2-ASED-MN-390), and according to the instruction of ESA, it has been agreed to apply partially the SPIRE ECR 39v1 :

– include the additional external overshield (between SVM warm units and Connector Bracket (CB), and between the CB to CVV external wall),

– not include the internal (inside CVV) overshield, and keep the connection by wires from the CB to the FPU ground.

So in this present document, ~~and~~ in this section 5.10, and in annex 3: Internal Overshield corresponding to SPIRE ECR 39v1 must not be taken into account, and all figures and tables including or referring to this internal overshield shall be reissued.

5.10.1 Harness and Connectors

The Spire harnesses shall be compliant with the requirements specified in annex 3~~2~~ (RD 19): SPIRE Harness definition document SPIRE-RAL-PRJ-000608 issue 1.1(or issue 1.2 if available). The requirements in the

following figures or tables have been extracted from RD-19 and annex 3~~2~~.~~Spire harnesses shall be as defined in RD9.~~ See annex 3 to have complete harness information.

 Harness length details are to be incorporated in RD19, but may not be available at the time of issue of the present document. For information, the following data has been extracted from RD19. It should however be noted that any electrical requirements of Spire, which may be implicitly represented by Figure 5.10-1, are accepted ONLY when such requirements are expressed in the text of the present document.

Figure below gives an overview of the Spire harness layout.
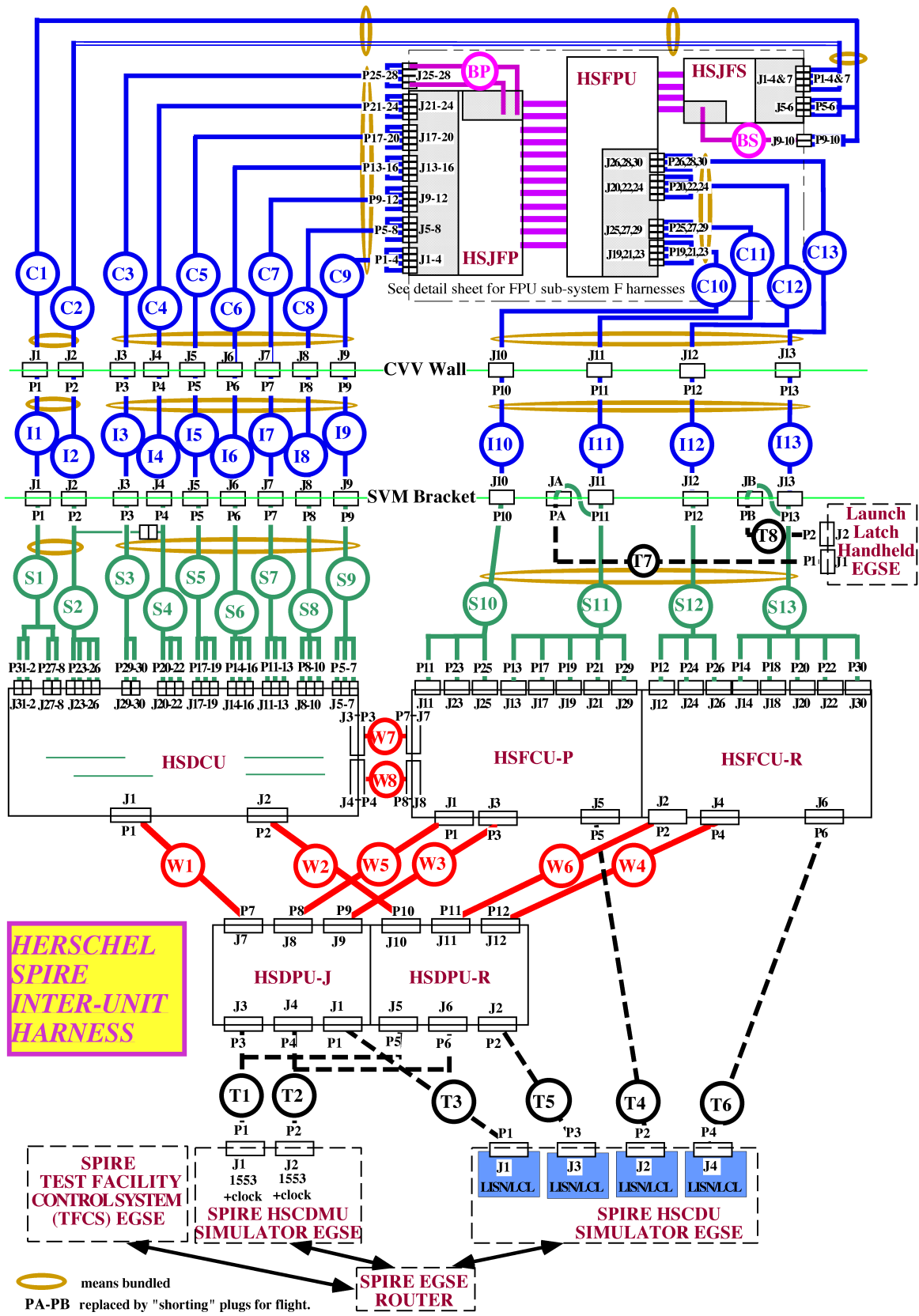
Figure 5.10-1 : SPIRE harness layout

