# FIRST/Planck

## INSTRUMENT INTERFACE DOCUMENT

## PART B

## INSTRUMENT “SPIRE”

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|---|---|---|
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# 1 INTRODUCTION

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

The IIDs consist of two parts, IID-A and IID-B. There is one part A 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 contractor.

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

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

The IIDs are living documents and updates are to be approved by the instrument teams and ESA.

After initial issue by ESA, the contractor will be responsible to maintain the IID-A in line with the requirements as defined in the IID-Bs and in agreement with ESA.

Both IID-A and the IID-Bs were part of the AO and are part of the Invitation To Tender.

Chapter 4 of each of the IID-B documents consists of two parts.
The first part, from para 4 up to and including para 4.6.5 is devoted to descriptive information and background data necessary to enable a full and mutual understanding of the interface constraints between the spacecraft and instruments. This part is not to be considered as containing any requirement whatsoever, nor to imply any particular interpretation or meaning other than the one explicitly stated in the other chapters of this document and is therefore not applicable in any contractual sense.

The second part from para 4.7 onwards contains information relative to the scientific performance of the instrument. This part is to be considered as containing information which needs to be verified by test, analysis or a combination of the two and shall serve the purpose of demonstrating that the instrument will operate as intended for the particular mission.

on this subject.

The IIDs will not cover any of the interfaces of the Instrument Control Centres (ICCs), the Data Processing Centres (DPCs) or the FIRST Science Centre (FSC).

# 2 APPLICABLE/REFERENCE DOCUMENTS

## 2.1 APPLICABLE DOCUMENTS

| | |
|---|---|
| AD 1 | (deleted) |
| AD 2 | OIRD FIRST/Plank Operations Interface Requirements Document |
| AD 3 | FIRST-SIRD FIRST Science-operations Implementation Requirements Document |
| AD4 | SPIRE Management Plan (FIRST-SPI-PRG-000011) |
| AD5 | Product Assurance Requirements for the FIRST/Planck Scientific Instruments (SCI-PT-RQ-04410) |

## 2.2 REFERENCE DOCUMENTS

RD 1 Caldwell, M., Richards, A., Swinyard, B., Straylight Analysis - PHOT, BOL/RAL/N/0021

RD 2 Rutherford Appleton Laboratory, SPIRE Product Assurance Plan SPIRE-RAL-PRG-00017

RD 3 Swinyard. B , Power profiles for SPIRE operating modes, SPIRE/RAL/N/0046

RD 4 SPIRE AIV Plan, SPIRE-RAL-Doc-000410

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

## 4.1 INTRODUCTION

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

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

## 4.2 SCIENTIFIC RATIONALE

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

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

One of the most important scientific projects for the FIRST 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 FIRST 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 FIRST 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 FIRST 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 $\text{cm}^{-1}$ (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 FIRST 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. A JFET preamplifier module is 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 a Detector Readout and Control Unit (DRCU) and a Digital Processing Unit (DPU). The DRCU provides bias and signal conditioning for the arrays and cold readout electronics, reads out the detector signals, and controls the FPU mechanisms and the $^3$He cooler. 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:

| | |
|---|---|
| FSPU | Cold Focal Plane Unit (FPU):<br>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. |
| FSFTB | JFET box<br>This box is mounted on the optical bench next to the FPU, and contains JFET preamplifiers for the detector signals. The JFETs operate at |

| | |
|---|---|
| | around 120 K, and are thermally isolated inside the enclosure. |
| FSDRC | Detector Read-out and Control Unit (on FIRST SVM)<br>A warm analogue electronics box for detector read-out analogue signal processing, multiplexing, A/D conversion, array sequencing, mechanism control, temperature sensing and general housekeeping and $^3$He refrigerator operation. |
| FSSPU | Signal Processing Unit (on FIRST SVM)<br>A warm electronics box for signal processing and data compression. |
| FSDPU | Digital Processing Unit (on FIRST SVM)<br>A warm digital electronics box for signal processing and instrument commanding and interfacing to the spacecraft telemetry. |
| FSHAR | Warm interconnect harness (on FIRST SVM)<br>Harness making connections between the electronics boxes. |

### 4.5 SOFTWARE DESCRIPTION

The OBS will carry out the following functions:

- Read and log housekeeping data
- Control and monitor the instrument mechanisms and internal calibration sources
- Process science data prior to transmission to the ground. This will include deglitching and averaging of data (if necessary) and lossless compression.
- Carry out pre-defined observing sequences
- Implement pre-defined procedures on detection of instrument anomalies

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

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

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

## 4.6 OPERATING MODES

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

### 4.6.1 OFF Mode

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

### 4.6.2 Initialise (INIT) Mode

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

### 4.6.3 ON Mode

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

### 4.6.4 Ready (REDY) Mode

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

### 4.6.5 Standby (STBY) Mode

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

### 4.6.6 Observe Mode (OBSV) Mode

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

### 4.6.7 Cooler Recycle (CREC) Mode

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

### 4.6.8 SAFE Mode

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

## 4.7 OBSERVING MODES

The spacecraft will be pointed in a specific direction or, for mapping, will either slew slowly over a given region of the sky, or execute a raster pattern by movements of the telescope. The instrument will take scientifically meaningful data and use the full telemetry bandwidth. It is assumed that any calibrations required will also be done in the observe mode (TBC). There will be 7 sub-modes of the basic observe:

### 4.7.1 Photometer Observing Modes

The photometer can carry out essentially three kinds of observation: chopping, jiggling, and scanning. They are implemented as 9 (TBC) observing modes, named POFs (Photometer Observatory Functions), which are briefly described below.

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.

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.

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.

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.

### 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

Complete operation of the FPU is possible in any orientation. 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-$\sigma$ 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-$\sigma$ depth of 3 mJy at 250 $\mu$m 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 currently 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 1.0 arcsecond on the sky.

Requirement SRD-R 16: the spectrometer design shall be optimised for optimum sensitivity to point sources.

Requirement SRD-R 17: the spectrometer dynamic range for astronomical signals shall be 12 bits or higher.

Requirement SRD-R 18: the FTS absolute accuracy shall be 15% or better at all wavelengths, with a goal of 10%.

Requirement SRD-R 19: 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 20: The width of the FTS instrument response function shall be uniform to within 10% across the field of view.

Requirement SRD-R 21: 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 22: 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 23: The photometer observing modes shall include provision for 5-point or 7-point jiggle maps for accurate point source photometry.

Requirement SRD-R 24: The photometer shall have a "peak-up" observing mode capable of being implemented using the beam steering mirror.

### 4.8.2 Instrument Specifications

Tables 4.1 and 4.2 list the performance specifications for the photometer and spectrometer, based on the SPIRE proposal.

**Table 4.1: Photometer specifications**

| | | 250 mm | 350 mm | 500 mm |
|---|---|---|---|---|
| **Filter pass-band (l/Dl)** | | | | |
| **Field-of-view (arcminutes)** | **Requirement**<br>**Goal** | 4 x 4<br>4 x 8 | 4 x 4<br>4 x 8 | 4 x 4<br>4 x 8 |
| **Beam FWHM (arcsec)** | | 18 | 25 | 36 |
| **Point source observation:**<br>**1s 1sec limiting flux density (mJy)** | | 0.6 | 0.6 | 0.7 |
| **Mapping observation:**<br>**1s 1sec limiting flux density (mJy)**<br>**for fully sampled map of FOV** | | 1.4 | 1.5 | 1.9 |

**Table 4.2: Spectrometer specifications**

| | | | | |
|---|---|---|---|---|
| **Wavelength range (mm)** | | SW Band: | 200-300 (TBC) | |
| | | LW Band: | 300-670 (TBC) | |
| **Max. resolution (cm$^{-1}$ )** | **Requirement** | | 0.4 | |
| | **Goal** | | 0.04 | |
| **Min resolution (cm$^{-1}$)** | **Requirement** | | 2 | |
| | **Goal** | | 4 | |
| **Field of view (arcmin.)** | **Requirement** | | 2 x 2 | |
| | **Goal** | | 2.6 x 2.6 | |
| **Beam FWHM (arcsec)** | | SW Band: | 18 | |
| | | LW Band: | 35 (TBC) | |
| **Line spectroscopy<br>(point source observation):<br>1s:1 hr limiting line flux (W m$^{-2}$)** | | SW Band: | 7.6 x 10$^{-18}$ | |
| | | LW Band: | 7.0 x 10$^{-18}$ | (300 μm) |
| | | | 7.0 x 10$^{-18}$ | (400 μm) |
| | | | 1.4 x 10$^{-17}$ | (670 μm) |
| **Line spectroscopy<br>(mapping observation):<br>1 s; 1 hr limiting line flux for fully sampled FOV map (W m$^{-2}$)** | | SW Band: | 1.8 x 10$^{-17}$ | |
| | | LW Band: | 1.7 x 10$^{-17}$ | (300 μm) |
| | | | 1.7 x 10$^{-17}$ | (400 μm) |
| | | | 3.4 x 10$^{-17}$ | (670 μm) |
| **Spectrophotometry 1 cm$^{-1}$ resolution<br>(pont source observation)<br>1s:1 hr limiting flux density (mJy)** | | SW Band: | 25 | |
| | | LW Band: | 23 | 300 μm) |
| | | | 23 | 400 μm) |
| | | | 46 | 670 μm) |
| **Spectrophotometry 1 cm$^{-1}$ resolution<br>(point source observation)<br>1 s; 1 hr limiting flux density for fully sampled FOV map (mJy)** | | SW Band: | 59 | |
| | | LW Band: | 57 | (300 μm) |
| | | | 57 | (300 μm) |
| | | | 114 | (670 μm) |

## 4.8.3 Instrument Performance Estimation

### 4.8.3.1 Assumptions

The following assumptions are made in estimating the scientific performance of the instrument.

| | | | | | |
|---|---|---|---|---|---|
| Telescope: | Temperature | 80 K | | | |
| | Used diameter | 3.29 m (secondary mirror pupil stop) | | | |
| | Emissivity | 0.04 | | | |
| Detectors: | Optical NEP | 3.0 x 10$^{-17}$ W Hz$^{-1/2}$ | | | |
| | Quantum efficiency | 0.8 | | | |
| | Feed-horn efficiency | 0.7 | | | |
| | Throughput for each detector | $A\Omega = \lambda^2$ (2.0F$\lambda$ feed-horns) | | | |
| Photometer: | Central wavelengths | 250 | 350 | and | 500 μm |
| | Numbers of detectors | 149 | 88 | and | 43 |
| | Beam FWHM | 17.4 | 24.4 | and | 34.6 arcseconds |

| | | | |
|---|---|---|---|
| | Field of view of each array | 4 x 8 arcminutes | |
| | Overall instrument transmission | 30% | |
| | Filter widths (λ/Δλ) | 3 | |
| | Observing efficiency | 90% | |
| FTS: | Nominal bands | 33.5-50 $\mathrm{cm}^{-1}$<br>(200-300 μm) | 15-33.5 $\mathrm{cm}^{-1}$<br>(300-670 μm) |
| | Numbers of pixels | 37 | 19 |
| | Field of view | 2.6 arcminutes, approx. circular | |
| | Max. spectral resolution | 0.04 $\mathrm{cm}^{-1}$ (λ/Δλ = 1000 at 250 μm) | |
| | Overall instrument transmission | 15% | |
| | $\mathrm{Cos}^2$ signal modulation efficiency | 0.5 | |
| | Observing efficiency | 0.8 | |
| | Electrical filter efficiency | 0.8 | |

### 4.8.3.2 Performance Estimates

The scientific capabilities of SPIRE (based on the above assumptions), are summarised in the following tables.

