FIRST/Planck

INSTRUMENT INTERFACE DOCUMENT

PART B

INSTRUMENT "SPIRE"

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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.

Spacecraft performances, capabilities and requirements imposed on the instruments are described in part A of the documents, whilst instrument requirements on the spacecraft as well as instrument capabilities and performances are described in part B. The IID-B is in fact the successor to the Payload Definition Document (PDD)
In case of conflict between the contents of the IID-A and the IID-B's, the contents of the IID-A shall take precedence.

There is one part A and there are just as many parts B, as there are instruments.

The IIDs are living documents.

The ESA Project team is responsible for updating and distributing the parts B. Updating takes place at regular intervals as a result of discussions and in agreement with the instrument teams.

As for the part A, after the initial issue by the ESA Project team it will be handed-over to the Contractor, who will take care of further updates in agreement with ESA.

Both IID-A and the IID-Bs will be part of the AO.

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.

Para 9.5 "Scientific Performance Verification" of the IIDs provides more information 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

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 BOL/RAL/D/001

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

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3.1 KEY PERSONNEL

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3.2 RESPONSIBILITIES

INSTITUTE	RESPONSIBILITIES
ATC, Edinburgh	Chopping/beam steering mechanism
CEA, Grenoble	^{3}He cooler
CEA, SAp, Paris	Bolometers (option); Detector Readout and Control Unit (DRCU); On-board software for Signal Processing Unit (SPU); ICC DAPSAS Centre; Ionising radiation effects testing
DESPA, Paris	FTS expertise and design support
GSFC, Maryland	Bolometers (option); Internal calibrators
IAC, Tenerife	Signal Processing Unit (SPU)
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	Bolometers (option)
LAS, Marseille	Optics; FTS mechanism
MSSL, Surrey	Focal Plane Unit Structure
QMW, London	Focal plane arrays; filters, dichroics, , beam dividers
RAL, Oxfordshire	Project management and Project Office; AIV and ground calibration facilities; ICC Operations Centre
Stockholm Observatory	Instrument simulator
University of Padua	Provision of ICC Operations Staff
University of Saskatchewan	EGSE (TBC); Chopper (TBC)

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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 ^3He refrigerator. The photometer is optimised for deep photometric surveys, and can observe simultaneously the same field of view of at least 4 x 4 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. 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 red shift. 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 the SPIRE FTS, other FIRST instruments and ground-based facilities.

4.3 OVERALL CAPABILITIES

The SPIRE instrument contains a three-band imaging photometer and a Fourier Transform spectrometer. The detector arrays are cooled to 300 mK by a re-cyclable ^3He refrigerator which runs from the 2-K temperature level provided by a direct thermal strap to the FIRST cryostat helium tank. It has a hold time of at least 46 hrs and a re-cycle time of 2-4 hrs (TBC).

4.3.1 Photometer

The imaging photometer operates at nominal wavelengths of 250, 350 and 500 μm with a spectral resolution of around 3. Three bolometric detector arrays observe the same field of view simultaneously, with dichroic beam dividers separating the bands. The 250, 350 and 500 μm arrays have 32 x 32, 24 x 24 and 16 x 16 detectors, respectively for the baseline 4 x 4 arcminute field of view. The possibility of having a larger, 8 x 4 arcminute field of view is being studied, and would involve doubling the number of detectors. Cryogenic readout and multiplexer electronics in the focal plane unit are used to read out the detector signals. A chopping/beam-steering mirror within the instrument is used to modulate the signals.

Several detector array technology options are under development, and a decision on which one to fly has not yet been made. This must wait for evaluation of the various options - a final decision will be made in early 2000.

The options under evaluation are:

- Filled planar arrays of 0.5λ/D pixels using Transition Edge Superconducting (TES) detectors and cold multiplexed SQUID readout (under development at NASA GSFC and NIST).

- Filled planar arrays of 0.5λ/D pixels using ion-implanted Si thermistors and cold multiplexed CMOS readout (under development at CEA and LETI in France).

- Feedhorn fed arrays of 2λ/D pixels using spider web bolometers using NTD germanium thermistors with JFET readout (under development at Caltech/JPL).

A selection will be made in January 2000 based on laboratory test results on prototype detectors, modelled instrument performance, maturity of instrument system design, compatibility with spacecraft resources, and fabrication and qualification schedule.

4.3.2 Spectrometer

The FTS covers the range 200 - 670 μm (15 - 50 cm^{-1}) with a spectral resolution of at least 0.4 cm^{-1} ($\lambda/\Delta\lambda$ = 100 at 250 μm) with a goal of 0.04 cm^{-1} ($\lambda/\Delta\lambda$ = 1000 at 250 μm). It uses a moving mirror to modulate the signal and generate the interferograms. An intensity beam divider covers the required spectral range with high efficiency. An on-board calibration source is used to null the thermal background from the telescope and to provide absolute calibration. By adjusting the length of travel of the mirror, the spectral resolution can be adjusted to match the scientific requirements of a particular observation, with the lowest resolution being 2 cm^{-1} (TBC). Two arrays of detectors at the FTS output cover different parts of the 200-670 μm range with a field of view of 2.6 arcminutes. If filled arrays are employed, there will be a 16 x 16 array for 200-300 μm, and a 12 x 12 array for 300-670 μm. The detector arrays are of the same type as used in the photometer.

4.4 HARDWARE DESCRIPTION

The SPIRE instrument consists of:

FSPU Cold Focal Plane Unit (FPU):
This interfaces to the 15-K, 4-K and 2-K temperature stages provided by the cryostat. If the feedhorn array option is chosen, a JFET module will be included which will interface to the 15-K box. 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. The 15-K shield will be a Faraday cage to protect the bolometers from RFI.

FSBAU Buffer amplifier Unit (BAU) (on outside of CVV)
Differential buffer amplifiers for the detector signals
This unit is not required for the TES detector option (TBC)

FSDRC Detector Read-out and Control Unit (on FIRST SVM)
A warm analogue electronics box for detector read-out analogue signal processing, multiplexing, A/D conversion, array sequencing, mechanism control, temperature sensing and general housekeeping and ^{3}He refrigerator operation.

FSSPU Signal Processing Unit (on FIRST SVM)
A warm electronics box for signal processing and data compression.

FSDPU Digital Processing Unit (on FIRST SVM)
A warm digital electronics box for signal processing and instrument commanding and interfacing to the spacecraft telemetry.

FSWI Warm interconnect harness (on FIRST SVM)
Harness making connections between the electronics boxes.

4.5 SOFTWARE DESCRIPTION

The OBS will carry out the following functions:

- Read and log housekeeping data
- Control and monitor the instrument mechanisms and internal calibration sources
- 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

SPIRE will have 10 (TBC) basic operating modes. These will be:

4.6.1 Observe

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:

4.6.1.1 Obs 1 Photometer chop

The focal plane chopper is used to switch between two separate portions of the sky with the spacecraft pointed at a fixed position, thus modulating the signal onto the detectors. The full telemetry bandwidth will be required. To maintain the absolute calibration of the instrument, periodic calibrations will be done during observations of this type by switching on the on-board photometric calibration source. It is assumed that these calibrations will have no impact on spacecraft operations (TBC).

4.6.1.2 Obs 2 Photometer scan

This is an alternative method of mapping an area of sky larger than the instantaneous field of view of the instrument. The spacecraft will slew slowly over a given area. In this way the signal is modulated by chopping from one pixel to the next. A further variation is to use the focal plane chopper to switch to another portion of the sky in a direction orthogonal to the direction of slew. The speed of slew will be no more than 50 arcsec/sec and may be in an arbitrary direction with respect to the spacecraft axes. The full telemetry bandwidth will be required.

4.6.1.3 Obs 3 SPIRE-PACS partner (TBC)

It is envisaged that PACS and SPIRE may sometimes be used to make simultaneous observations of the same portion of the sky. In this case a reduced telemetry rate will be available to each instrument. In the case of the bolometer this will mean that either the data will have a reduced resolution (spatial or intensity) or that there will be on-board integration of images (TBC).

4.6.1.4 Obs 4 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. It is assumed that at least half the bandwidth will be available to the bolometer instrument (P may have a similar mode) and this will be filled with science data from the photometer arrays (only). 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.

4.6.1.5 Obs 5 Photometer parallel

When observations are being made with another instrument, that are not partner observations, then scientifically useful data may be obtainable from the photometer, albeit with degraded intensity 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.

It is assumed that this will be the default standby mode for the bolometer instrument.

4.6.1.6 Obs 6 Spectrometer full spectrum

The spectrometer mirrors will be constantly scanned back and forth over the distance required for the requested spectral resolution. The spacecraft will be pointed at a fixed position and the focal plane chopper will not be switched on. The spectral calibrator will be on during all spectrometer operations. The full telemetry bandwidth will be required and there will be on-board integration of spectra.

4.6.1.7 Obs 7 Low-resolution spectrophotometry

The FTS can be used as a narrow band photometer by scanning the mirrors over a small distance close to the central maximum of the interferogram. The spectral calibrator will be on during these observations to give a constant reference signal. In this mode no on-board integration will be necessary and the full bandwidth will be used.

If the backup detector option of individual spider web bolometers and feed-horns which under-sample the focal plane has to be flown, different observing modes will be necessary for the spectrometer and photometer. These are:

4.6.1.8 Obs 8 Photometer peak up

If the absolute pointing error of the spacecraft is too poor to allow for instantaneous acquisition of a given target to within 2 arcsec (TBC), then a peak up procedure will be required. This will use the photometer chop mode (see above) to identify the position of a source by executing a small cross raster across the pointing given by the spacecraft. If this mode is required it will involve moderately sophisticated on-board signal processing and the ability to communicate the calculated off set to the AOCS independently of ground communication.