Note that the Cryo-harness, i.e. series C, ~~and~~ I, and S 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 two F harnesses (FPU sub-system F harness) between JFETs and FPU (HSFPU-HSJFP and HSFPU-HSJFS) are provided by SPIRE with the instrument units.

Requirements for the SPIRE cryo harness, series C, ~~and~~ I, and S as agreed with industry, are given in the tables in annex 3~~2below~~.

Internal Harness - Data taken from ECR-029 / TBC

5.10.2   Grounding

To fulfil Spire's grounding requirements, the HSFPU and both of the 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.

SPIRE grounding diagram provided in the figure below is for information only, and shall not represent any requirements on the spacecraft.

Note: A new SPIRE grounding and shielding concept is subject of ECR-039, which is not finally approved.

Note : to be replaced by a new figure to be provided by SPIRE

Figure 5.10-2 : SPIRE Grounding scheme

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 FCPU.

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. The DRCU decreases interface inductance by using conductive interface gasket, see Annex 2. Spire would much prefer a formal S/C aluminium strap bonding tree, coupled by controlled straps to all equipment, and will therefore provide a bonding strap mounting point on each SVM mounted unit to permit this.

5.10.4   Electrical Signal Interfaces

5.10.4.1   1553 Data Buses

Reference   **HP-SPIRE-REQ-0070**

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.

*

Reference   **HP-SPIRE-REQ-0080**

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

*

Reference   **HP-SPIRE-REQ-0090**

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.

*

Reference   **HP-SPIRE-REQ-0100**

Connector use is as follows:

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

*

The DPU's 1553B interface to the Herschel S/C is configured as follows inside each SPIRE HSDPU
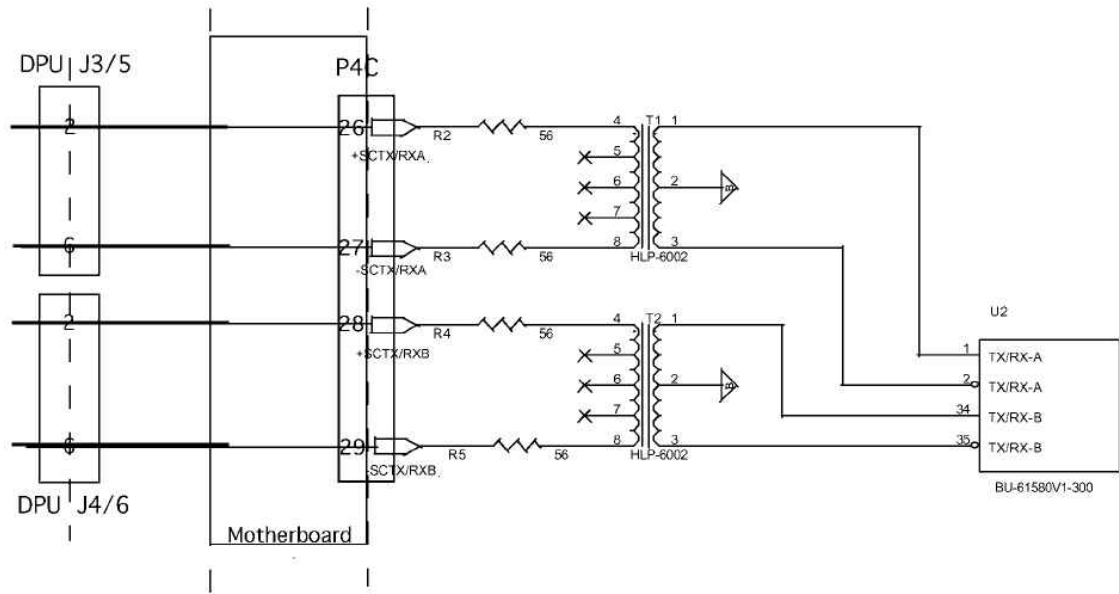
5.10.4.2   Master Clock

Reference **HP-SPIRE-REQ-0110**

Herschel shall supply 2 differential signal lines of 2^{17}Hz (131 kHz). master clock signals. They are therefore supplied unground-referenced. These are shown as brown lines in figure 5.2.1.

*

Reference **HP-SPIRE-REQ-0120**

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

*

Reference **HP-SPIRE-REQ-0130**

This shall be supplied to both powered and un-powered Spire HSDPUs.

*

Reference **HP-SPIRE-REQ-0140**

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.

*

S/C wide synchronisation of dc-dc converters, will NOT be implemented.

5.10.4.3   Launch confirmation

Spire has ~~three~~ twocryogenic mechanisms: BSM~~,~~ and SMEC~~, shutter~~. It is baselined that each will need to be launch-locked and that their latching will need to be confirmed after launch stack integration. All functions are Prim, and Redundant.

During Launch preparation, hand-held Spire provided EGSE will require cable access to the ~~four~~ two connectors JA~~-~~ and JB~~D~~ shown in the Harness configuration drawing.

Note: JA and JB connectors implementation/delivery are TBC by ASED, use of these connectors to be clarified by SPIRE (when and for what)

Note: access to SVM connector bracket will not be possible in launch configuration

Connector blanking plugs PA-P~~BD~~ that interconnect connector contacts as defined by Spire will be HERSCHEL provided and fitted whenever the EGSE is not connected, which includes in-flight.

Until timing and physical access details for the days before launch, are better defined, industry cannot confirm that this section's requirements can be met or provide details of the access that can be afforded to Spire

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

Reference   **HP-SPIRE-REQ-0150**

SPIRE needs a minimum of 100 kbps of TM data rate.

*

5.11.1.2   Data-bus rate

Reference   **HP-SPIRE-REQ-0160**

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.

Reference   **HP-SPIRE-REQ-0170**

In order to prevent data overflow in this Spire data storage, the HCDMU shall request packets from Spire at least as frequently as once per second (TBC).

*

5.11.2   S/C housekeeping

Reference   **HP-SPIRE-REQ-0180**

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. HSDPU and HSDRC.
- Requested temperatures in Section 5.7.5.2.

*

5.11.3   Timing and synchronisation signals

Reference   **HP-SPIRE-REQ-0190**

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.

Reference **HP-SPIRE-REQ-0200**

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 5 milliseconds, although the actual UT of the pulse only needs to be within one second of its planned time.

time. *

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

HSC
Take scientists' wishes + mission profile and generate Time-tagged* Observation Command Packet Sequence. Build an up-to-48 hour file.