**Table 4.3: Photometer performance estimates**

| **Filter pass-band (l/Dl)** | **250 mm** | **350 mm** | **500 mm** |
|---|---|---|---|
| **Point source observation:**<br>**1s 1sec limiting flux density (mJy)** | 0.48 | 0.53 | 0.59 |
| **Mapping observation:**<br>**1s 1sec limiting flux density (mJy)**<br>**for fully sampled map of FOV** | 1.1 | 1.2 | 1.5 |

**Table 4.4: Spectrometer performance estimates**

| | |
|---|---|
| **Line spectroscopy**<br>**(point source observation):**<br>**1s:1 hr limiting line flux (W $\mathrm{m}^{-2}$)** | SW Band: 5.4 x $10^{-18}$<br>LW Band: 6.9 x $10^{-18}$ (300 μm)<br>6.9 x $10^{-18}$ (400 μm)<br>1.4 x $10^{-17}$ (670 μm) |
| **Line spectroscopy**<br>**(mapping observation):**<br>**1 s; 1 hr limiting line flux**<br>**for fully sampled**<br>**FOV map (W $\mathrm{m}^{-2}$)** | SW Band: 1.3 x $10^{-17}$<br>LW Band: 1.3 x $10^{-17}$ (300 μm)<br>1.6 x $10^{-17}$ (400 μm)<br>3.2 x $10^{-17}$ (670 μm) |
| **Spectrophotometry 1 $\mathrm{cm}^{-1}$ resolution**<br>**(pont source observation)**<br>**1s:1 hr limiting flux density (mJy)** | SW Band: 18<br>LW Band: 23 (300 μm)<br>23 (400 μm)<br>46 (670 μm) |
| **Spectrophotometry 1 $\mathrm{cm}^{-1}$ resolution**<br>**(mapping observation)**<br>**1 s; 1 hr limiting flux density for**<br>**fully sampled FOV map (mJy)** | SW Band: 44<br>LW Band: 53 (300 μm)<br>53 (300 μm)<br>106 (670 μm) |

These figures are comparable to or better than the specifications given in Tables 4.1 and 4.2.

# 5 INTERFACE WITH SATELLITE

**Spacecraft resource allocations, as specified for the scientific instruments in the IID-A, are based on present knowledge.**

**Resource allocations might have to be amended as a result of the Industrial study work.**

## 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 allocated 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. The project code is part of the spacecraft code. (See IID-A section 5.1)

The project codes allocated to this instrument are:

| Project code | Instrument unit |
|---|---|
| FSFPU | Cold Focal Plane Unit (FPU) |
| FSFTB | Focal plane JFET box (FTB) |
| FSDRC | Detector Read-out and Control Unit (DRCU) |
| FSDPU | Digital Processing Unit (DPU) |
| FSWIH | Warm interconnect harnesses (HARNESS) |

## 5.2 COORDINATE SYSTEM

The unit specific definitions are shown in the External Configuration Drawings. (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 Focal Plane Units (FPUs) on the Optical Bench (OB) inside the cryostat and the concept of the location of the HIFI Local Oscillator Unit (FHLOU) external to the cryostat.

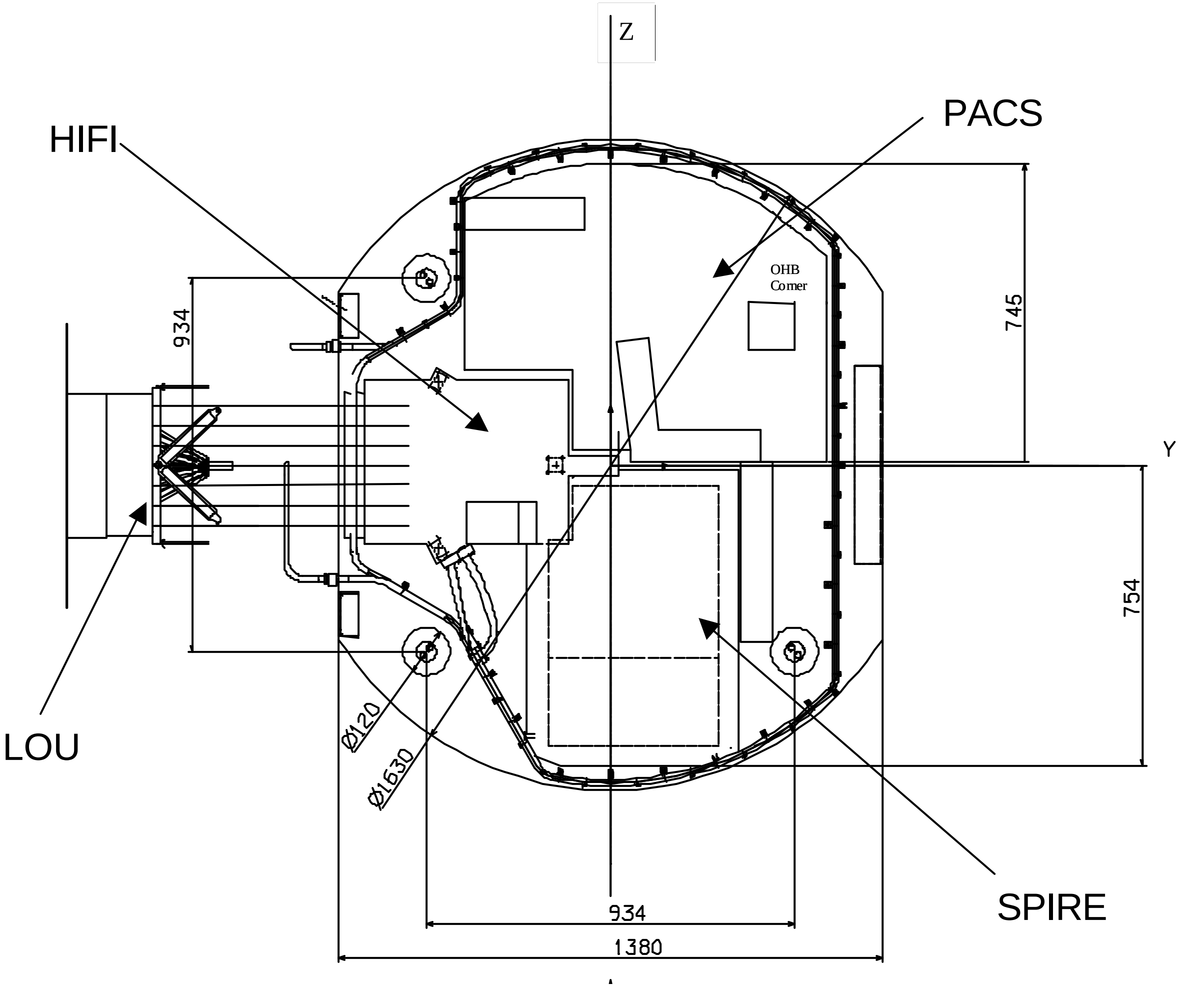


Figure 5.3-1: The FIRST Focal Plane, top view towards -X

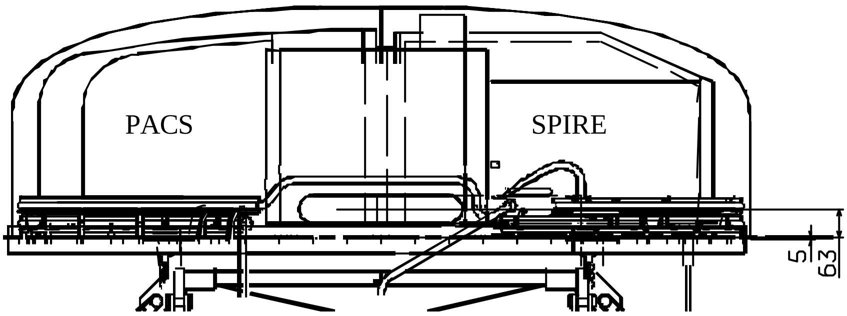


Figure 5.3-2: The FIRST Focal Plane, side view towards +Y

### 5.3.1 Instrument Location

The locations of the SPIRE units are as follows:

| Project code | Instrument location |
|---|---|
| FSFPU | On FIRST optical bench inside cryostat |
| FSFTB | On FIRST optical bench inside cryostat |
| FSDRC | On SVM |
| FSDPU | On SVM |
| FSWIH | On SVM |

#### 5.3.1.1 Inside cryostat

As shown in figure 5.4-1

#### 5.3.1.2 Outside cryostat

No SPIRE units are located on the outside of the cryostat

#### 5.3.1.3 On SVM

There are no location requirements for units on the SVM. It is expected that the FSDRC and the FSDPU are located close to each other.

#### 5.3.1.4 On Planck module

NA

### 5.3.2 Instrument Alignment

There are no alignment and/or alignment stability requirements except for the focal plane unit, the FSFPU.

#### 5.3.2.1 Absolute Requirements

The absolute alignment requirements of the FSFPU to the Optical Bench at operating conditions are TBC. However the SPIRE instrument places the following general requirement on the alignment of the instrument on the optical bench and the FIRST telescope with optical bench.

The optical alignment for the SPIRE instrument will be designed to control the degree of undersize required on the instrument cold stop to prevent the instrument viewing undesirable parts of the telescope structure (TBD). The present SPIRE optical alignment plan (reference) gives an undersize of 4.1%. The SPIRE instrument requires that the contribution of the alignment of the instrument on the FIRST optical bench and the FIRST telescope with the optical bench contributes no more than 5% to the required cold stop undersize i.e. the contribution from misalignment of the instrument and telescope is not significantly different to that from the instrument itself.

The telescope alignment plan (reference) calls for the instruments to be placed on the FIRST optical bench with no adjustment thereafter and for the FIRST telescope to be aligned to within TBD mm. This actual value is critically dependent on the telescope optical design. For a 308 mm secondary mirror the 5% requirement equates to a **total** positional accuracy of +-3.9 mm (TBC).

There are no alignment requirements on the SPIRE JFET box.

#### 5.3.2.2 Stability Requirements

The alignment stability requirements at operating conditions are TBD

## 5.4 EXTERNAL CONFIGURATION DRAWINGS

### 5.4.1 FSFPU

Figure 5.4-1 shows a drawing for the FSFPU and FSFTB inside the cryostat and their relationship to the telescope focal plane, the cryostat radiation shield and the diameter of the OB.

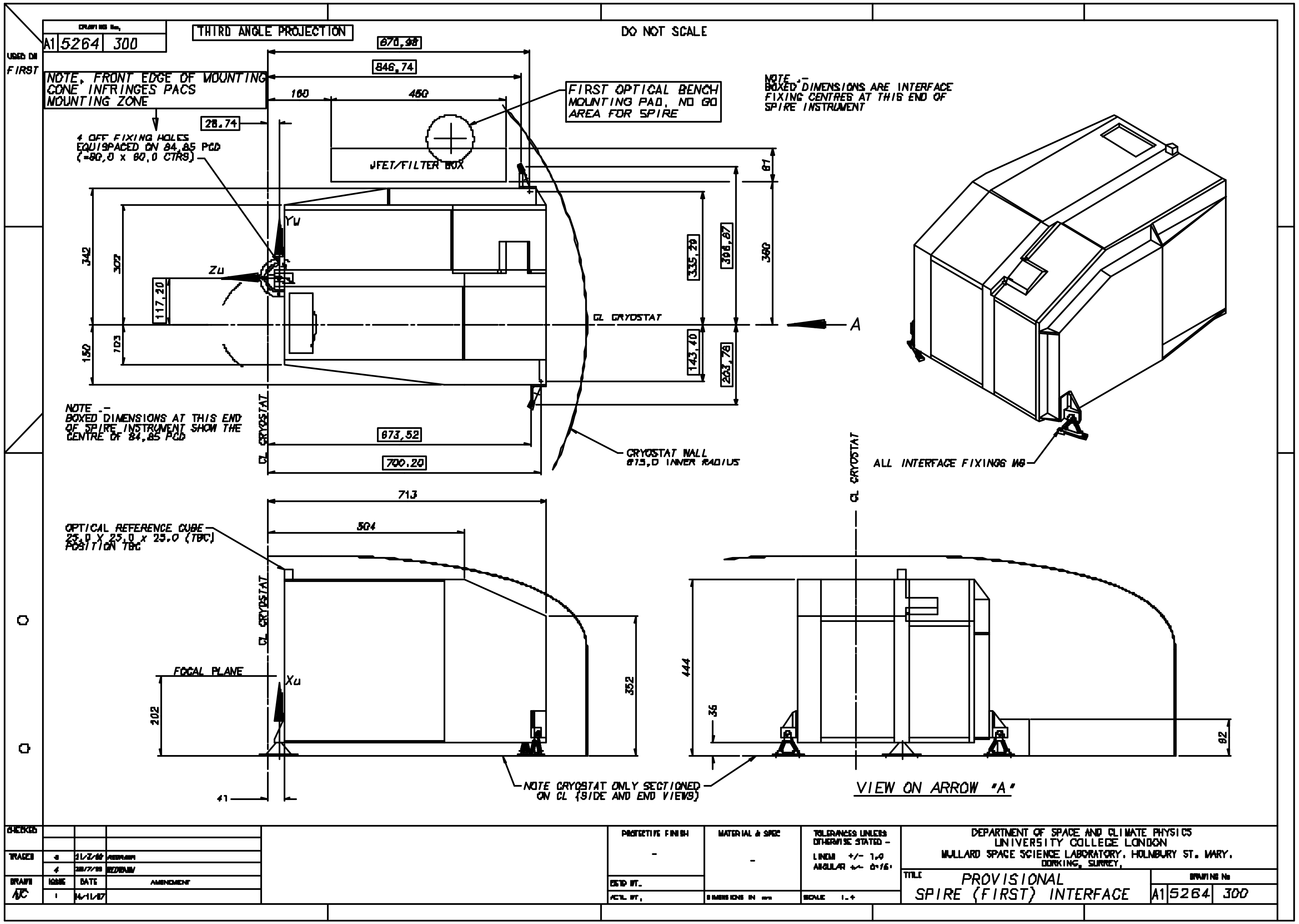


Figure 5.4-1: SPIRE Focal Plane Unit. The postion and size of the JFET box is indicative only

### 5.4.2 FSFTB

Figure 5.4-2 shows the external configuration drawing for the SPIRE JFET box (TBW).