4.6.1.9 Obs 9 Jiggle-photometry

In this case as well as chopping in a fixed direction, the chopper unit will have to move the field-of-view in small steps in two directions in order to allow the field-of-view to be fully-sampled.

4.6.1.10 Obs 10 Jiggle-spectral-imaging

The delivery of SPIRE with the fallback detector option would have serious implications for the spectrometer observing modes. As well as scanning the mirrors to complete a spectrum, the chopper would be used to 'jiggle' the detectors around the field of view to obtain a fully-sampled image, at each of which a fully-sampled spectrum would be obtained. This mode of operation is more complex than would be the case with a focal plane array that fully samples the field of view.

4.6.2 Standby

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.

4.6.3 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.

4.6.4 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.

4.6.5 Cooler Recycle

The ^3He cooler requires recycling every 46 hours (TBC). During this time the instrument will be switched off except for vital housekeeping and cooler functions (TBC). The recycling takes 2 hours (TBC) to complete with another N hours (TBD) minutes before instrument operations can recommence. During the 2 hours recycling the heat load on the helium bath is 20 mW (TBC).

4.6.6 On

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

4.6.7 Off

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

4.6.8 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.

4.6.9 FPU Orientation

Complete operation of the FPU is possible in any orientation. There is a restriction on the orientation of the ^3He cooler during recycling.

4.7 INSTRUMENT SCIENTIFIC PERFORMANCE

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. Para 9.5 “Scientific Performance Verification” of the IIDs provides more information on this subject.

4.7.1 Instrument and telescope parameters

The following assumptions are made in estimating the scientific performance of the instrument. We here assume the more conservative feed-horn fed bolometer arrays, similar to those already working in SCUBA and other ground-based instruments. The figures for the FTS do not yet take into account the increased efficiency of the new FTS design.

<u>Telescope:</u>

Temperature	80 K
Used diameter	3.29 m
Emissivity	0.04

<u>Detectors</u>

Bolometer optical NEP	3.0 x 10^{-17} W $Hz^{-1/2}$
Bolometer quantum efficiency	0.8
Bolometer feed-horn efficiency	0.7
Throughput for each pixel	$A\Omega = \lambda^2$ (2.0Fλ feed-horns)

Photometer (three arrays of hexagonally close-packed 2.0Fλ pixels)

Central wavelengths	250	350	and	500 μm
Numbers of detectors	61	37	and	19
Beam FWHM (arcseconds)	18	25	and	36
Field of view of each array (arcminutes)	4.4			
Overall optics efficiency	30%			
Filter widths($\lambda/\Delta\lambda$)	3			
Chopping efficiency factor	0.45			
Observing efficiency	90% (point source); 80% (mapping)			
Required jiggle step size	9 arcseconds			

FTS spectrometer (two arrays of hexagonally close-packed 2.0Fλ pixels)

Nominal bands	33.5-50 cm^{-1} (200-300 μm)
	15-33.5 cm^{-1} (300-670 μm)
Numbers of pixels	37 19
Field of view (arcminutes)	2.6 x 2.6
Spectral resolution (requirement)	0.4 cm^{-1} – 2 cm^{-1}
(goal)	0.04 cm^{-1} – 2 cm^{-1}
Overall optics efficiency	25%
Cos^2 signal modulation efficiency	0.5
Observing efficiency	0.8
Electrical filter efficiency	0.8

4.7.2 Modes of operation

Document TBD will specify the instrument scientific performance and its verification. The present status is summarised in Tables 1 and 2, for information only. The figures given here may be updated in the near future following completion of our definition of the FTS and photometer designs.

Table 1: SPIRE Photometer Sensitivity

		250 µm	350 µm	500 µm
Passband	λ/Δλ	3	3	3
Field of view	Arcmin Req. Goal	4 x 4 4 x 8	4 x 4 4 x 8	4 x 4 4 x 8
Beam FWHM	Arcsec	18	25	26
Point source	1 σ -1 sec (mJy) 1 σ -1 hr (mJy)	34 0.6	35 0.6	41 0.7
Mapping 1 FOV	1 σ -1 hr (mJy)	1.4	1.5	1.9

Table 2: SPIRE Spectrometer Sensitivity

Wavelength range	Band A Band B	200 – 300 µm (TBC) 300 – 700 µm (TBC)	
Max. resolution	cm^{-1} Req. Goal	0.4 0.04	
Min. resolution	cm^{-1} Req. Goal	2 4	
Field of view	Arcmin	2.6 x 2.6	
Beam FWHM	Arcsec Band A Band B	18 (TBC) 25 (TBC)	
<u>Point source</u>			
Limiting flux density	mJy (1 σ -1 hr; 0.4 cm^{-1} resol.)	Band A Band B 300-400 um Band B 400-700 um	47 (TBC) 43 (TBC) TBD
Limiting line flux	W m^{-2} (1 σ -1 hr)	Band A Band B 300-400 um Band B 400-700 um	5.6×10^{-18} (TBC) 5.1×10^{-18} (TBC) TBD
<u>2.6 X 2.6 arcmin map</u>			
Limiting flux density	mJy (1 σ -1 hr; 0.4 cm^{-1} resol.)	Band A Band B 300-400 um Band B 400-700 um	108 (TBC) 104 (TBC) TBD
Limiting line flux	W m^{-2} (1 σ -1 hr)	Band A Band B 300-400 um Band B 400-700 um	1.3×10^{-17} (TBC) 1.3×10^{-17} (TBC) TBD

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.
Furthermore should the system studies reveal costs in excess of the allocation for the combined FIRST/Planck mission, Spacecraft resource allocations might have to be revised to a level compatible with the minimum scientific requirements as defined in the final versions of the FSEC and PSEC reports. Also other requirements (e.g. Product Assurance and Management) may be revised as a consequence of the cost ceiling imposed on the Project. This will be formalised by an update of the IID-A.

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 and/or RF filter box (FTB)
FSBAU	Buffer Amplifier Unit (BAU)
FSDRC	Detector Read-out and Control Unit (DRCU)
FSDPU	Digital Processing Unit (DPU)
FSWIH	Warm interconnect harnesses (HARNESS)

5.2 COORDINATE SYSTEM

Compliant with requirements in IID-A. 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.

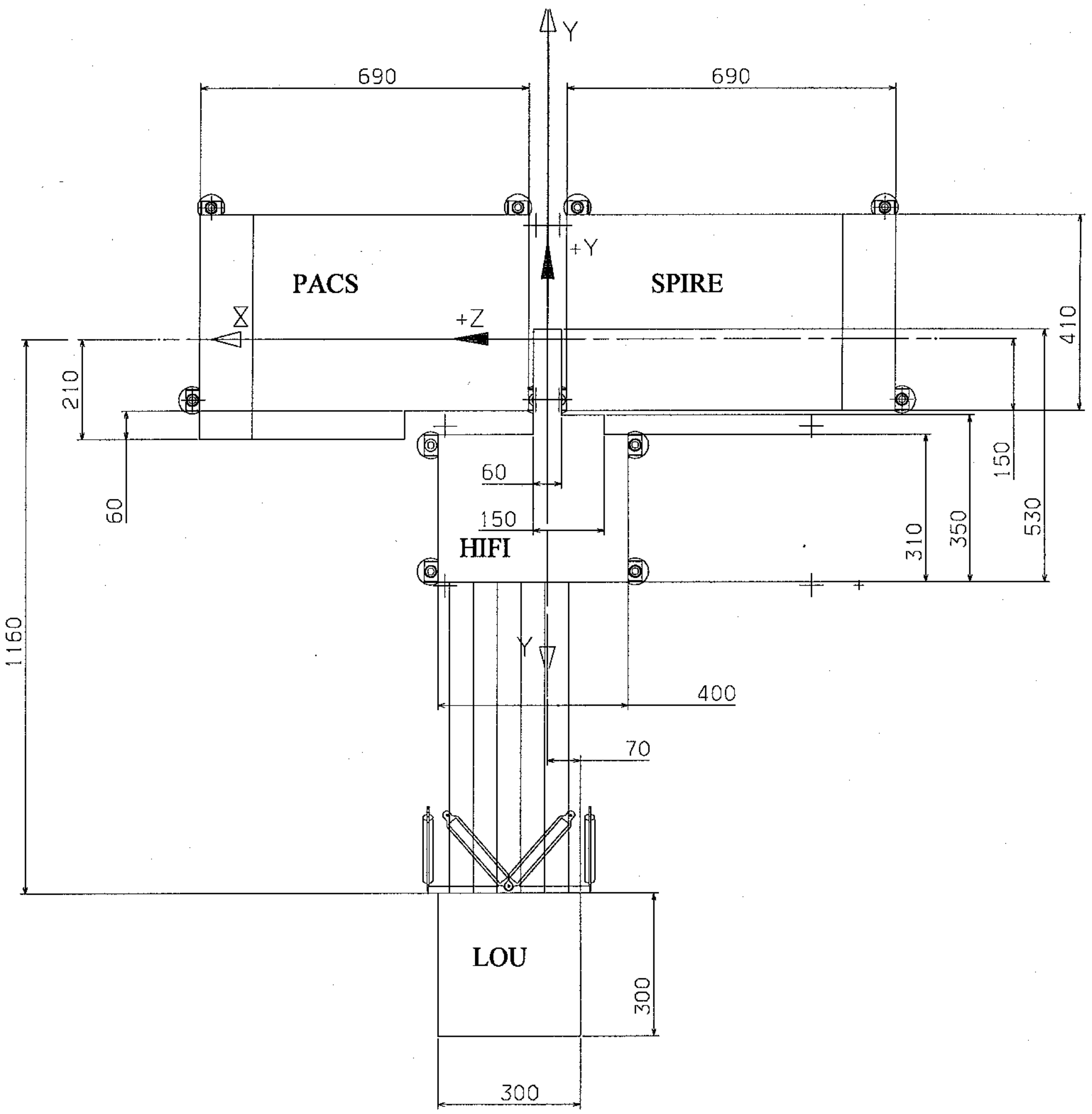


Figure 5.3-1: The FIRST Focal Plane, top view towards - X (TBC pending out come of focal plane sharing meeting)