HCDMU clock setup

S/C uplink

HSC
Associate SPIRE data with sequences carried out and detailed timings with instument state/viewed vector.

S/C Downlink

HCDMS
Receive and store up to 48Hours of SPIRE commands

HCDMU
Send single commands at their tagged times

1553 + Higher Protocols, *including a time sync. every second.* Observation Sequences, Mode Commands, Settings, etc.

HCDMS
Store and send SPIRE data, folded in with packets from other sources.

HCDMU
Relay SPIRE data

1553 + Higher Protocols for data packets

HSDPU
Unpack Command Sequences from a queue as they are received. Pass on with required timings, interleaved with any HSDPU generated commands.

Clock, to good resolution

HSDPU
Assemble packets &*give them time stamps using S/S counter reset times.*

Slow links 32/32 bit commands sent with *a continuous 2^{7}Hz. clock.*
Counter reset commands sent at known HSDPU times

Interaction protocol

Slow links 32/32 bit responses

Fast links data, always receivable by HSDPU

HSDCU/FCU ...FCU=MCU+SCU
"Immediate" action as commanded. All three S/Ss run a clock counter

Mainly analogue signals with some simple digital

HSDCU/FCU
Response packets to HSDPU commands as required,*each with latched "clock" counter value. {SMEC zero crossings each latch a counter incremental delta}*

Mainly analogue signals with some simple digital

HSFPU SYSTEMS

"Immediate" action and response information return. Note that most of these actions are physically slow compared to the HSDCU/FCU electronics+software.

*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 needs 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.

Reference   **HP-SPIRE-REQ-0210**

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

*

Reference   **HP-SPIRE-REQ-0220**

The maximum telecommand packet length is 256 octets.

*

Reference   **HP-SPIRE-REQ-0230**

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)

Spire agreed during the convergence meeting not to request this, given the information is provided on ground, and the IID-A specifies how.

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 HSDPUs. Each HSDPU shall have a different 1553 address. The HSDPUs have the only non-hard-coded 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 HSDPU is required to trap out any such situations. For the same reason, the HSDPU shall ensure its own correct function, at least as far as checking memory function in the background, check-summed read only areas, and an inhibitable SEU safing capability.

5.13.3   Autonomy functions

Reference   **HP-SPIRE-REQ-0240**

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

*

Reference **HP-SPIRE-REQ-0250**

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 the SPIRE S/C housekeeping.

*

Reference **HP-SPIRE-REQ-0260**

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*

N.A.

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 frequencies are arranged to minimise noise problems in the bolometer sub-system's highly sensitive analogue sections, and are provided in the following table.

SPIRE Unit	Frequency Source – subsystem	Frequency Range		Wave-form	Signal level(s)		Comments
		Lower	**Upper**				
DCU	Cmd IF Clock	312 kHz		Rect.	0	5 V	Differential RS422 – Continuous
	Data IF Clock	1MHz	2.5 MHz	Rect	0	5 V	Differential RS422
	Master Clock	10 MHz		Rect		5 V	Crystal Oscillator – Internal to unit
	Bolometer Bias	50 Hz	300 Hz	Sine	0	100 mV	Differential – Highly sensitive signal
	T/C Bias	50 Hz	300 Hz	Sine	0	500 mV	Differential – Highly sensitive signal
MCU	Cmd IF Clock	312 kHz		Rect.	0	5 V	Differential RS422- Continuous
	Data IF Clock	1MHz	2.5 MHz	Rect	0	5 V	Differential RS422
	Master Clock	40 MHz		Rect		5 V	Crystal Oscillator – Internal to unit
	DSP Clock	20 MHz		Rect		5 V	Master clock / 2 Internal to unit
	LVDTexcitation	2.5 kHz		Sine		3 V	Differential +/- 20 %
	DAC change	3.0 kHz	10 kHz	Rand.		10 V	Internal to unit
	Position encoder	0	2.5 kHz	Sine		3 mV	Differential 250 Hz at nominal speed
SCU	Cmd IF Clock	312 kHz		Rect.	0	5 V	Differential RS422- Continuous
	Data IF Clock	1MHz	2.5 MHz	Rect	0	5 V	Differential RS422
	Master Clock	10 MHz		Rect		5 V	Crystal Oscillator – Internal to unit
	300 mK TS Bias	20 Hz		Rect		6 mV	Tr/Tf = 1ms Highly sensitive signal
	Photo Stimulus	0	5 Hz	Rect			
PSU	DC/DC switching frequency	131 kHz TBC					Free runing - ± 10% - internal to unit