### 5.4.3 FSDRC

Figure 5.4-4 shows the external configuration drawing for the SPIRE detector readout and control unit (TBW).

### 5.4.4 FSDPU

Figure 5.4-5 shows the external configuration drawing for the SPIRE data processing unit (TBW).

### 5.4.5 FSWIH

Figure 5.4-6 shows the external configuration drawing for the SPIRE warm electronics interconnect harness (TBW).

## 5.5 SIZES AND MASS PROPERTIES

The table below shows for each unit its size, mass and the number of units:

| Project code | Instrument unit | # of | Dimensions (mm) * | Max. Mass +Margin (kg) |
|---|---|---|---|---|
| FSFPU | Cold Focal Plane Unit (FPU) | 1 | 750 x 650 x 455<br>Irregular shape | 42 + 8.4 |
| FSFTB | JFET/RF box | 1 | 300x100x100 (TBC) | 6 +1.2 |
| FSDRC | Detector Read-out and Control Unit (DRCU) | 1 | 285 x 256 x 234 | 18 + 3.6 |
| FSDPU | Digital Processing Unit (DPU) | 1 | 240 x 218 x 194 | 7 + 1.4 |
| FSWIH | Warm interconnect harnesses: FSDRC-FSDPU | 1 | < 2000 | 2 + 0.4 |
| TOTAL | | | | 75 + 15 |

* Dimensions are given as Length x Width x Height. Length and Width define the fixation baseplate.

Note 1: Masses **include margins as defined in the IID A**

Note 2: Harnesses from the FSFTB and the FSFPU to the FSDRC will be ESA responsibility.

## 5.6 MECHANICAL INTERFACES

### 5.6.1 Inside cryostat

The Focal Plane Unit, the FSFPU, will have 3 support interfaces to the Optical Bench. One of these interfaces is the reference, as marked in the External Configuration Drawing. The interface will be such as to allow unit alignment and alignment-stability requirements to be fulfilled.

The JFET box will also mechanically interface directly to the Optical Bench. The number and location of the interfaces for fixation are 4 (TBC). There is no alignment requirement for this unit.

The FTS and the BMS are sensitive to µ-vibrations. SPIRE will define the required maximum level and bandwidth at the optical bench interface in due course.

### 5.6.2 Outside Cryostat

NA

### 5.6.3 On SVM

Units mounted on the SVM will have 6 attachment points for fixation to the equipment platform, as shown in figure (5.5-4).

The SPIRE warm electronics interconnect harness will attach to the SVM via TBD straps

### 5.6.4 On Planck Payload Module

NA

### 5.6.5 Cooler valves and piping

NA

## 5.7 THERMAL INTERFACES

### 5.7.1 Inside cryostat

The various instrument stages require 3 different temperatures. This will be achieved by strapping the stages to various “cold” parts of the cryostat.
These cryostat parts are:

| | |
|---|---|
| Level 0: | The He II tank for temperatures at the 1.7 K level |
| Level 1: | Strap to the He ventline at about 4K |
| Level 2: | Strap to the He-ventline at about 10 K |

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

| Project code | Operating | | Start-up | Switch-off | Non-operating | |
|---|---|---|---|---|---|---|
| | Min. K | Max. K | $^0$C | $^0$C | Min. $^0$C | Max. $^0$C |
| FSFPU (Level 1 enclosure) | N/A | 6 | TBD*** | TBD*** | TBD | + 60*<br>+ 80 ** |
| FSFPU Dedicated $^3$He cooler strap | N/A | 2**** | TBD*** | TBD*** | TBD | + 60*<br>+ 80 ** |
| FSFPU Level 0 Enclosure | N/A | 2 | TBD*** | TBD*** | TBD | + 60*<br>+ 80 ** |
| FSFTB | N/A | 15 | TBD*** | TBD*** | TBD | + 60*<br>+ 80 ** |
| | | | | | | |

* Continuous temperature limit.

** Short-duration temperature limit for bake-out during a maximum of 72 hours.

*** Certain sub-systems may not be able to be operated above 20 K.

**** For sorption cooler recycling see 5.7.1.1

#### 5.7.1.1 Thermal Straps for $^3$He Cooler

The operation of the $^3$He cooler requires that it is recycled by heating the sorption pump to ~40-K whilst the evaporator is kept at 1.7-K, thus condensing the $^3$He into the evaporator. At the end of the condensation phase the heat switch on the sorption pump is turned ON as the switch on the evaporator is turned OFF. Then there is a substantial peak power from the sorption pump to the bath via the strap. This peak power and associated energy will not have any significant impact on the bath – the cryostat LHe tank. However it will have a substantial impact on the thermal gradient along the strap.

It is strongly recommended that the strap from the cooler to the LHe tank is actually split into two straps, one for the pump and one for the evaporator, and the attachment points of each strap on the helium tank are separated. In this way the temperature of the evaporator strap will remain at $T_{bath}+\Delta T$ (as small as possible), leading to a good condensation efficiency and less $^3$He lost during the cooldown from 1.7 K to 0.3 K. The sorption pump will still operate properly even if the "hot" end of its strap rises momentarily to as much as 10 K. The temperature of the evaporator during condensation is critical to the efficiency of the cooler. Therefore it is also highly desirable that the connection between the evaporator and the LHe tank is direct as possible – i.e. not via any internal structure in the SPIRE instrument which may impose parasitic loads leading to a higher temperature.

For these reasons SPIRE will provide two Level 0 thermal strap interfaces to the $^3$He cooler which must be taken to the LHe tank via separate straps at separate locations on the tank. The SPIRE instrument will provide a third, separate, Level 0 strap interface for the internal structure of the instrument. The required thermal conductance is defined by the maximum temperature allowed at the interface, i.e. for cooler recycling up to 10 K.

### 5.1.2 Outside Cryostat

NA

### 5.1.3 On SVM

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

| Project code | Operating | | Start-up | Switch-off | Non-operating | |
|---|---|---|---|---|---|---|
| | Min. $^0$C | Max. $^0$C | $^0$C | $^0$C | Min. $^0$C | Max. $^0$C |
| FSDRC | - 15 | + 45 | - 30 | + 50 | - 35 | + 80 |
| FSDPU | - 15 | + 45 | - 30 | + 50 | - 35 | + 80 |

Note:
Acceptance temperature is 5 $^0$ below min. and 5 $^0$ above max. operating temp.
Qualification temperature is 10 $^0$ below min. and 10 $^0$ above max. operating temp.

### 5.1.4 On Planck Payload Module

NA

### 5.1.5 Temperature channels

#### 5.1.5.1 Instrument Temperature Sensors

The table below shows information relevant to the measurement of instrument temperatures.

| Unit | Location | Acronym | Sensor Type | Temp. Range | TM ref. |
|---|---|---|---|---|---|
| | | (all TBC) | | (all TBC) | |
| FSFPU | 200 µm array | T_PSW_1 | TBD | 0.2 K>5 K | TBD |
| FSFPU | 200 µm array | T_PSW_2 | TBD | 0.2 K>5 K | TBD |
| FSFPU | 350 µm array | T_PMW_1 | TBD | 0.2 K>5 K | TBD |
| FSFPU | 350 µm array | T_PMW_2 | TBD | 0.2 K>5 K | TBD |
| FSFPU | 500 µm array | T_PLW_1 | TBD | 0.2 K>5 K | TBD |
| FSFPU | 500 µm array | T_PLW_2 | TBD | 0.2 K>5 K | TBD |
| FSFPU | FTS array 1 | T_SSW_1 | TBD | 0.2 K>5 K | TBD |
| FSFPU | FTS array 1 | T_SSW_2 | TBD | 0.2 K>5 K | TBD |
| FSFPU | FTS array 2 | T_SLW_1 | TBD | 0.2 K>5 K | TBD |
| FSFPU | FTS array 2 | T_SLW_2 | TBD | 0.2 K>5 K | TBD |
| | | | | | |
| FSFPU | PHOT Level 0 box | T_PL0_2 | TBD | 1 K>300 K | TBD |
| | | | | | |
| FSFPU | FTS Level 0box | T_SL0_2 | TBD | 1 K>300 K | TBD |

| **Unit** | **Location** | **Acronym** | **Sensor Type** | **Temp. Range** | **TM ref.** |
|---|---|---|---|---|---|
| | | (all TBC) | | (all TBC) | |
| | | | | | |
| FSFPU | Level 1structure | T_CL1_2 | TBD | 3 K>300 K | TBD |
| | | | | | |
| FSFPU | Instrument cover (May not be needed) | T_COV_2 | TBD | 3 K>300 K | TBD |
| FSFPU | Phot Calibrator | T_PCAL_1 | TBD | 3 K>300 K | TBD |
| FSFPU | Phot Calibrator | T_PCAL_2 | TBD | 3 K>300 K | TBD |
| FSFPU | FTS Mechanism | T_FTS_1 | TBD | 3 K>300 K | TBD |
| FSFPU | FTS Mechanism | T_FTS_2 | TBD | 3 K>300 K | TBD |
| FSFPU | FTS Calibrator | T_SCAL_1 | TBD | 3 K>300 K | TBD |
| FSFPU | FTS Calibrator | T_SCAL_2 | TBD | 3 K>300 K | TBD |
| FSFPU | Cooler Pump | T_CPMP_1 | TBD | 3 K>300 K | TBD |
| FSFPU | Cooler Pump | T_CPMP_2 | TBD | 3 K>300 K | TBD |
| FSFPU | Cooler Evaporator | T_CEV_1 | TBD | 0.2 K>5 K | TBD |
| FSFPU | Cooler Evaporator | T_CEV_1 | TBD | 0.2 K>5 K | TBD |
| FSFPU | Cooler Pump heat switch | T_CPHS_1 | TBD | 1 K>50 K | TBD |
| FSFPU | Cooler Pump heat switch | T_CPHS_2 | TBD | 1 K>50 K | TBD |
| FSFPU | Cooler Evap. Heat switch | T_CEHS_1 | TBD | 1 K>50 K | TBD |
| FSFPU | Cooler Evap. Heat switch | T_CEHS_2 | TBD | 1 K>50 K | TBD |
| FSFPU | Shutter Vane | T_SHUT_1 | TBD | 3 K > 30 K | TBD |
| FSFPU | Shutter Vane | T_SHUT_2 | TBD | 3 K > 30 K | TBD |
| FSFPU | BSM (TBC) | T_BSM_1 | TBD | 3 K>300 K | TBD |
| FSFPU | BSM (TBC) | T_BSM_2 | TBD | 3 K>300 K | TBD |
| FSFTB | JFET/Filter box | T_FTB_2 | TBD | 3 K>300 K | TBD |
| FSDRC | DRCU | T_DRCU_2 | TBD | -45 $^{0}$C >90 $^{0}$C | TBD |
| FSDRC | DRCU | T_DRCU_3 | TBD | -45 $^{0}$C >90 $^{0}$C | TBD |
| FSDPU | DPU | T_DPU_2 | TBD | -45 $^{0}$C >90 $^{0}$C | TBD |