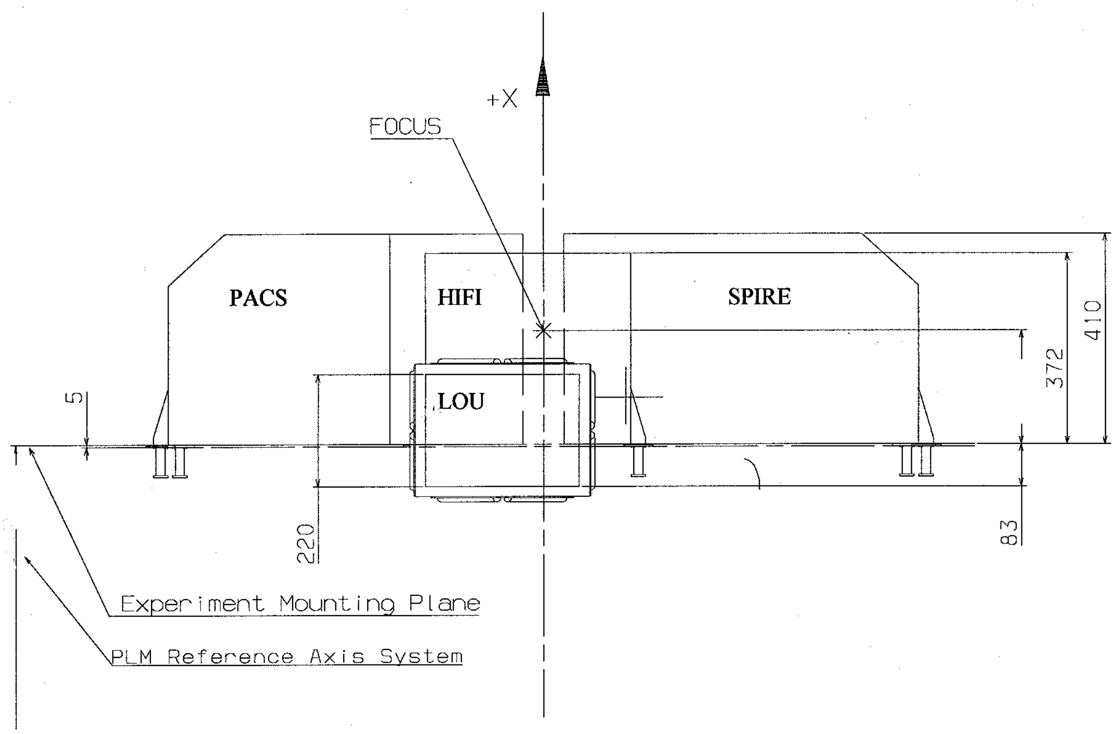


Figure 5.3-2: The FIRST Focal Plane, side view towards +Y (TBC, including height of focus)

5.3.1 Instrument Location

The locations of the SPIRE units are as follows:

Project code	Instrument unit
FSFPU	On FIRST optical bench inside cryostat
FSFTB	On FIRST optical bench inside cryostat
FSBAU	On CVV
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

The FSBAU should be located as close as possible to the CVV vacuum feedthroughs.

5.3.1.3 On SVM

There are no location requirements for units on the SVM. (TBC)

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/Filter 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.

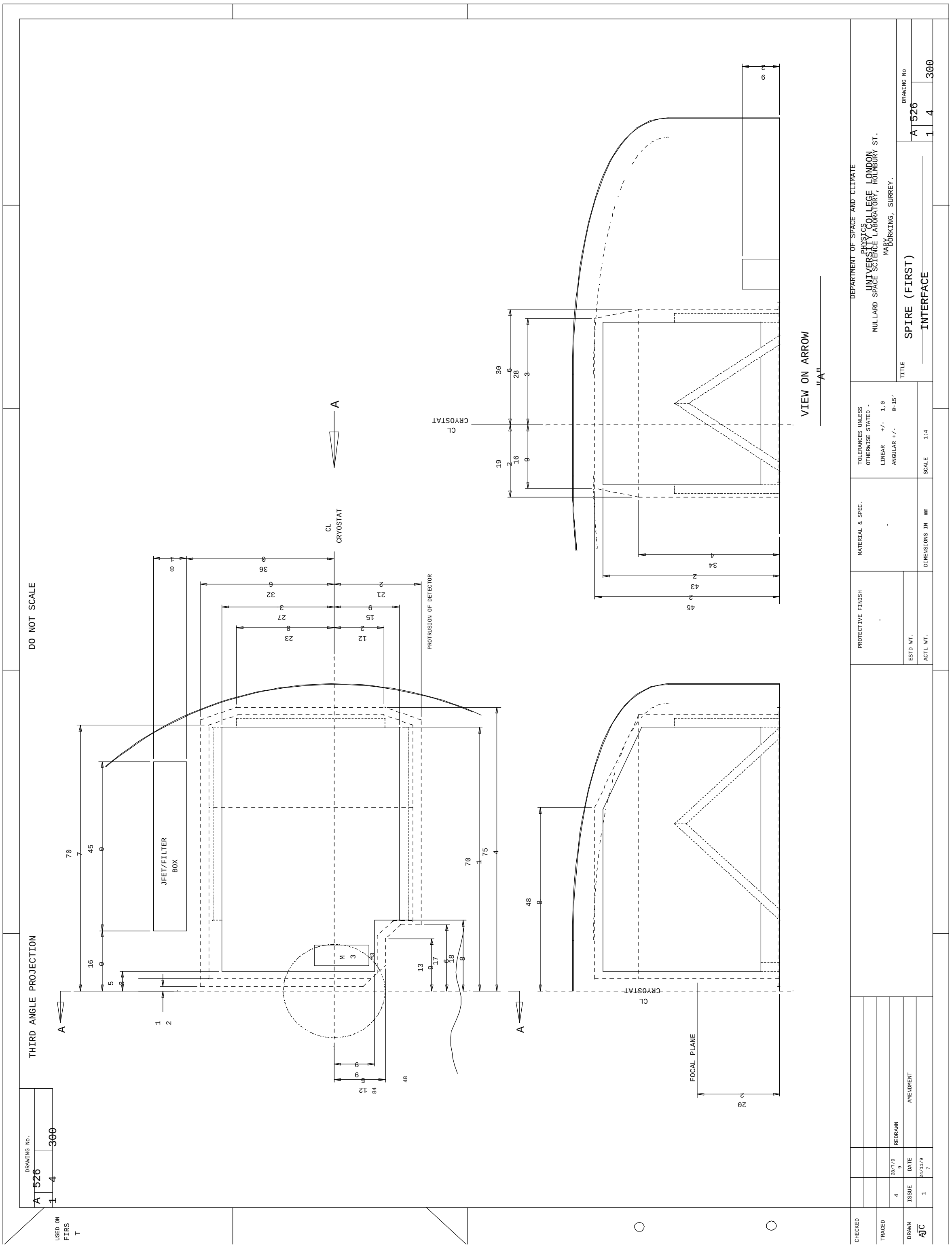


Figure 5.4-1: SPIRE Focal Plane Unit. (TBD pending outcome of focal plane sharing)

5.4.2 FSFTB

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

5.4.3 FSBAU

Figure 5.4-3 shows the external configuration drawing for the SPIRE buffer amplifier unit (TBW).

5.4.4 FSDRC

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

5.4.5 FSDPU

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

5.4.6 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) *	Mass (kg)
FSFPU	Cold Focal Plane Unit (FPU)	1	690 x 450 x 450 Irregular shape	31.5 (TBC)
FSFTB	JFET/RF box	1	300x100x100	2.5 (TBC)
FSBAU	Buffer Amplifier Unit (BAU)	1	200 x 150 x 120 (JPL 360x50x380) (TBC)	3.0 (TBC)
FSDRC	Detector Read-out and Control Unit (DRCU)	1	285 x 256 x 234	18 (TBC)
FSDPU	Digital Processing Unit (DPU)	1	240 x 210 x 194	10 (TBC)
FSWIH	Warm interconnect harnesses: FSDRC-FSDPU	1	< 2000	2 (TBC)
TOTAL				67.0 (TBC)

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

Note 1: Dimensions and mass do not include margins

Note 2: Harness from the FSFTB to the FSBAU, from the FSBAU to the FSDRC and from 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 TBD holes for fixation by bolts to the Optical Bench. One of these holes is the reference hole, 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 thermal and electrical resistance between the FSFPU interface and the Optical Bench is TBD.

The JFET/Filter box may also mechanically interface directly to the Optical Bench. The number and location of the holes for fixation are TBD. There is no alignment requirement for this unit. The thermal and electrical resistance between the JFET/Filter box and the Optical Bench is TBD.