Note: PSU DC/DC switching frequency to be confirmed/clarified by SPIRE

5.15 Transport and Handling Provisions

5.15.1 Focal Plane Unit

For reasons of possible damage caused by vibration during transport, environmental testing and launch, mechanisms shall be transported in their launch-latched state.

5.15.1.1 Transport Container

The Spire FPU (HSFPU) 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 HSFPU can sustain in any direction is (TBD). The transport container is fitted with shock recorders and internal humidity monitors. The HSFPU 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 HSFPU 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 (HSFTP/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 HSFTP/S can sustain in any direction is (TBD). The transport container is fitted with shock recorders and internal humidity monitors. The HSFTP/S transport container is shown in figure TBD.

5.15.2.2 Unpacking Procedure

The procedure for removing and installing the HSFTP/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 (HSDPU; HSFCU; HSDCU, HSWIH) will be transported in clean hermetically sealed containers to be opened only in class 100 000 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

Note: All section 5.16 to be updated and clarified by SPIRE according the new model philosophy and AIV plan

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)RD5.

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 re-qualification 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 HSFTP/S, to enable integration of the HSDCU,HSDPU, HSFCFU and HSWIH

–   TBD EGSE for integration of the HSFPU

–   Quick Look Facility to enable testing of the instrument at system level. This will interface to the S/C test environment

Note: EGSE deliverables (including connectors savers and caps) to be clarified by SPIRE

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

Note: MGSE deliverables (including protective caps) and hoisting provisions to be clarified by SPIRE

5.16.4   Optical Ground Support Equipment (OGSE)

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

The SPIRE alignment can be removed following the FPU alignment to the Herschel Optical Bench

Deliverables:

–   Instrument optics primary alignment and alignment verification jigs/equipment

–   Plus TBD

Note: OGSE deliverables (alignment cube + …) to be clarified by SPIRE

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.

Note: to be clarified by SPIRE

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.

Note: to be clarified by SPIRE

5.16.8   Instrument Software Simulator

TBD

Note: to be clarified by SPIRE

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.

Note: to be clarified by SPIRE

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.

Note: to be clarified by SPIRE

5.16.11   Technical Documentation

The following documents will be delivered:

–   Instrument User Manual following the requirements laid down in the OIRD (AD3~~2~~)

–   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~~.

Note: to be clarified by SPIRE

6 GROUND SUPPORT EQUIPMENT

6.1 MECHANICAL GROUND SUPPORT EQUIPMENT

TBD To be clarified by SPIRE

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.
Note: A SCOS 2000 definition document reference is to be provided by ESA and put in ADs .

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~~ A common EGSE system ~~could be~~has been 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

IIDB SPIRE

REFERENCE :	SCI-PT-IIDB/SPIRE-02124
DATE :	30-06-2003
ISSUE :	2.3 DRAFT 4 **PAGE** : 7-1

7. INTEGRATION, TESTING AND OPERATIONS

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

Note: all section 7 to be updated and clarified by SPIRE, in line with Integration and Test Plan.

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 (HSFPU) and the SPIRE JFET boxes ~~(HSFTB)~~ will be integrated separately onto the Herschel optical bench. Electrical and RF-shield connections ~~(TBD) will~~ would be made between these boxes after mechanical integration with the Herschel optical bench. Herschel cryoharness shall then be attached. *Note: to be clarified by SPIRE (separately or together ?)*

This applies to both the CQM and PFM units.