#### 5.1.5.2 Satellite Temperature sensors

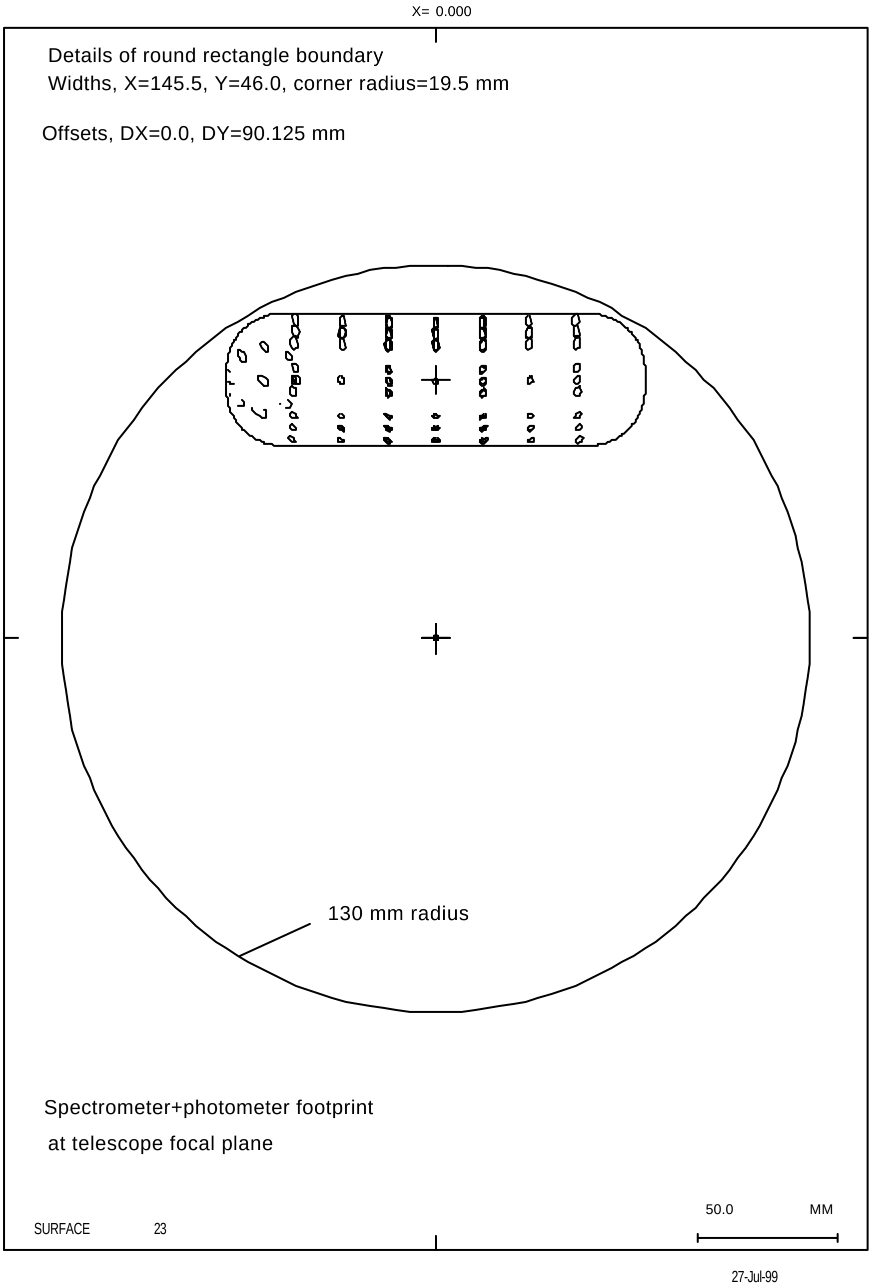
In addition to the instrument temperature channel, SPIRE requires that the satellite monitors the temperatures of certain parts of the cryostat and SVM independently to ensure the safety of the instrument when it is not operating. These are given in the table below.

| Location | Acronym | Sensor Type | Temp. Range | TM ref. |
|---|---|---|---|---|
| | (all TBD) | (All TBD) | (all TBC) | (All TBD) |
| Level 0 Strap to cooler | | | 1.5K - 90°C | |
| Level 0 Strap to FSFPU enclosure | | | 1.5K - 90°C | |
| Level 1 strap to FSFPU | | | 1.5K - 90°C | |
| Level 2 strap to FSFTB | | | 1.5K - 90°C | |
| Optical bench at FSFPU mechanical interfaces (number TBD) | | | 1.5K - 90°C | |
| SVM at FSDRC mechanical interface | | | -80 + 90$^{o}$c | |
| SVM at FSDPU mechanical interface | | | -80 + 90$^{o}$c | |

## 5.8 OPTICAL INTERFACES

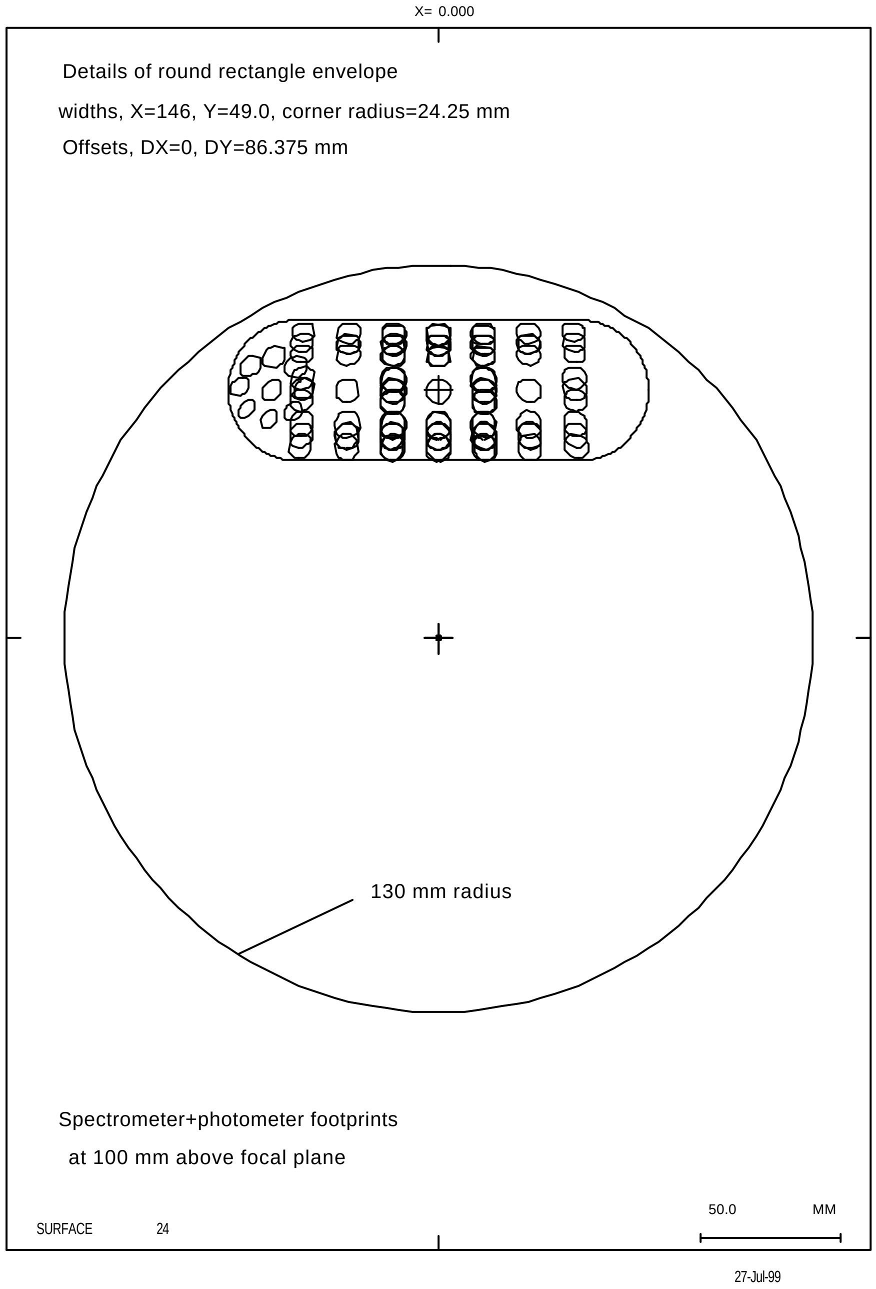
Figures 5.8-1, 5.8-2, 5.8-3,5.8-4 and 5.8-5 show the SPIRE optical beam envelope at various places through the path from the telescope focal plane to the hole in the FIRST primary mirror. No structure or other material is allowed within the envelope defined by these “footprints”.

The footprints are subject to revision as the optical design of the telescope, and thus of the SPIRE instrument, is refined. Note that with the present design the 130 mm radius hole in the cryostat is barely large enough for the beam to pass through un-vignetted and the hole in the primary is required to be at least 135 mm radius. In fact these are sized for the geometrical footprints only, when the effects of diffraction are taken into account there is certain to be some vignetting at some parts of the FOV for some beam steering mirror positions.