5.6.2 Outside cryostat

Mounting of the FSBAU will be to a mounting plate which is ESA responsibility. It will be fixed to this plate by 6 bolts, as shown in figure (5.4-3)

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 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:

- The He II tank for temperatures at the 1.7 K level
- A wheel-shaped heat-exchanger cooled by the He-flow from the tank for the 4.3 K level
- A connection to the He-ventline for the 15 K level

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

Project code	Operating		Start-up	Switch-off	Non-operating	
	Min. K	Max. K	^{0}C	^{0}C	Min. ^{0}C	Max. ^{0}C
FSFPU (15 K enclosure)	4	20	TBD	TBD	TBD	+ 60 * TBD**
FSFPU (4.3 K enclosure)	Strapped to a 4.3 K cryostat level		TBD***	TBD***	TBD	+ 60 * TBD **
FSFPU (1.7 K enclosure)	Strapped to cryostat helium tank		TBD***	TBD***	TBD	+ 60 * TBD **
FSFTB	Strapped to “15-K” cryostat level		TBD***	TBD***	TBD	TBD

* Continuous temperature limit.

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

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

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

5.7.2 Outside cryostat

Project code	Operating		Start-up	Switch-off	Non-operating	
	Min. K	Max. K	K	K	Min. ^{0}C	Max. ^{0}C
FSBAU	120 (TBC)	150 (TBC)	TBD	TBD	TBD	+ 60 TBC

5.7.3 On SVM

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

Project code	Operating		Start-up	Switch-off	Non-operating	
	Min. ^{0}C	Max. ^{0}C	^{0}C	^{0}C	Min. ^{0}C	Max. ^{0}C
FSDRC	- 15	+ 45	- 30	+ 50	- 35 (TBC)	+ 60 (TBC)
FSDPU	- 15	+ 45	- 30	+ 50	- 35	+ 60

<u>Note:</u>
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.

5.7.4 On Planck module

NA

5.7.5 Temperature channels

The table below shows information relevant to the measurement of instrument temperatures. The column "Power" indicates whether the relevant channel is part of the instrument HK or of the S/C HK. In the latter case temperature information would also be available when the instrument is in its OFF state.

Unit	Power		Location	Acronym	Sensor Type	Temp. Range	TM ref.
	S/C	Instr.		(all TBC)		(all TBC)	
FSFPU		X	200 µm array	T_PSW_1	TBD	0.2 K>5 K	TBD
FSFPU		X	200 µm array	T_PSW_2	TBD	0.2 K>5 K	TBD
FSFPU		X	350 µm array	T_PMW_1	TBD	0.2 K>5 K	TBD
FSFPU		X	350 µm array	T_PMW_2	TBD	0.2 K>5 K	TBD
FSFPU		X	500 µm array	T_PLW_1	TBD	0.2 K>5 K	TBD
FSFPU		X	500 µm array	T_PLW_2	TBD	0.2 K>5 K	TBD
FSFPU		X	FTS array 1	T_SSW_1	TBD	0.2 K>5 K	TBD
FSFPU		X	FTS array 1	T_SSW_2	TBD	0.2 K>5 K	TBD
FSFPU		X	FTS array 2	T_SLW_1	TBD	0.2 K>5 K	TBD
FSFPU		X	FTS array 2	T_SLW_2	TBD	0.2 K>5 K	TBD
FSFPU	X		PHOT 2-K box	T_P2K_1	TBD	1 K>300 K	TBD
FSFPU		X	PHOT 2-K box	T_P2K_2	TBD	1 K>300 K	TBD
FSFPU	X		FTS 2-K box	T_S2K_1	TBD	1 K>300 K	TBD
FSFPU		X	FTS 2-K box	T_S2K_2	TBD	1 K>300 K	TBD
FSFPU	X		4-K structure	T_C4K_1	TBD	3 K>300 K	TBD
FSFPU		X	4-K structure	T_C4K_2	TBD	3 K>300 K	TBD
FSFPU	X		Instrument cover	T_COV_1	TBD	3 K>300 K	TBD
FSFPU		X	Instrument cover	T_COV_2	TBD	3 K>300 K	TBD
FSFPU		X	Phot Calibrator	T_PCAL_1	TBD	3 K>300 K	TBD
FSFPU		X	Phot Calibrator	T_PCAL_2	TBD	3 K>300 K	TBD
FSFPU		X	FTS Mechanism	T_FTS_1	TBD	3 K>300 K	TBD
FSFPU		X	FTS Mechanism	T_FTS_2	TBD	3 K>300 K	TBD
FSFPU		X	FTS Calibrator	T_SCAL_1	TBD	3 K>300 K	TBD
FSFPU		X	FTS Calibrator	T_SCAL_2	TBD	3 K>300 K	TBD
FSFPU		X	Cooler Pump	T_CPMP_1	TBD	3 K>300 K	TBD
FSFPU		X	Cooler Pump	T_CPMP_2	TBD	3 K>300 K	TBD
FSFPU		X	Cooler Evaporator	T_CEV_1	TBD	0.2 K>5 K	TBD
FSFPU		X	Cooler Evaporator	T_CEV_1	TBD	0.2 K>5 K	TBD
FSFPU		X	Cooler Pump heat switch	T_CPHS_1	TBD	1 K>50 K	TBD

Unit	Power		Location	Acronym	Sensor Type	Temp. Range	TM ref.
	S/C	Instr.		(all TBC)		(all TBC)	
FSFPU		X	Cooler Pump heat switch	T_CPHS_2	TBD	1 K>50 K	TBD
FSFPU		X	Cooler Evap. Heat switch	T_CEHS_1	TBD	1 K>50 K	TBD
FSFPU		X	Cooler Evap. Heat switch	T_CEHS_2	TBD	1 K>50 K	TBD
FSFPU		X	Shutter Vane	T_SHUT_1	TBD	3 K > 30 K	TBD
FSFPU		X	Shutter Vane	T_SHUT_2	TBD	3 K > 30 K	TBD
FSFPU		X	BSM (TBC)	T_BSM_1	TBD	3 K>300 K	TBD
FSFPU		X	BSM (TBC)	T_BSM_2	TBD	3 K>300 K	TBD
FSFTB	X		JFET/Filter box	T_FTB_1	TBD	3 K>300 K	TBD
FSFTB		X	JFET/Filter box	T_FTB_2	TBD	3 K>300 K	TBD
FSBAU	X		Buffer Amp Unit	T_BAU_1	TBD	70 K > 300 K	TBD
FSBAU		X	Buffer Amp Unit	T_BAU_2	TBD	70 K > 300 K	TBD
FSDRC	X		DRCU	T_DRCU_1	TBD	-40 ^{0}C >80 ^{0}C	TBD
FSDRC		X	DRCU	T_DRCU_2	TBD	-40 ^{0}C >80 ^{0}C	TBD
FSDRC		X	DRCU	T_DRCU_3	TBD	-40 ^{0}C >80 ^{0}C	TBD
FSDPU	X		DPU	T_DPU_1	TBD	-40 ^{0}C >80 ^{0}C	TBD
FSDPU		X	DPU	T_DPU_2	TBD	-40 ^{0}C >80 ^{0}C	TBD

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 at 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.