Spire's mechanical alignment shall be checked after mounting, and its aperture cover removed as late as practical during the closing of CVV.

Note: to be clarified by SPIRE

7.1.2 PPLM Integration

NA

7.1.3 SVM Integration

The SVM warm units shall be first integrated as panels, and the SPIRE units linked by warm Spire warm harness and checked with the HSFPU simulator. Remove SVM static protection …

Note: to be clarified by SPIRE

7.1.4 Herschel/Planck Integration

TBD

Note: to be clarified by SPIRE

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 thermal 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 so the SPIRE optical bench, in plane Y=const. becomes horizontal. Spire's cooler is mounted with the evaporator towards +Y, its

~~axis being parallel to the Y axis. To regenerate the cooler, the pump must be above the evaporator, i.e. the +Y-axis must be >20deg. Below horizontal or equivalently <70deg away from pointing downwards."~~

~~The cooler will not recycle unless the cryostat is tilted to at least 17 degrees about the S/C Z-axis.~~

The nominal on-ground orientations of the SPIRE test cryostat, and of the HOB when the HPLM is aligned in the vertical position, are such that the SPIRE FTS mechanism cannot be operated.

For correct operation of the FTS, the SOB - which lies in the X-Z plane of the HPLM coordinate system - must be rotated by either +90° or -90° about the Z axis. This would be achieved by rotating the complete HPLM by ±90° about the Z axis.

Similarly, correct recycling of the SPIRE 0.3K He3 cooler requires that the HPLM be tilted around the Z axis by an angle θ such that $+20° \leq \theta \leq +160°$.

This will ensure that, for recycing, the cooler evaporator lies below the cooler pump, thereby avoiding the adverse convection effects which can occur if the (colder) evaporator lies near-horizontally or above the (warmer) pump.

Note: alternative text from SPIRE ?, new version of ECR 41 ?

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 HSDPU		At the end of this SPIRE will be switched to REDY mode
3		Validate function of HSDRCU		
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	

IIDB SPIRE

REFERENCE :	SCI-PT-IIDB/SPIRE-02124
DATE :	30-06-2003
ISSUE :	2.3 DRAFT 4 **PAGE** : 7-4

Sequence	Duration [days]	Objective	Requirements	Remarks
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
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 HSFPU 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.

IIDB SPIRE

REFERENCE :	SCI-PT-IIDB/SPIRE-02124
DATE :	30-06-2003
ISSUE :	2.3 DRAFT 4	**PAGE :** 7-5

Sequence	Duration [days]	Objective	Requirements	Remarks
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 HSFPU 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~~ HCSS and processing software etc
2		Test SPIRE spectrometer POFs		Ditto
SPIRE/PACS parallel Operation				
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 23 Herschel/Planck Operations Interface Requirements Document (OIRD)

AD 34 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~~AD2).

Details are to be found in SPIRE Product Assurance Plan (~~RD2~~RD7).

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~~ HCSS.

– 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

Note: section 9.2 to be updated by SPIRE according new model philosophy

9.3 MECHANICAL VERIFICATION

TBD. Text to be provided by SPIRE

IIDB SPIRE

REFERENCE :	SCI-PT-IIDB/SPIRE-02124
DATE :	30-06-2003
ISSUE :	2.3 draft 4 **PAGE** : 9-2

9.4   THERMAL VERIFICATION

TBD. Text to be provided by SPIRE

9.5   VERIFICATION OF SCIENTIFIC PERFORMANCE

TBD. Text to be provided by SPIRE

9.6   ELECTRICAL TESTING

TBD. Text to be provided by SPIRE

9.7   EMC TESTING

TBD. Text to be provided by SPIRE

10 MANAGEMENT, PROGRAMME, SCHEDULE

All relevant information can be found in the SPIRE Management Plan, ~~AD4~~RD4.