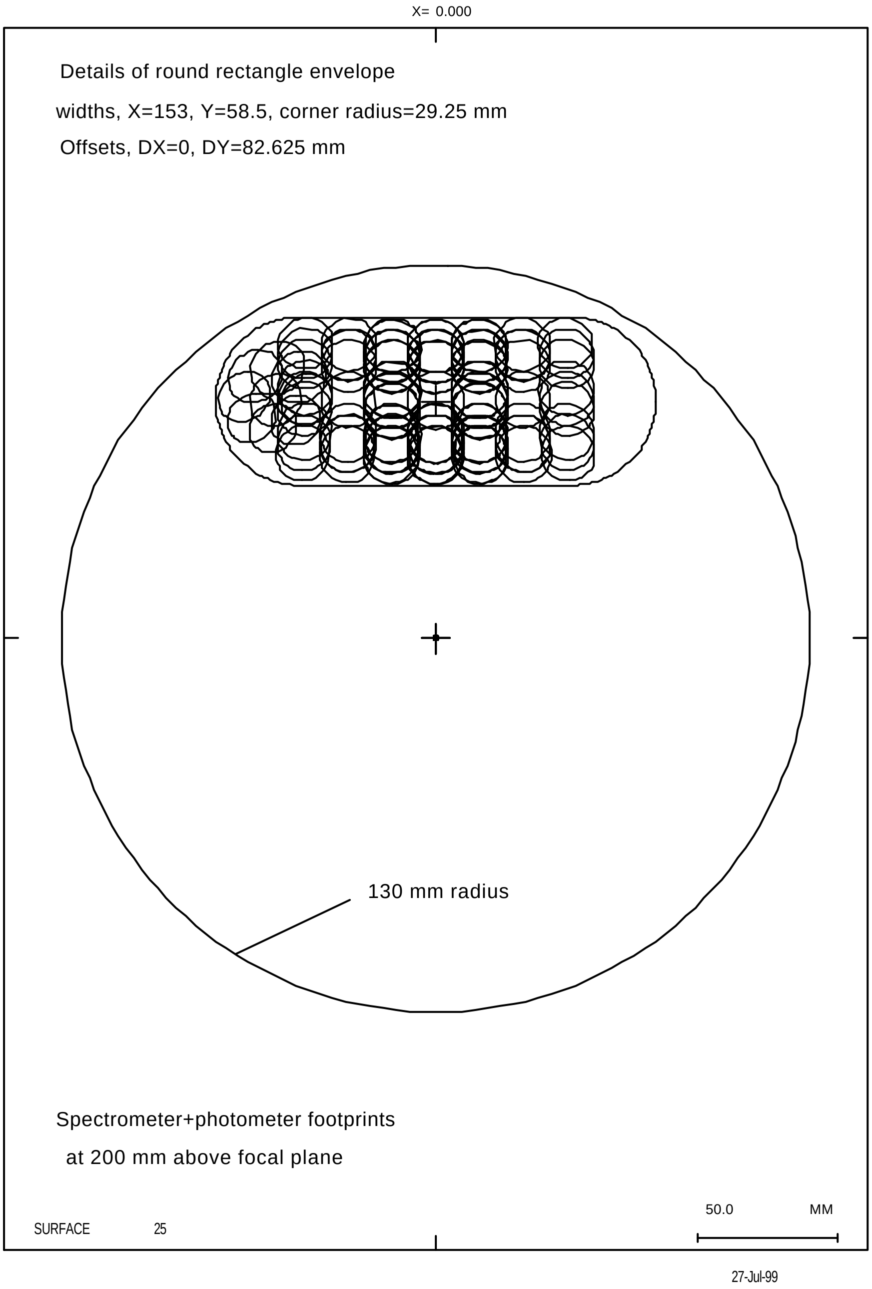
Reversed PHOT126B + SP460C

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



Reversed PHOT126B + SP460C

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



Reversed PHOT126B + SP460C

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

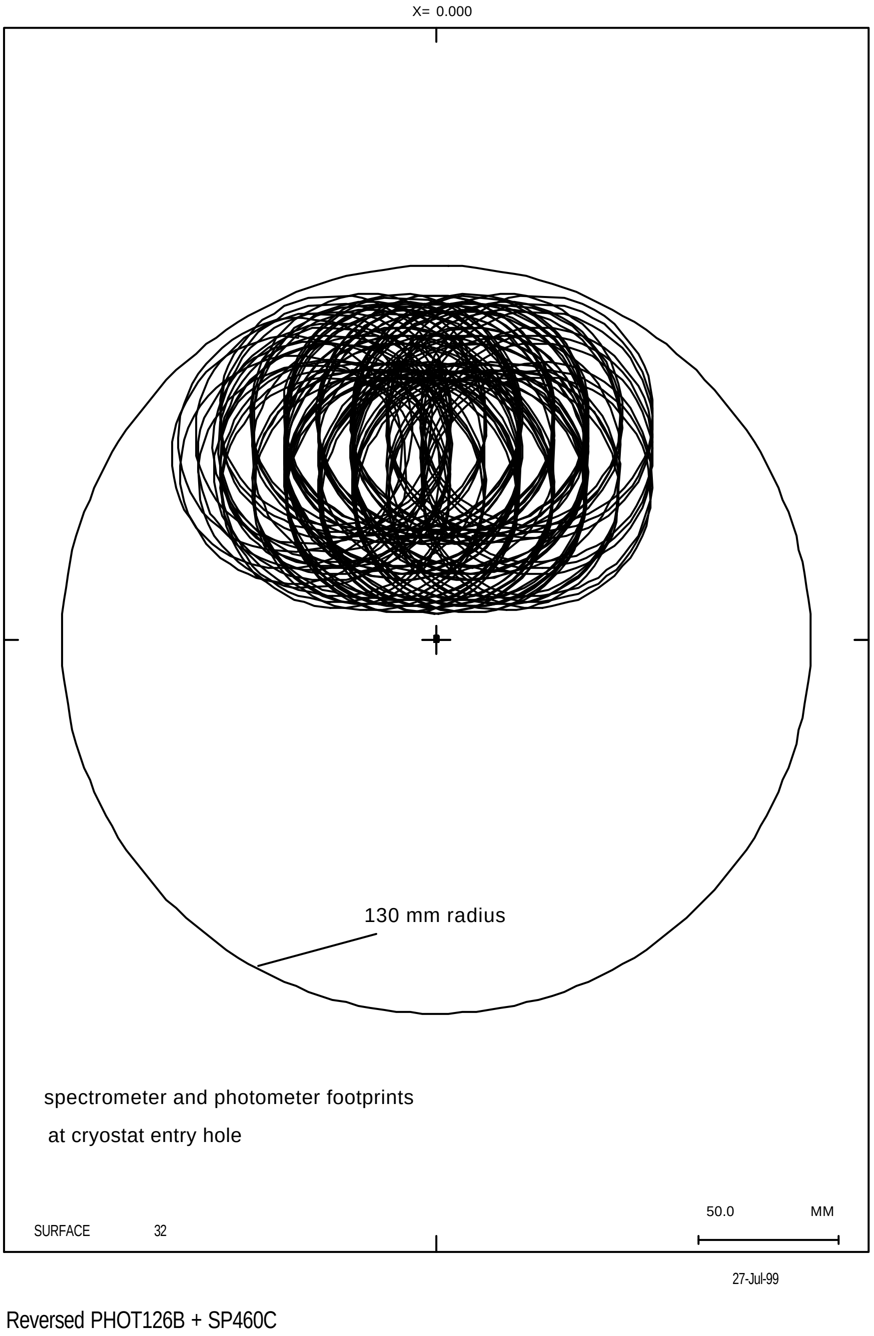


Figure 5.8-4 SPIRE optical beam envelope at the exit hole from the FIRST cryostat.

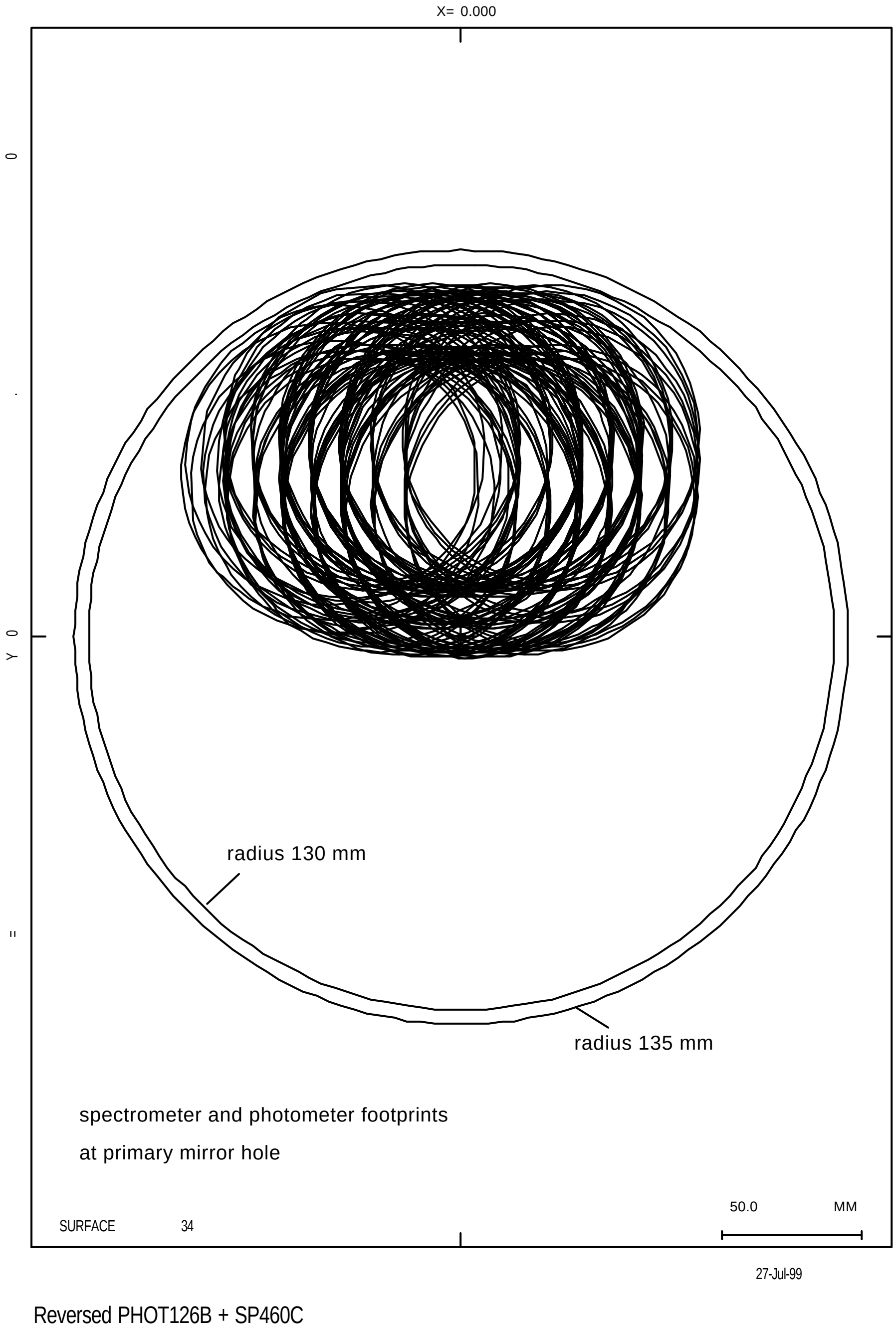


Figure 5.8-5 SPIRE optical beam envelope at the hole in the FIRST telescope primary mirror.

### 5.8.1 Straylight

Instrument straylight model is described in RD1: Caldwell. M; Richards. A; Swinyard. B. Straylight Analysis – SPIRE/RAL/N0044 Descriptions of CodeV and APART models of FIRST-SPIRE.

## 5.9 POWER

### 5.9.1 Inside cryostat

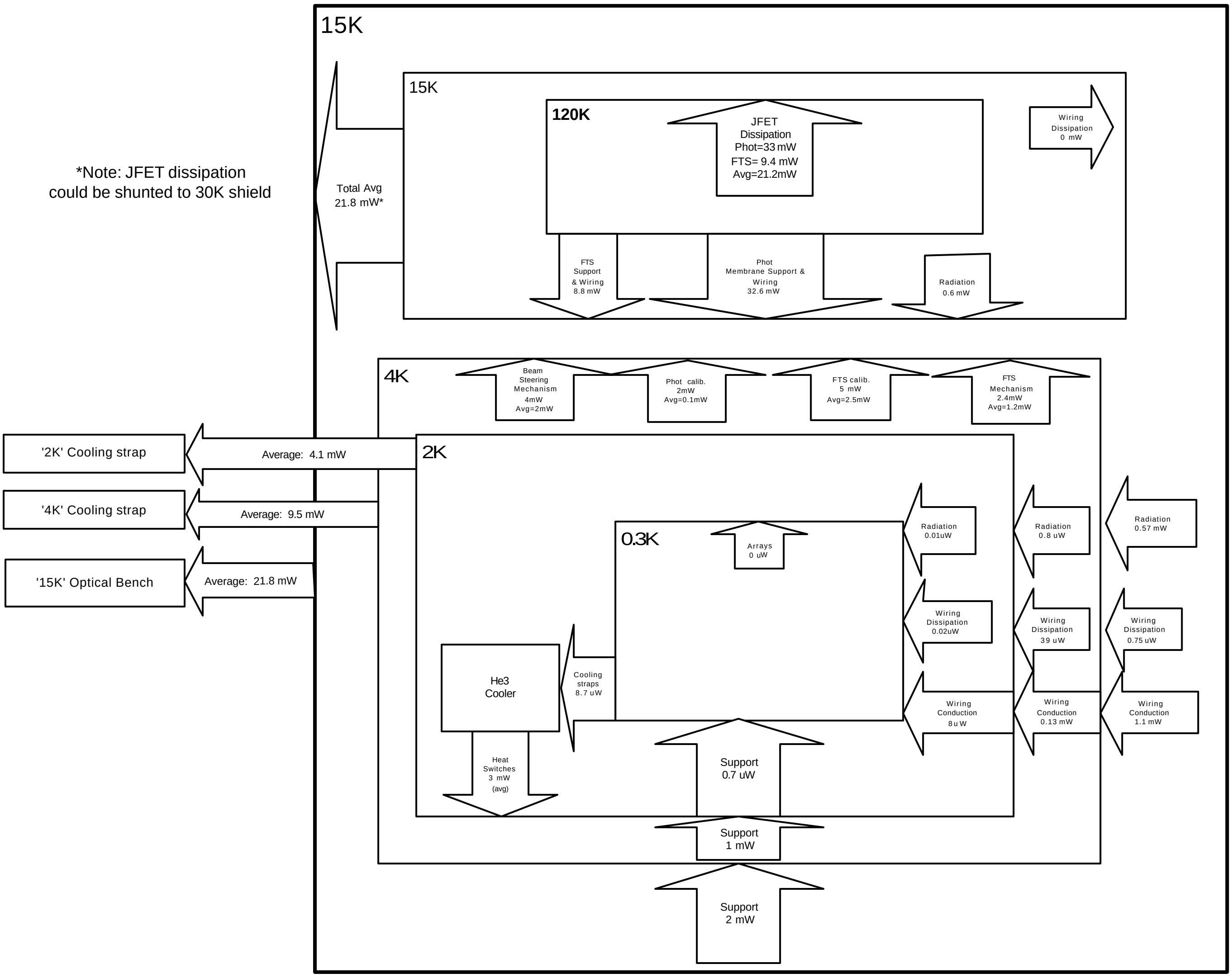
The tables and models below show the heat dissipation of the units mounted inside the cryostat:

| Project code | Instrument unit | Power Dissipation (W) |
|---|---|---|
| FSFPU | Cold Focal Plane Unit | See: Thermal Model and Thermal Table |

#### 5.9.1.1 Thermal model FSFPU

Please note that the diagram above is for information purposes only, budget values are given in the thermal tables.