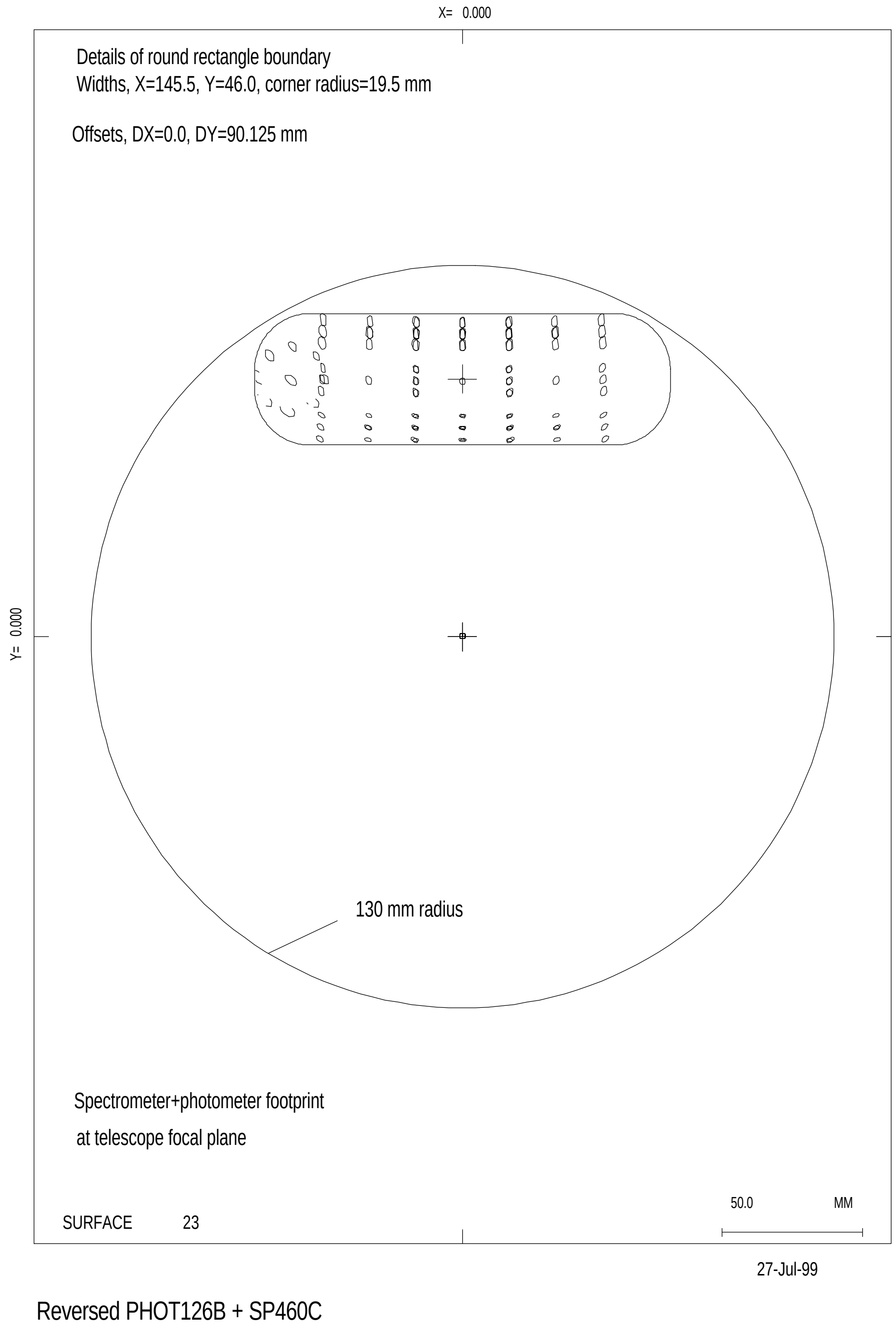


Figure 5.8-1 SPIRE optical beam envelope at the telescope focal plane.

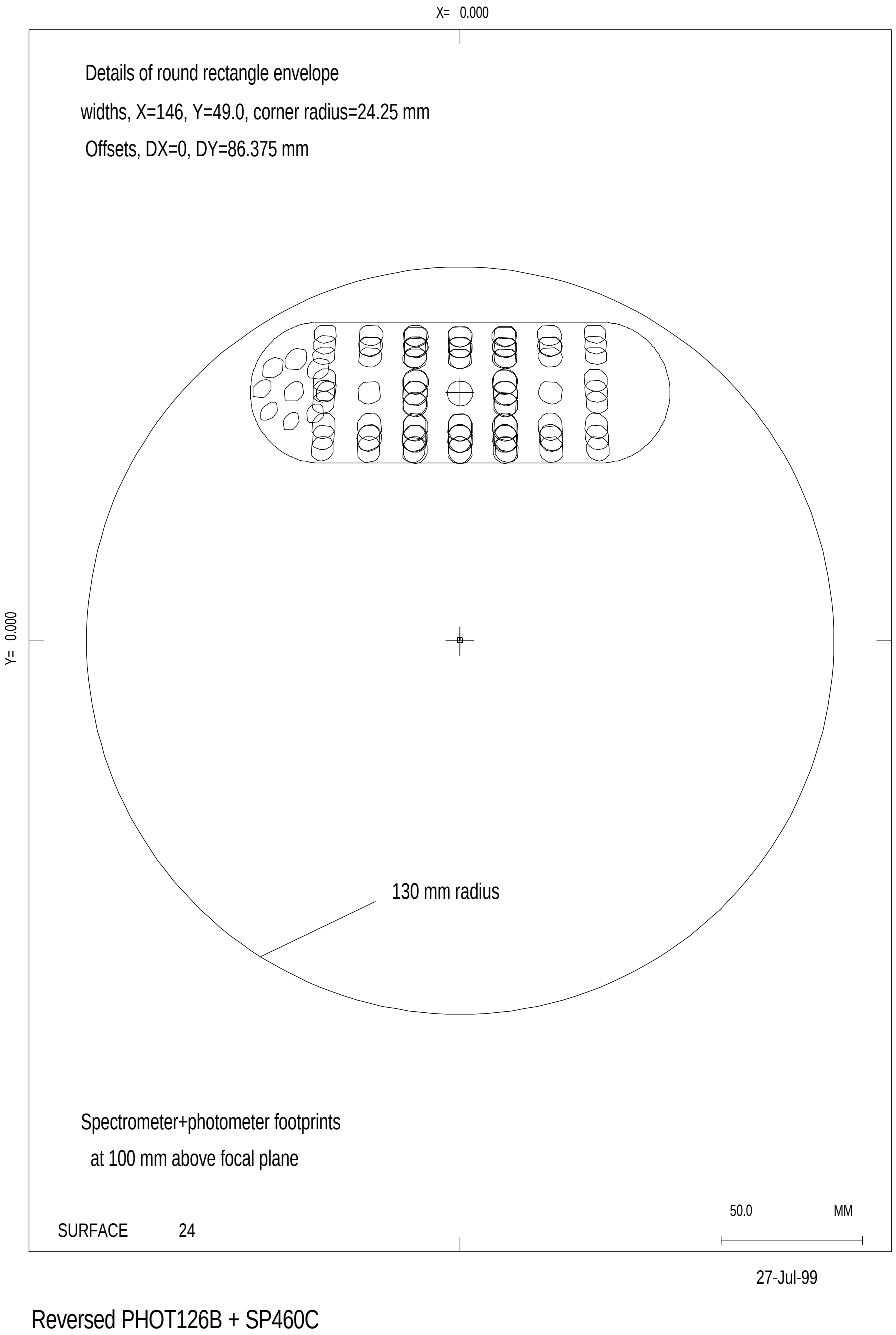


Figure 5.8-2 SPIRE optical beam envelope at 100 mm above telescope focal plane.

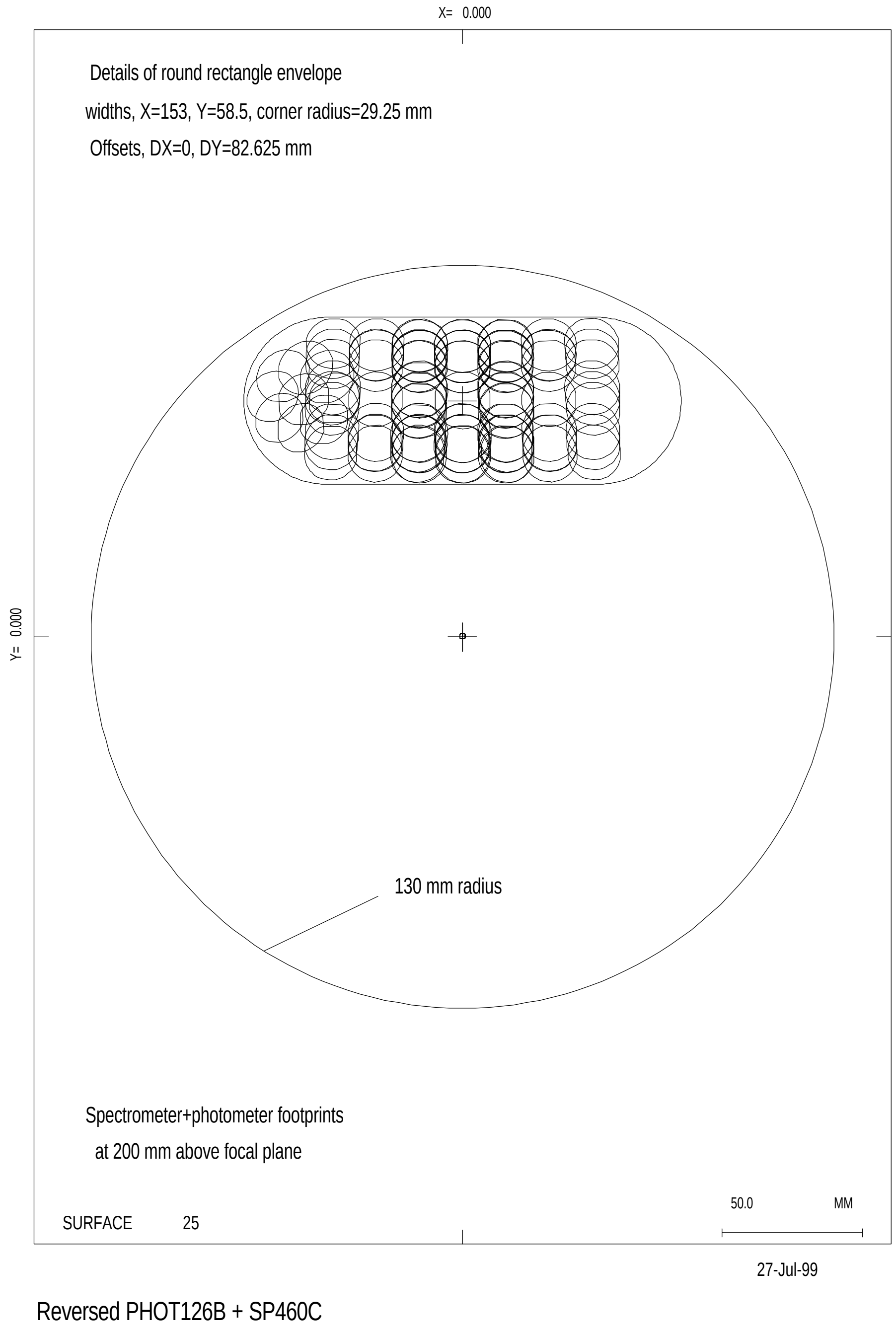


Figure 5.8-3 SPIRE optical beam envelope at 200 mm above telescope focal plane.