344 bolometers, JFETs ON
(note: Average figures are for 50% photometry/spectrometry operation)



SPIRE Thermal block diagram: Feed-horn option V3.4 Date: 13/07/99

### 5.9.1.2 Thermal table FSFPU

| Temp. Stage | Item | Loads in mW (All TBC) | | | |
|---|---|---|---|---|---|
| | | **Standby** | **OFF** | **PHOT** | **SPEC** |
| Level 2 | JFET Box | 33 | 0 | 33 | 9.4 |
| Level 1 | Wires | 1.1 | 1.1 | 1.1 | 1.1 |
| | Radiation | 0.6 | 0.6 | 0.6 | 0.6 |
| | Mechanisms & calibrators | 0.0 | 0.0 | 4.1 | 7.4 |
| | Structure | 6.0 | 6.0 | 6.0 | 6.0 |
| | Total | 7.7 | 7.7 | 11.8 | 15.1 |
| Level 0 | Wires | 0.1 | 0.1 | 0.1 | 0.1 |
| | Dissipation | 0.0 | 0.0 | 0.0 | 0.0 |
| | Cooler*** | 4.0 | 1.0 | 4.0 | 4.0 |
| | Structure | 1.0 | 1.0 | 1.0 | 1.0 |
| | Total | 5.1 | 2.1 | 5.1 | 5.1 |

Either Photometer or Spectrometer JFETS are switched on in STANDBY mode, and switched off in OFF mode. Average power in OBSERVING mode can be calculated assuming JFETS for photometer can be turned off when spectrometer is in operation, and vice versa.
Level 1 heatloads assume level 2 is 11K and level 1 is 4 K

** Excludes conducted and dissipative heatloads from cryo harness connecting to 300 K level.

*** Includes dissipation of $^3$He refrigerator when operating (Averaging the load during operation and recycling – recycle mode dissipates 90 mW (TBC) for 2 out of every 48 hours). The parasitic loads from 4 to 2 K through the structure and heat switches amount to 1 mW (TBC).

### 5.9.2 Outside Cryostat

NA

### 5.9.3 On SVM

The table below shows the heat dissipation of the units mounted on the SVM:

| **Project code** | **Instrument unit** | **Power (W)** |
|---|---|---|
| FSDRC | Detector Read-out and Control Unit | 71 |
| FSDPU | Digital Processing Unit | 15 |
| FSWIH | Warm Interconnect Harness | 0 |
| TOTAL | | 86 |

### 5.9.4 On Planck Payload Module

NA

### 5.9.5 Instrument Operating Modes

The table below shows the status of the instrument subsystems in the various instrument modes. (It is the idea to link this, at a later stage, to para 5.9.1 through 5.9.4 for the purpose of power dissipation calculations inside and outside the cryostat).

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

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

### 5.9.6 Supply voltages

#### 5.9.6.1 28 Volt main-bus

##### 5.9.6.1.1 Load on main-bus

The power load on the 28V. main-bus for the instrument is as follows:

| **Operating mode** | **Average BOL (beginning of life) (W)** | **Average EOL (end of life) (W)** | **Peak (W)** |
|---|---|---|---|
| Observe | 86 W | TBD | TBD |
| Parallel | 86 W | TBD | TBD |
| Serendipity | 86 W | TBD | TBD |
| Standby | 86 W | TBD | TBD |
| Cooler Recycle | 86 W | TBD | TBD |
| On | 15 W | TBD | TBD |
| Off | 0 | 0 | 0 |

#### 5.9.6.1.2 Interface circuit

There will be two 28 V lines plus redundancy into the SPIRE instrument. One to the FSDPU and one to the FSDRC.

### 5.9.6.2 Keep Alive Line (KAL)

Because the instrument will not be switched-on/off frequently, the implementation of a KAL is not envisaged.

## 5.10 CONNECTORS, HARNESS, GROUNDING, BONDING

### 5.10.1 Connectors

Compliant with section 5.10 of IID-A.

### 5.10.2 Harness

#### 5.10.2.1 S/C Harness

The S/C harness provides the interconnection between the instrument and two other subsystems i.e. the Power subsystem and the Command and Data Management System.
The harness is supplied through the S/C Contractor.
On the instrument side, pin functions are specified in Annex A to this document.

#### 5.10.2.2 Instrument Harness

The “warm” harness i.e. the interconnect harness between the FSDRC and FSDPU will be delivered by the instrument team, manufactured to agreed requirements as specified in the IID-A section 5.10.2.2
Pin functions and wiring characteristics are specified in Annex A to this document.
The Contractor will specify length and routing as soon as an SVM lay-out is available. A Configuration Drawing will be included under item 5.4 of the IID-B.

#### 5.10.2.3 Cryo Harness

The cryo harness, interconnecting the FSFTB and FSFPU to 300 K, will be delivered through the S/C Contractor, manufactured to agreed requirements.
The cryo harness interconnecting the cold instrument parts is considered part of the instrument and therefore to be manufactured by the instrument teams.
Pin functions are specified in Annex A to this document.

The block diagram shows the cryo harness routing between the various interface levels, whilst the tables show the cryo harness compositions for the 4.3- to 15 K and the 15- to 300 K interfaces.

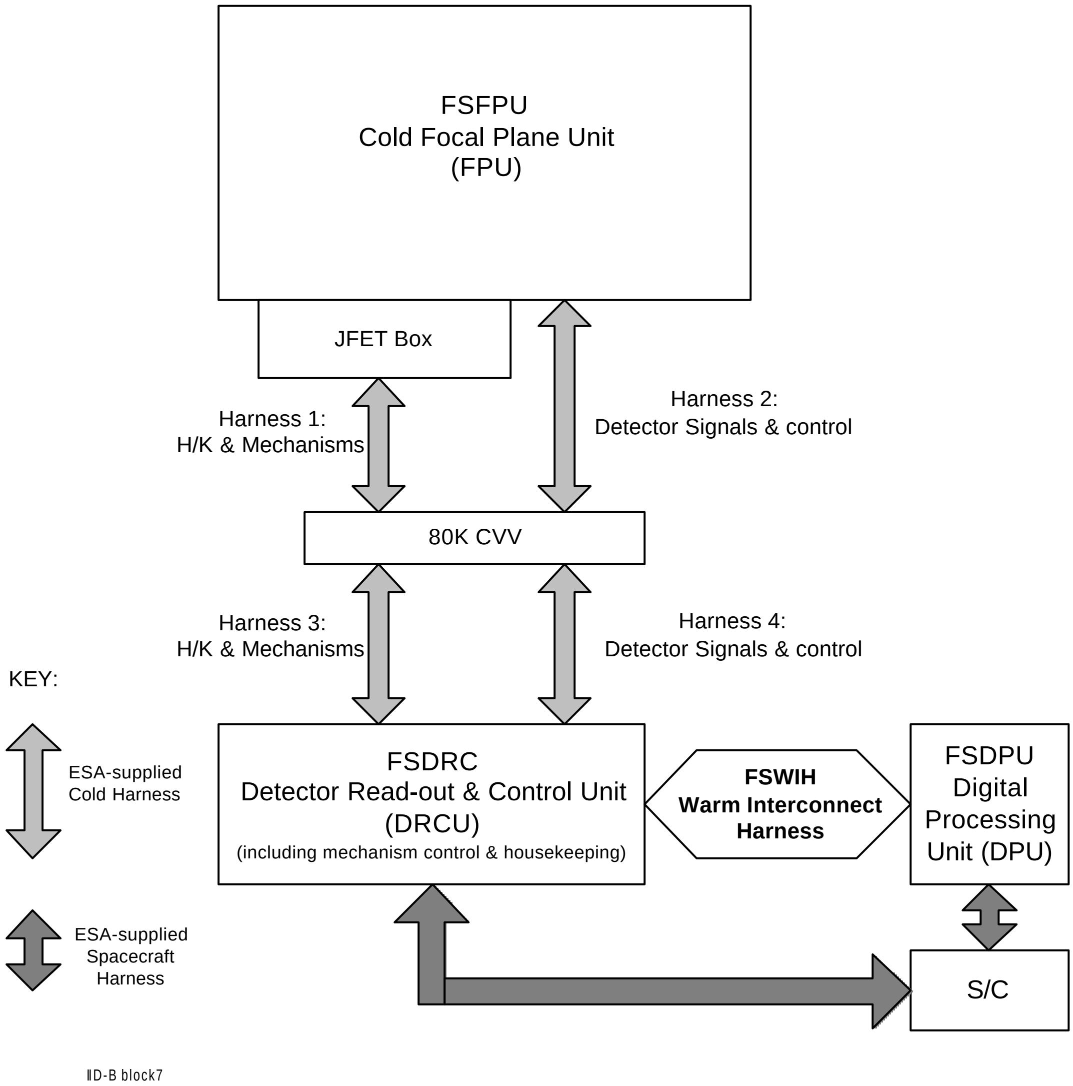


Figure 5.10-1: SPIRE block diagram

## SPIRE cryo-harness list for Level 1 (FSFPU) to CVV 80-K Feedthrough

### 1: Housekeeping and Mechanisms

| | Instrument: SPIRE Level 1 to Level 2 | Name | No. of Cond. | No. of shields | Max. allowed impedances | | | Current | Duty Cycle | Max. Line Volt |
|---|---|---|---|---|---|---|---|---|---|---|
| ID | Signal definition | | | | R (Ω) | C(F) | L(H) | (A) | (t*T) | (V) |
| 21 | 0.3- K therms. (10) | TH-300 | 40 | 10 | 1000 | | | 1.0E-5 | 1 * 1/3 | TBD |
| 22 | 2- K therms (2) | TH-2 | 8 | 2 | 1000 | | | 1.0E-5 | 1 * 1/3 | TBD |
| 23 | 4- K therms (2) | TH-4 | 8 | 2 | 1000 | | | 1.0E-5 | 1 * 1/3 | TBD |
| 24 | N.A. | | | | | | | | | |
| 25 | FTS temp sensors | F_Temp | 8 | 2 | 1000 | | | 1.0E-5 | 1 * 1/3 | TBD |
| 26 | FTS posn sensors (main) | F_Posn_M | 5 | 1 | 1000 | | | 1.0E-4 | 0.5 * 1/3 | TBD |
| 27 | FTS posn sensors (red) | F_Posn_R | 5 | 1 | 1000 | | | 0.0E+0 | 1 * 1/3 | TBD |
| 28 | FTS drive coils (main) | F_Drive_M | 4 | 0 TBC | 10 TBC | | | 8.0E-3 | 0.5 * 1/3 | TBD |
| 29 | FTS drive coils (red.) | F_Drive_R | 4 | 0 TBC | 10 TBC | | | 0.0E+0 | 0 | TBD |
| 30 | FTS BB calibrator (main) | F_BBC_M | 2 | 0 TBC | 10 TBC | | | 3.0E-3 | 0.5 * 1/3 | TBD |
| 31 | FTS BB calibrator (red.) | F_BBC_R | 2 | 0 TBC | 10 TBC | | | 0.0E+0 | 0 | TBD |
| 32 | FTS BB therms (2) | F_BBC_T | 8 | 2 | 1000 | | | 1.0E-5 | 1 * 1/3 | TBD |
| 33 | Pump heater (main) | PH_M | 2 | 0 | 10 TBC | | | 2.0E-2 | 0.014 * 1/3 | TBD |
| 34 | Pump heater (red.) | PH_R | 2 | 0 | 10 TBC | | | 0.0E+0 | 0 | TBD |
| 35 | Pump therm. (main) | PT_M | 4 | 1 | 1000 | | | 1.0E-5 | 1 * 1/3 | TBD |
| 36 | Pump therm. (red.) | PT_R | 4 | 1 | 1000 | | | 1.0E-5 | 1 * 1/3 | TBD |
| 37 | Evap. therm. (main) | ET_M | 4 | 1 | 1000 | | | 1.0E-5 | 1 * 1/3 | TBD |
| 38 | Evap. therm. (red.) | ET_R | 4 | 1 | 1000 | | | 1.0E-5 | 1 * 1/3 | TBD |
| 39 | Pump heat SW heater (main) | PHSWH_M | 2 | 0 | 10 TBC | | | 2.0E-3 | 0.96 * 1/3 | TBD |
| 40 | Pump heat SW heater (red.) | PHSWH_R | 2 | 0 | 10 TBC | | | 0.0E+0 | 0 | TBD |
| 41 | Evap. heat SW heater (main) | EHSWH_M | 2 | 0 | 10 TBC | | | 2.0E-3 | 0.04 * 1/3 | TBD |
| 42 | Evap. heat SW heater (red.) | EHSWH_R | 2 | 0 | 10 TBC | | | 0.0E+0 | 0 | TBD |
| 43 | Pump heat SW therm. (main) | PHSWT_M | 4 | 1 | 1000 | | | 1.0E-5 | 1 * 1/3 | TBD |
| 44 | Pump heat SW therm. (red.) | PHSWT_R | 4 | 1 | 1000 | | | 1.0E-5 | 1 * 1/3 | TBD |
| 45 | Evap. heat SW therm. (main) | EHSWT_M | 4 | 1 | 1000 | | | 1.0E-5 | 1 * 1/3 | TBD |
| 46 | Evap. heat SW therm. (red.) | EHSWT_R | 4 | 1 | 1000 | | | 1.0E-5 | 1 * 1/3 | TBD |
| 47 | BSM drive coil (main) | CH_DR_M | 4 | 1 | 10 TBC | | | 2.5E-3 | 0.5 * 1/3 | TBD |
| 48 | BSM drive coil (red.) | CH_DR_R | 4 | 1 | 10 TBC | | | 0 | 0 | TBD |
| 49 | BSM pickup coil (main) | CH_PU_M | 5 | 1 | 1000 | | | 1E-3 | 0.5 * 1/3 | TBD |
| 50 | BSM pic-up coil (red.) | CH_PU_R | 5 | 1 | 1000 | | | 0.0E+0 | 0 | TBD |
| 51 | BSM them (main) | CH_T_M | 4 | 1 | 1000 | | | 1.0E-5 | 1 * 1/3 | TBD |
| 52 | BSM them (red.) | CH_T_R | 4 | 1 | 1000 | | | 1.0E-5 | 1 * 1/3 | TBD |
| 53 | Shutter drive coil (main) | SH_DR_M | 4 | 0 | 10 TBC | | | TBD | 0 | TBD |
| 54 | Shutter drive coil (red.) | SH_DR_R | 4 | 0 | 10 TBC | | | TBD | 0 | TBD |
| 55 | Shutter therm (main) | SH_T-M | 4 | 1 | 1000 | | | 1.0E-5 | 1 * 1/3 | TBD |
| 56 | Shutter therm (red.) | SH_T-R | 4 | 1 | 1000 | | | 1.0E-5 | 1 * 1/3 | TBD |

| ID | Instrument: SPIRE Level 1 to Level 2 Signal definition | Name | No. of Cond. | No. of shields | Max. allowed impedances R (Ω) | C(F) | L(H) | Current (A) | Duty Cycle (t*T) | Max. Line Volt (V) |
|---|---|---|---|---|---|---|---|---|---|---|
| 57 | Phot BB Calibrator (main) | P_BBC_M | 2 | 0 | 10 TBC | | | 3.0E-3 | 0.5 * 1/3 | TBD |
| 58 | Phot BB Calibrator (red.) | P_BBC_R | 2 | 0 | 10 TBC | | | 0.0E+0 | 0 | TBD |
| 59 | Phot BB therms (2) | P_BBC_T | 8 | 2 | 1000 | | | 1.0E-5 | 1 * 1/3 | TBD |
| | **Total** | | **192** | **38** | | | | | | |

## SPIRE cryo-harness list for Level 2 (FSFTB) to 80-K CVV feedthrough

### 2 : Detector Signals and control

| ID | Description | Name | No. of Conductors | No. of Shields | Max. Allowed Impedances R (Ω) | C (F)* | L(H)* | Current (A) | Duty Cycle (t*T) | Max Volts (V) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | P250 Sig | P250S | 288 | 144 STP + 12 common shields | 200 | 1000pF | 0.08 | 1n | 1 * 1/3 | 0.1 |
| 2 | P350 Sig | P350S | 184 | 92 STP + 8 common shields | 200 | 1000pF | 0.08 | 1n | 1 * 1/3 | 0.1 |
| 3 | P500 Sig | P500S | 96 | 48 STP + 4 common shields | 200 | 1000pF | 0.08 | 1n | 1 * 1/3 | 0.1 |
| 4 | S250 Sig | S250S | 84 | 42 STP + 4 common shields | 200 | 1000pF | 0.08 | 1n | 1 * 1/3 | 0.1 |
| 5 | S350 Sig | S350S | 48 | 24 STP + 2 common shield | 200 | 1000pF | 0.08 | 1n | 1 * 1/3 | 0.1 |
| 6 | Det. Bias | BIAS | 20 | 10 STP +1 common shield (TBC) | 1k | 1000pF | - | 1u | 1 * 1/3 | 0.1 |
| 7 | JFET Power | JFETP | 64 | 32 STP | 1k | 1000pF | - | 1m | 0.3 * 1/3 | 10 |
| 8 | JFET Heater | JFETH | 24 | 12 STP | 200 | 1000pF | - | 1m | 0.01 * 1/3 | 10 |
| 9 | TC Bias | TBIAS | 6 | 3 STP + 1 common shield | 1k | 1000pf | - | 1u | 1 * 1/3 | 1 |
| 10 | TC Sig | TSIG | 12 | 6 STP + 1 common shield | 200 | 1000pF | 0.08 | 1n | 1 * 1/3 | 0.1 |
| | | Totals | 830 | 415 STP + 33 Common shields | | | | | | |
| | ID 11 - 20 not used | | | | | | | | | |

## SPIRE cryo-harness list for CVV to 300 K SVM

### 3: Housekeeping and mechanism control

| | Instrument: SPIRE 15-K to 300-K interface | Name | No. of Cond. | No. of shields | Max. allowed Impedances | | | Current | Duty Cycle | Max. Line Volt |
|---|---|---|---|---|---|---|---|---|---|---|
| ID | Signal definition | | | | R (Ω) | C (F) | L(H) | (A) | (t*T) | (V) |
| 21 | 0.3- K therms. (5) | TH-300 | 20 | 5 | 1000 | | | 1.0E-5 | 1 * 1/3 | TBD |
| 22 | 2- K therms (2) | TH-2 | 8 | 2 | 1000 | | | 1.0E-5 | 1 * 1/3 | TBD |
| 23 | 4- K therms (2) | TH-4 | 8 | 2 | 1000 | | | 1.0E-5 | 1 * 1/3 | TBD |
| 24 | 15- K therms (2) | TH-15 | 8 | 2 | 1000 | | | 1.0E-5 | 1 * 1/3 | TBD |
| 25 | FTS temp sensors | F_Temp | 8 | 2 | 1000 | | | 1.0E-5 | 1 * 1/3 | TBD |
| 26 | FTS posn sensors (main) | F_Posn_M | 5 | 1 | 1000 | | | 1.0E-4 | 0.5 * 1/3 | TBD |
| 27 | FTS posn sensors (red) | F_Posn_R | 5 | 1 | 1000 | | | 0.0E+0 | 1 * 1/3 | TBD |
| 28 | FTS drive coils (main) | F_Drive_M | 4 | 0 TBC | 10 TBC | | | 8.0E-3 | 0.5 * 1/3 | TBD |
| 29 | FTS drive coils (red.) | F_Drive_R | 4 | 0 TBC | 10 TBC | | | 0.0E+0 | 0 | TBD |
| 30 | FTS BB calibrator (main) | F_BBC_M | 2 | 0 TBC | 10 TBC | | | 3.0E-3 | 0.5 * 1/3 | TBD |
| 31 | FTS BB calibrator (red.) | F_BBC_R | 2 | 0 TBC | 10 TBC | | | 0.0E+0 | 0 | TBD |
| 32 | FTS BB therms (2) | F_BBC_T | 8 | 2 | 1000 | | | 1.0E-5 | 1 * 1/3 | TBD |
| 33 | Pump heater (main) | PH_M | 2 | 0 | 10 TBC | | | 2.0E-2 | 0.014 * 1/3 | TBD |
| 34 | Pump heater (red.) | PH_R | 2 | 0 | 10 TBC | | | 0.0E+0 | 0 | TBD |
| 35 | Pump therm. (main) | PT_M | 4 | 1 | 1000 | | | 1.0E-5 | 1 * 1/3 | TBD |
| 36 | Pump therm. (red.) | PT_R | 4 | 1 | 1000 | | | 1.0E-5 | 1 * 1/3 | TBD |
| 37 | Evap. therm. (main) | ET_M | 4 | 1 | 1000 | | | 1.0E-5 | 1 * 1/3 | TBD |
| 38 | Evap. therm. (red.) | ET_R | 4 | 1 | 1000 | | | 1.0E-5 | 1 * 1/3 | TBD |
| 39 | Pump heat SW heater (main) | PHSWH_M | 2 | 0 | 10 TBC | | | 2.0E-3 | 0.96 * 1/3 | TBD |
| 40 | Pump heat SW heater (red.) | PHSWH_R | 2 | 0 | 10 TBC | | | 0.0E+0 | 0 | TBD |
| 41 | Evap. heat SW heater (main) | EHSWH_M | 2 | 0 | 10 TBC | | | 2.0E-3 | 0.04 * 1/3 | TBD |
| 42 | Evap. heat SW heater (red.) | EHSWH_R | 2 | 0 | 10 TBC | | | 0.0E+0 | 0 | TBD |
| 43 | Pump heat SW therm. (main) | PHSWT_M | 4 | 1 | 1000 | | | 1.0E-5 | 1 * 1/3 | TBD |
| 44 | Pump heat SW therm. (red.) | PHSWT_R | 4 | 1 | 1000 | | | 1.0E-5 | 1 * 1/3 | TBD |
| 45 | Evap. heat SW therm. (main) | EHSWT_M | 4 | 1 | 1000 | | | 1.0E-5 | 1 * 1/3 | TBD |
| 46 | Evap. heat SW therm. (red.) | EHSWT_R | 4 | 1 | 1000 | | | 1.0E-5 | 1 * 1/3 | TBD |
| 47 | BSM drive coil (main) | CH_DR_M | 4 | 1 | 10 TBC | | | 2.5E-3 | 0.5 * 1/3 | TBD |
| 48 | BSM drive coil (red.) | CH_DR_R | 4 | 1 | 10 TBC | | | 0 | 0 | TBD |
| 49 | BSM pic K-up coil (main) | CH_PU_M | 5 | 1 | 1000 | | | 1E-3 | 0.5 * 1/3 | TBD |
| 50 | BSM pic K-up coil (red.) | CH_PU_R | 5 | 1 | 1000 | | | 0.0E+0 | 0 | TBD |
| 51 | BSM them (main) | CH_T_M | 4 | 1 | 1000 | | | 1.0E-5 | 1 * 1/3 | TBD |
| 52 | BSM them (red.) | CH_T_R | 4 | 1 | 1000 | | | 1.0E-5 | 1 * 1/3 | TBD |
| 53 | Shutter drive coil (main) | SH_DR_M | 4 | 0 | 10 TBC | | | TBD | 0 | TBD |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 54 | Shutter drive coil (red.) | SH_DR_R | 4 | 0 | 10 TBC | | | TBD | 0 | TBD |
| 55 | Shutter therm (main) | SH_T-M | 4 | 1 | 1000 | | | 1.0E-5 | 1 * 1/3 | TBD |
| 56 | Shutter therm (red.) | SH_T-R | 4 | 1 | 1000 | | | 1.0E-5 | 1 * 1/3 | TBD |
| 57 | Phot BB Calibrator (main) | P_BBC_M | 2 | 0 | 10 TBC | | | 3.0E-3 | 0.5 * 1/3 | TBD |
| 58 | Phot BB Calibrator (red.) | P_BBC_R | 2 | 0 | 10 TBC | | | 0.0E+0 | 0 | TBD |
| 59 | Phot BB therms (2) | P_BBC_T | 8 | 2 | 1000 | | | 1.0E-5 | 1 * 1/3 | TBD |
| | **Total** | | **180** | **39** | | | | | | |