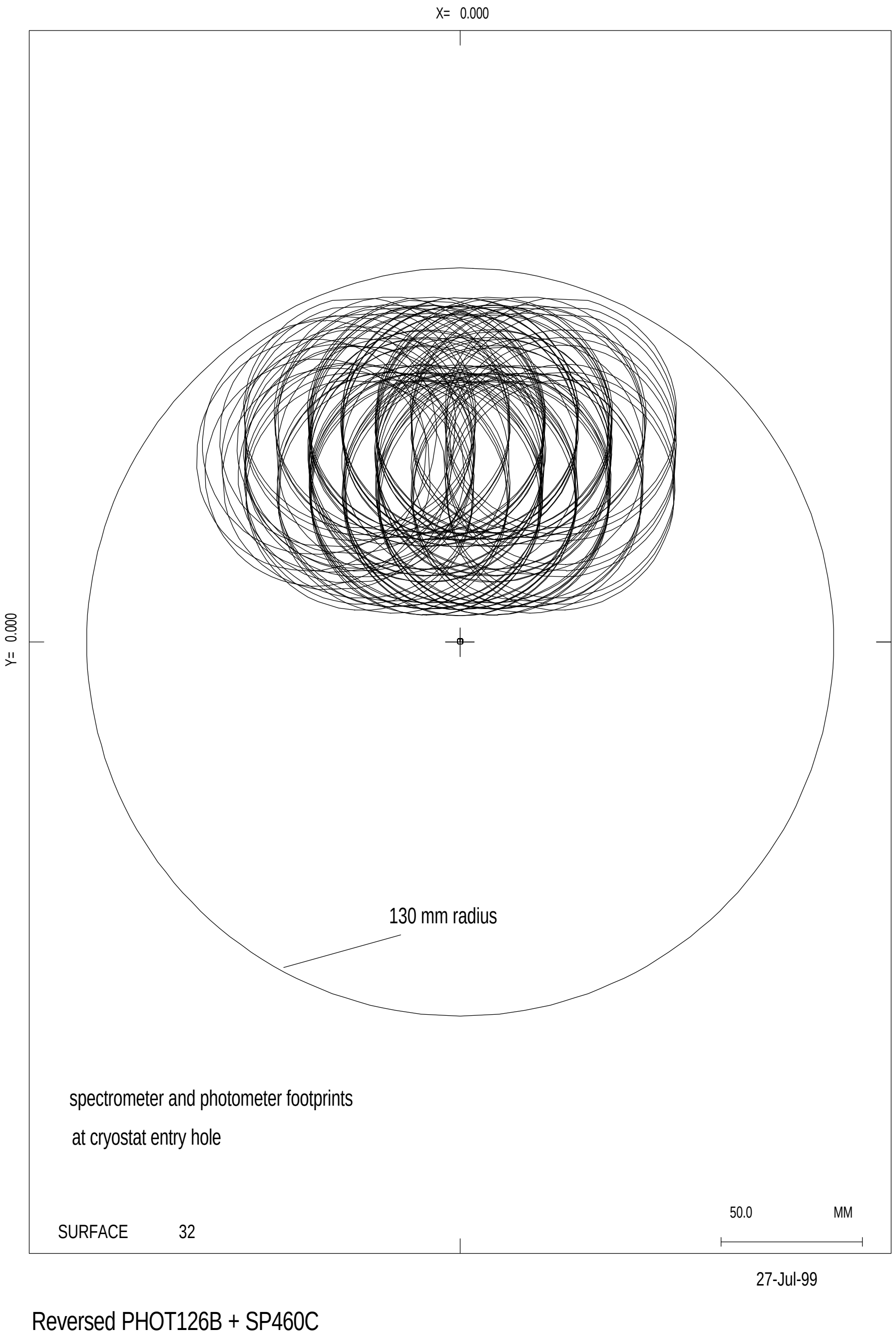


Figure 5.8-4 SPIRE optical beam envelope at the exit hole from the FIRST cryostat.

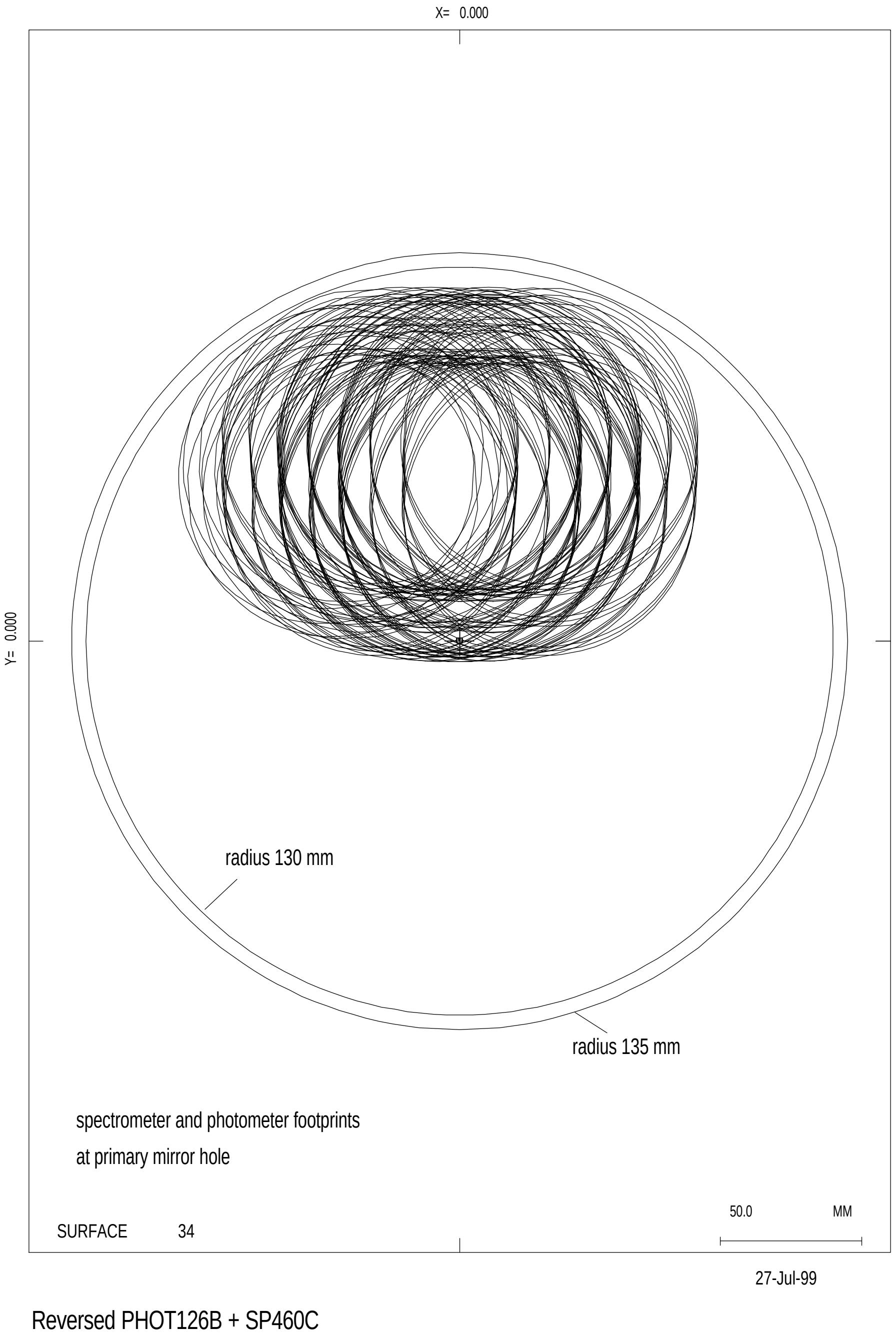


Figure 5.8-5 SPIRE optical beam envelope at the hole in the FIRST telescope primary mirror.