## 4: Detector Signals and control

| ID | Description | Name | No. of Conductors | No. of Shields | Max. Allowed Impedances | | | Current (A) | Duty Cycle (t*T) | Max Volts (V) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | R (Ω) | C (F)* | L(H)* | | | |
| 1 | P250 Sig | P250S | 288 | 144 STP + 12 common shields | 100 | 1500 pF | 0.12 | 1n | 1 * 1/3 | 0.1 |
| 2 | P350 Sig | P350S | 184 | 92 STP + 8 common shields | 100 | 1500 pF | 0.12 | 1n | 1 * 1/3 | 0.1 |
| 3 | P500 Sig | P500S | 96 | 48 STP + 4 common shields | 100 | 1500 pF | 0.12 | 1n | 1 * 1/3 | 0.1 |
| 4 | S250 Sig | S250S | 84 | 42 STP + 4 common shields | 100 | 1500 pF | 0.12 | 1n | 1 * 1/3 | 0.1 |
| 5 | S350 Sig | S350S | 48 | 24 STP + 2 common shield | 100 | 1500 pF | 0.12 | 1n | 1 * 1/3 | 0.1 |
| 6 | Det. Bias | BIAS | 20 | 10 STP +1 common shield (TBC) | 1000 | 1500 pF | - | 1u | 1 * 1/3 | 0.1 |
| 7 | JFET Power | JFETP | 64 | 32 STP | 1000 | 1500 pF | - | 1m | 0.3 * 1/3 | 10 |
| 8 | JFET Heater | JFETH | 24 | 12 STP | 200 | 1500 pF | - | 1m | 0.3 * 1/3 | 10 |
| 9 | TC Bias | TBIAS | 6 | 3 STP + 1 common shield | 1000 | 1500 pF | - | 1u | 1 * 1/3 | 1 |
| 10 | TC Sig | TSIG | 12 | 6 STP + 1 common shield | 100 | 1500 pF | 0.12 | 1n | 1 * 1/3 | 0.1 |
| | | Totals | 830 | 415 STP + 33 Common shields | | | | | | |
| | ID 11 - 20 not used | | | | | | | | | |

*Detector Harness requires proper consideration of inductance and capacitance. Values are indicative and should be further evaluated with SPIRE during harness design.

Notes:
Allowed resistance values are at “operational temperatures” and assume that the cryostat harness will be at an average temperature of 45 K and the external harness at an average temperature of 190 K.
In column Duty cycle t= part of T in which signal is active; T= time for which SPIRE is in observe mode.
STP = Shielded Twisted Pair
From the instrument or OB connector to the CVV connector distance~2 m
From CVV to SVM distance between 3 and 5 m
Shields could be joined at the CVV feedthroughs in agreement with SPIRE.

#### 5.1.3 Grounding

The grounding scheme is TBD.

#### 5.1.4 Bonding

TBD

## 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) (All TBC) |
|---|---|
| Housekeeping data rate (non-prime) | 2.1 |
| Housekeeping data rate (prime) | 4.2 |
| Science data rate: Photometer only | 87 |
| Science data rate: Spectrometer only | 92 |
| Science data rate: Parallel mode | 10 (TBC) |
| Science data rate: Serendipity mode | 87 (TBC) |

Any increase in telemetry rate would have science benefits, as the detector frame rate could be increased making SPIRE more immune from any systematic 1/f noise.

#### 5.11.1.2 Data-bus rate

For the purpose of possible (short duration) higher instrument data-rates the bus interconnecting the instrument and the Data-handling subsystem 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

The instrument is capable to buffer 10 seconds of data. In order to prevent data overflow in the SPIRE on-board data storage units, the S/C CDMS subsystem shall request packets at intervals of no more than 10 seconds (TBC).

### 5.11.2 S/C housekeeping

The S/C should be capable of monitoring the following instrument parameters every TBD minutes and provide a data packet with the results.

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

### 5.11.3 Timing and synchronisation signals

The S/C shall provide SPIRE with a timing synchronisation at least once per 24 hours to allow synchronisation of the SPIRE and spacecraft clocks.

When using the telescope scan mode, the SPIRE instrument will require a “start of scan” indication to be sent be included in the telemetry with a timing precision of better than 5 milliseconds. This is required so that the SPIRE data can be correctly processed it is not required for the operation of the SPIRE instrument.

### 5.11.4 Telecommand

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

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

The maximum telecommand packet length is 256 octets.

### 5.11.5 Interface circuits

The interface between the SPIRE instrument DPU and the CDMS shall conform to MIL-STD-1553B.

The high-level packet transfer protocol is TBD.

## 5.12 ATTITUDE AND ORBIT CONTROL/POINTING

### 5.12.1 Attitude and orbit control

The SPIRE instrument has the following 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 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.

  In the event of a failure in this sub-system the S/C will be used in raster mode to sample the FOV. This is acknowledged to be much less efficient than using the internal beam steering mirror. The spacecraft must, nevertheless, be capable of providing 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 telescope Normal Raster Mode. The instrument may perform fine sampling of each raster pointing using the internal beam steering mirror.

### 5.12.2 Pointing

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

### 5.12.3 On-Target Flag (OTF)

For pointed observations it is assumed that an on target flag will be provided through the telemetry with a timing precision of better than 0.1 seconds (TBC). This is required for the correct processing of the SPIRE data on the ground, it is not required for SPIRE operations.
(Note: inconsistent with IID-A)

## 5.13 ON-BOARD HARDWARE/SOFTWARE AND AUTONOMY FUNCTIONS

### 5.13.1 On-board hardware

There is a single on-board computer in the SPIRE FSDPU. Only the FSDPU has on-board software.

### 5.13.2 On-board software

It is assumed that the SPIRE warm electronics will be left on during all operational phases. The instrument on-board software will thus be preserved in the FSDPU. If the FSDPU is switched off for any reason on-board software must be reloaded during the DTCP before SPIRE operations can recommence.

No single instrument command nor any sequence of instrument commands will constitute a hazard for the instrument

### 5.13.3 Autonomy functions

The S/C must be capable of automatic monitoring all SPIRE Spacecraft Housekeeping parameters, i.e. the parameters listed in section 5.11.2, when the S/C is not in ground contact.

The S/C must also be capable of monitoring certain SPIRE Instrument Housekeeping parameters provided to it via “Housekeeping Data” packets from the SPIRE DPU – see 5.13.4.

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

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

### 5.13.4 Instrument Autonomy Housekeeping Packet Definition

TBD

### 5.13.5 Instrument Event Packet Definition

TBD

## 5.14 EMC

### 5.14.1 Conducted Emission/Susceptibility

TBD

### 5.14.2 Radiated Emission/Susceptibility

TBD

### 5.14.3 Frequency Plan

TBD

## 5.15 Transport and Handling Provisions

### 5.15.1 Focal Plane Unit

#### 5.15.1.1 Transport Container

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

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

#### 5.15.1.2 Cooling and Pumping restrictions

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

#### 5.15.1.3 Mechanism positions

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

#### 5.15.1.4 Unpacking Procedure

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

### 5.15.2 JFET/Filter Box

#### 5.15.2.1 Transport Container

The SPIRE JFET/Filter Box (FSFTB) 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 FSFTB can sustain in any direction is (TBD). The transport container is fitted with shock recorders and internal humidity monitors. The FSFTB transport container is shown in figure TBD.

#### 5.15.2.2 Unpacking Procedure

The procedure for removing and installing the FSFTB 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 (FSDRC; FSDPU; FSWIH) will be transported in clean hermetically sealed containers to be opened only in class 10000 clean conditions (TBC) with less than 75% humidity (TBC).

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

#### 5.15.3.2 Unpacking Procedure

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

## 5.16 DELIVERABLE ITEMS

### 5.16.1 Instrument Models

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

AVM – Avionics Model. “…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.”

We have interpreted this as being a DPU plus a simulator of the DRCU and cold FPU – this is termed the DRCU Simulator. As the schedule demands that this model will be delivered almost simultaneously with the CQM we intend using the CQM DPU plus a DRCU simulator as 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 instrument model that is intended for flight. It will be built to full flight standards and will only have minor differences in thermal, electrical and mechanical properties to the CQM. It will have the same mechanical, thermal and electrical interfaces to the satellite as the CQM but, may, however, have minor internal design changes compared to the CQM. For instance the bolometer arrays may have many more pixels. 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

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.

### 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 FSFTB, to enable integration of the FSDRC; FSDPU and FSWIH
- TBD EGSE for integration of the FSFPU
- Quick Look Facility to enable testing of the instrument at system level. This will interface to the S/C test environment via FINDAS.

### 5.16.3 Mechanical Ground Support Equipment (MGSE)

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

Deliverables:

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

### 5.16.4 Optical Ground Support Equipment (OGSE)

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

Deliverables:

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

### 5.16.5 System Test Software

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

### 5.16.6 Hardware for the Observatory Ground Segment

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

### 5.16.7 Software for the Observatory Ground Segment

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

Plus TBD.

### 5.16.8 Instrument Software Simulator

TBD

### 5.16.9 Test Reference Data

The SPIRE instrument test reference data will be delivered via FINDAS in the TBD form generated during instrument and system level testing.

### 5.16.10 Instrument Characterisation Data

The SPIRE instrument characterisation data will be delivered via FINDAS in the TBD form generated during instrument and system level testing.

### 5.16.11 Technical Documentation

The following documents will be delivered:

- Instrument User Manual following the requirements laid down in the OIRD (AD2)
- Instrument database – this will be delivered via FINDAS 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.

# 6 GROUND SUPPORT EQUIPMENT

## 6.1 MECHANICAL GROUND SUPPORT EQUIPMENT

TBD

## 6.2 ELECTRICAL GROUND SUPPORT EQUIPMENT

In agreement with all the other instruments of FIRST/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 FIRST only, contingency activities during the normal operations phase) will be the same as that between the EGSE and the CCE. This interface, concerning telemetry, telecommanding, the instrument database and procedures will follow the standard defined by SCOS 2000 i.e.

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

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

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

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

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

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

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

## 6.3 COMMONALITY

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

### 6.3.1 EGSE

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

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

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

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

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

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

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

### 6.3.2 INSTRUMENT CONTROL AND DATA HANDLING

All three FIRST 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 FINDAS activities
- A common approach to IA/QLA systems

# 7 INTEGRATION, TESTING AND OPERATIONS

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

## 7.1 Integration

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

### 7.1.1 FPLM Integration

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

This applies to both the CQM and PFM units.

### 7.1.2 PPLM Integration

NA

### 7.1.3 SVM Integration

TBD

### 7.1.4 FIRST/Planck Integration

TBD

## 7.2 Testing

After completion of the integration, be it at the level of the FPLM, PPLM, SVM or FIRST/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 FIRST/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 teststhe SPIRE instruments expects the CQM test environment to be as follows:

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

### Detailed Sequencing

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

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

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

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

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

### 7.2.2 PFM Testing

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

## 7.3 Operations

Covered in other applicable documentation as follows:

| | |
|---|---|
| AD 2 | FIRST/Planck Operations Interface Requirements Document (OIRD) |
| AD 3 | FIRST Science-operations Implementation Requirements Document (FIRST-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 FIRST/Planck Scientific Instruments’ (AD5).

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

# 9 DEVELOPMENT AND VERIFICATION

## 9.1 GENERAL

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

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

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

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

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

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

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

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

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

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

See section 5.16.1 for more details

## 9.3 MECHANICAL VERIFICATION

TBD

## 9.4 THERMAL VERIFICATION

TBD

## 9.5 VERIFICATION OF SCIENTIFIC PERFORMANCE

TBD

## 9.6 ELECTRICAL TESTING

TBD

## 9.7 EMC TESTING

TBD

# 10 MANAGEMENT, PROGRAMME, SCHEDULE

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