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

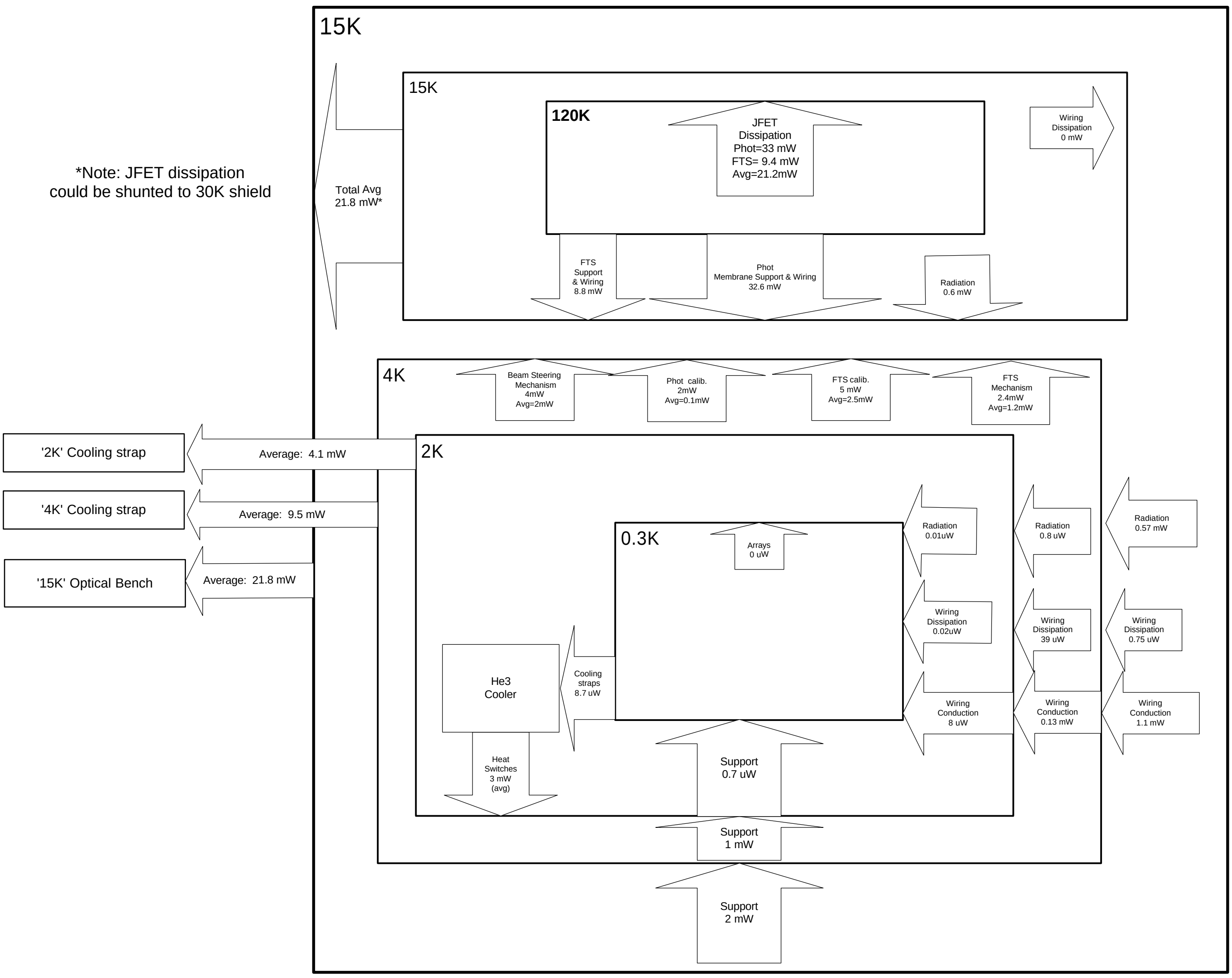
The tables and models below show the heat dissipation of the units mounted inside the cryostat:

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.

324 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

There are presently 3 versions under consideration.

5.9.1.2.1 CEA arrays (4x8 arcminutes FOV)

Temp. Stage	Item	Loads in mW			
		Standby	**OFF**	**PHOT**	**SPEC**
“15-K”**		0	0	0	0
“4-K”*	Wires	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	2.0	2.0	2.0	2.0
	Total	3.7	3.7	7.8	11.1
“2-K”***	Wires	0.1	0.1	0.1	0.1
	Dissipation	5.0	0.0	5.0	3.0
	Cooler	3.0	3.0	3.0	3.0
	Structure	1.0	1.0	1.0	1.0
	Total	9.1	4.1	9.1	7.1

Note: "Standby" with detectors and cold read-out on, ready to start observation, but mechanisms stopped.

5.9.1.2.2 GSFC array (4x8 arcminutes FOV, SQUIDs at 2 K)

Temp. Stage	Item	Loads in mW (all TBC)			
		Standby	**OFF**	**PHOT**	**SPEC**
“15-K”**		0	0	0	0
“4-K”*	Wires	16	16	17.1	16.2
	Radiation	0.6	0.6	0.6	0.6
	Mechanisms & Calibrators	0.0	0.0	4.1	7.4
	Structure	2.0	2.0	2.0	2.0
	Total	18.6	18.6	23.8	26.2
“2-K”***	Wires	5	5	5	5
	Dissipation	0.0	0.0	0.5	0.2
	Cooler	3.0	3.0	3.0	3.0
	Structure	1.0	1.0	1.0	1.0
	Total	9	9	9.5	9.2

5.9.1.2.3 Feed-horn array (324 bolometers, 4x8 arcminutes FOV)

Temp. Stage	Item	Loads in mW			
		Standby	**OFF**	**PHOT**	**SPEC**
“15-K”**	JFET Box	33	0	33	9.4
“4-K”*	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	2.0	2.0	2.0	2.0
	Total	3.7	3.7	7.8	11.1
"2-K"***	Wires	0.1	0.1	0.1	0.1
	Dissipation	0.0	0.0	0.0	0.0
	Cooler	3.0	3.0	3.0	3.0
	Structure	1.0	1.0	1.0	1.0
	Total	4.1	4.1	4.1	4.1

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.
4 K heatloads assume 15 K level is 11K

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

*** Includes average dissipation of ^{3}He refrigerator. This is ~ 1 mW. continuous and the recycle mode which dissipates 47 mW (TBC) for 2 out of every 48 hours.

	Cooler	1.0	1.0	1.0	1.0
	Structure	1.0	1.0	1.0	1.0
	Total	2.1	2.1	2.1	2.1

Either Photometer or SpectrometerJFETS 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.
4 K heatloads assume 15 K level is 11K

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

*** Includes dissipation of ^{3}He refrigerator when operating. Recycle mode dissipates 90 mW (TBC) for 2 out of every 48 hours.

5.9.1.3 Thermal Model FSBAU

TBDThermal design of the FSBAU is ESA responsibility (TBC).

5.9.1.4 Thermal Table FSBAU

TBD

5.9.2 Outside cryostat

Project code	**Instrument unit**	**Power dissipation (W)**

FSBAU	Buffer Amplifier Unit	2.5 (TBD) *

* Average may be lower if thermal and electronic design allows it to be switched off when inactive.

5.9.3 On SVM

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

Project code	Instrument unit			
	Option:	CEA	GSFC	JPL 324 horns
FSDRC	Detector Read-out and Control Unit	53	171	71
FSDPU	Digital Processing Unit	10	10	10
FSWIH	Warm Interconnect Harness	0	0	0
TOTAL		63	181	81

5.9.4 On Planck 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)

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

*	Only for JPL/Caltech detector option
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	TBD	TBD	TBD
Partner	TBD	TBD	TBD
Parallel/Serendipity	TBD	TBD	TBD
Standby	TBD	TBD	TBD
Real-time commanding	TBD	TBD	TBD
Commissioning/calibration	TBD	TBD	TBD
Cooler Recycle	TBD	TBD	TBD
On	TBD	TBD	TBD
Off	TBD	TBD	TBD

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.

Note from ESA Project: This may need to be reviewed in the light of email sent 08-07-1999 by S. Thuerey to all PI's and PM's in response to request from O. Bauer.

5.10 CONNECTORS, HARNESS, GROUNDING, BONDING

5.10.1 Connectors

Compliant with section 5.10 of IID-A. (TBC)

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 Data Handling subsystem.
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 15 to 300 K instrument parts, 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.

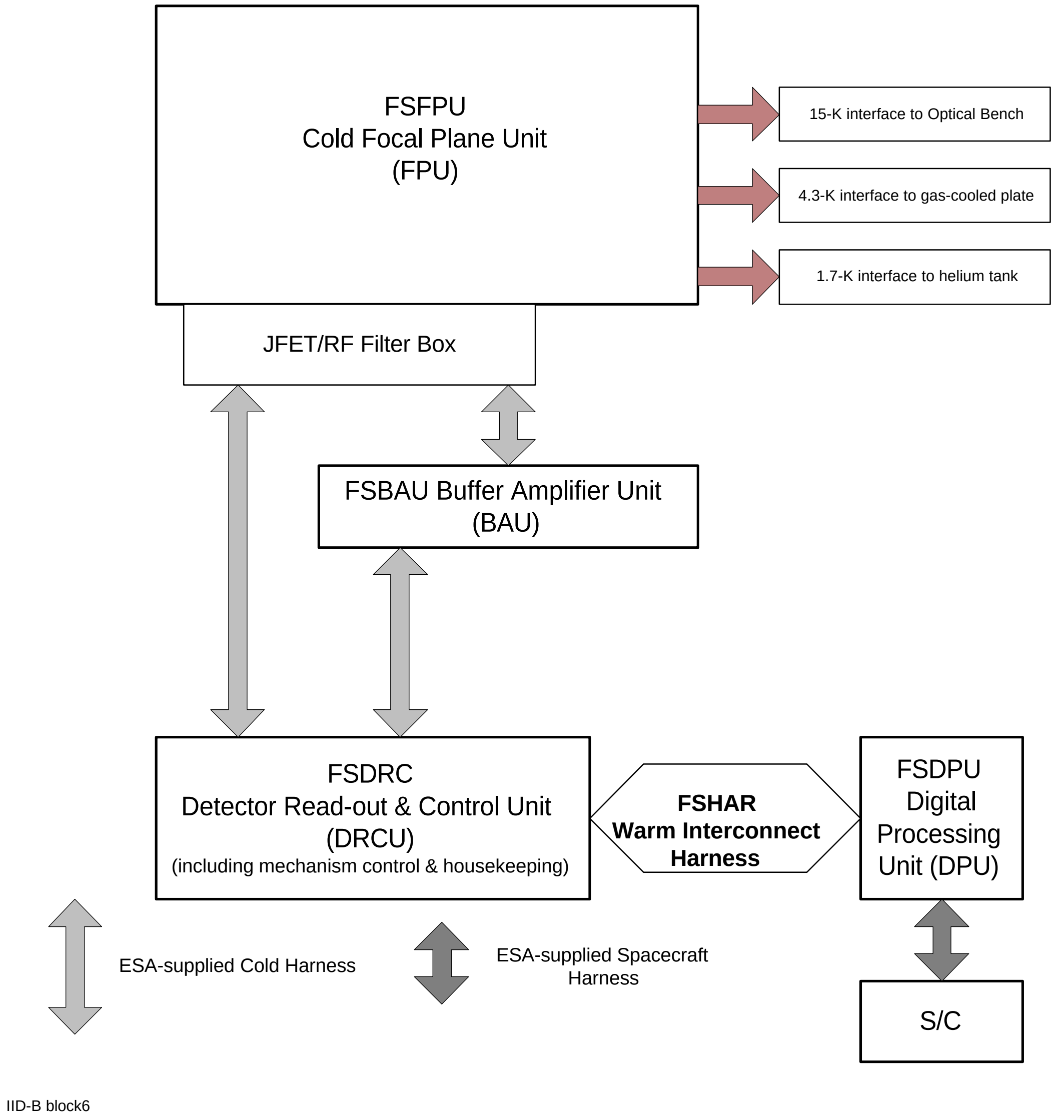


Figure 5.10-1: SPIRE block diagram

SPIRE cryo-harness list for 4.3 K to 15 K interface level:

1: Housekeeping and Mechanisms

ID	Instrument: SPIRE 4.3-K to 15-K interface 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)
21	0.3- K therms. (10)	TH-300	40	10	1000			1.0E-5	1	TBD
22	2- K therms (2)	TH-2	8	2	1000			1.0E-5	1	TBD
23	4- K therms (2)	TH-4	8	2	1000			1.0E-5	1	TBD
24	N.A.									
25	FTS temp sensors	F_Temp	8	2	1000			1.0E-5	1	TBD
26	FTS posn sensors (main)	F_Posn_M	5	1	1000			1.0E-4	0.5	TBD
27	FTS posn sensors (red)	F_Posn_R	5	1	1000			0.0E+0	1	TBD
28	FTS drive coils (main)	F_Drive_M	4	0 TBC	10 TBC			8.0E-3	0.5	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	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	TBD
33	Pump heater (main)	PH_M	2	0	10 TBC			2.0E-2	0.014	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	TBD
36	Pump therm. (red.)	PT_R	4	1	1000			1.0E-5	1	TBD
37	Evap. therm. (main)	ET_M	4	1	1000			1.0E-5	1	TBD
38	Evap. therm. (red.)	ET_R	4	1	1000			1.0E-5	1	TBD
39	Pump heat SW heater (main)	PHSWH_M	2	0	10 TBC			2.0E-3	0.96	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	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	TBD
44	Pump heat SW therm. (red.)	PHSWT_R	4	1	1000			1.0E-5	1	TBD
45	Evap. heat SW therm. (main)	EHSWT_M	4	1	1000			1.0E-5	1	TBD
46	Evap. heat SW therm. (red.)	EHSWT_R	4	1	1000			1.0E-5	1	TBD
47	BSM drive coil (main)	CH_DR_M	4	1	10 TBC			2.5E-3	0.5	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	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	TBD
52	BSM them (red.)	CH_T_R	4	1	1000			1.0E-5	1	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	TBD
56	Shutter therm (red.)	SH_T-R	4	1	1000			1.0E-5	1	TBD

ID	Instrument: SPIRE 4.3-K to 15-K interface 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	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	TBD
	Total		**192**	**38**						

2a : Detector Signals and control (CEA Option 4x8 arcminutes)

ID	Instrument: SPIRE 4.3-K to 15-K interface 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)
1	Detector signals	TBD	594	60	1000			1.0E-5	1	TBD
	ID 2 - 20 not used									

2b : Detector Signals and control (GSFC TES Option 4x8 arcminutes)

Connections from 4.3K to 15K										
ID	Description	Name	No. of Conductors	No. of Shields	Max. Allowed Impedances			Current	Duty Cycle	Max. Volts
					R (Ω)	C (F)	L(H)	(A)		(V)
1-1	Row Address 250 um	RADR P1	65	1 Bundle if Ribbon or 65 if Co-ax	19.4 TBC	252x10-12 TBC	600x10-9 TBC	3.2x10-3 TBC	1/64 of 50uS (781nS)	2
1-2	Row Address 350 um	RADR P2	65	1 Bundle if Ribbon or 65 if Co-ax	19.4 TBC	252x10-12 TBC	600x10-9 TBC	3.2x10-3 TBC	1/64 of 50uS (781nS)	2
1-3	Row Address 450 um	RADR P3	65	1 Bundle if Ribbon or 65 if Co-ax	19.4 TBC	252x10-12 TBC	600x10-9 TBC	3.2x10-3 TBC	1/64 of 50uS (781nS)	2
1-4	Row Address FTS 1	RADR F1	65	1 Bundle if Ribbon or 65 if Co-ax	19.4 TBC	252x10-12 TBC	600x10-9 TBC	3.2x10-3 TBC	1/64 of 50uS (781nS)	2
1-5	Row Address FTS 2	RADR F2	65	1 Bundle if Ribbon or 65 if Co-ax	19.4 TBC	252x10-12 TBC	600x10-9 TBC	3.2x10-3 TBC	1/64 of 50uS (781nS)	2
2-1	Det Bias 250 um	DBIAS P1	8	1 Bundle	19.4 TBC	252x10-12 TBC	600x10-9 TBC	3.2x10-3 TBC	DC	1
2-2	Det Bias 350 um	DBIAS P2	8	1 Bundle	19.4 TBC	252x10-12 TBC	600x10-9 TBC	3.2x10-3 TBC	DC	1
2-3	Det Bias 450 um	DBIAS P3	8	1 Bundle	19.4 TBC	252x10-12 TBC	600x10-9 TBC	3.2x10-3 TBC	DC	1
2-4	Det Bias FTS 1	DBIAS F1	8	1 Bundle	19.4 TBC	252x10-12 TBC	600x10-9 TBC	3.2x10-3 TBC	DC	1
2-5	Det Bias FTS 2	DBIAS F2	8	1 Bundle	19.4 TBC	252x10-12 TBC	600x10-9 TBC	3.2x10-3 TBC	DC	1
3-1	SQUID Mux Output P1	MXO P1	62	1 Bundle if Ribbon or 65 if Co-ax	19.4 TBC	252x10-12 TBC	600x10-9 TBC	1.0x10-3 TBC	1/64 of 50uS (781nS)	1

3-2	SQUID Mux Output P2	MXO P2	28	1 Bundle if Ribbon or 65 if Co-ax	19.4 TBC	252x10-12 TBC	600x10-9 TBC	1.0x10-3 TBC	1/64 of 50uS (781nS)	1
3-3	SQUID Mux Output P3	MXO P3	16	1 Bundle if Ribbon or 65 if Co-ax	19.4 TBC	252x10-12 TBC	600x10-9 TBC	1.0x10-3 TBC	1/64 of 50uS (781nS)	1
3-4	SQUID Mux Output F1	MXO P4	14	1 Bundle if Ribbon or 65 if Co-ax	19.4 TBC	252x10-12 TBC	600x10-9 TBC	1.0x10-3 TBC	1/64 of 50uS (781nS)	1
3-5	SQUID Mux Output F2	MXO P5	14	1 Bundle if Ribbon or 65 if Co-ax	19.4 TBC	252x10-12 TBC	600x10-9 TBC	1.0x10-3 TBC	1/64 of 50uS (781nS)	1
4-1	SQUID Mux Feedback P1	MXFB P1	62	1 Bundle if Ribbon or 65 if Co-ax	19.4 TBC	252x10-12 TBC	600x10-9 TBC	1.0x10-3 TBC	1/64 of 50uS (781nS)	1
4-2	SQUID Mux Feedback P2	MXFB P2	28	1 Bundle if Ribbon or 65 if Co-ax	19.4 TBC	252x10-12 TBC	600x10-9 TBC	1.0x10-3 TBC	1/64 of 50uS (781nS)	1
4-3	SQUID Mux Feedback P3	MXFB P3	16	1 Bundle if Ribbon or 65 if Co-ax	19.4 TBC	252x10-12 TBC	600x10-9 TBC	1.0x10-3 TBC	1/64 of 50uS (781nS)	1
4-4	SQUID Mux Feedback F1	MXFB P4	14	1 Bundle if Ribbon or 65 if Co-ax	19.4 TBC	252x10-12 TBC	600x10-9 TBC	1.0x10-3 TBC	1/64 of 50uS (781nS)	1
4-5	SQUID Mux Feedback F2	MXFB P5	14	1 Bundle if Ribbon or 65 if Co-ax	19.4 TBC	252x10-12 TBC	600x10-9 TBC	1.0x10-3 TBC	1/64 of 50uS (781nS)	1
	TOTAL:		633	26 or 633 if Co-ax						
	ID 5 - 20 not used									

2c : Detector Signals and control (Horn Option 4x8 arcminutes)

ID	Description	Name	No. of Conductors	No. of Shields	Max. Allowed Impedances R (Ω)	C (F)	L(H)	Current (A)	Duty Cycle	Max Volts (V)
1	P250 Sig	P250S	447	1	1k	1n	1u	1n	1	0.1
2	P350 Sig	P350S	264	1	1k	1n	1u	1n	1	0.1
3	P500 Sig	P500S	129	1	1k	1n	1u	1n	1	0.1
4	S350 Sig	S350S	111	1	1k	1n	1u	1n	1	0.1
5	S600 Sig	S600S	21	1	1k	1n	1u	1n	1	0.1
6	Det. Bias	BIAS	64	32	1k	1n	1u	1u	1	0.1
7	JFET	JFET	64/TBC	32/TBC	1k	1n	1u	1m	0.3	10
8	TC Bias	TBIAS	8/TBC	4/TBC	1k	1n	1u	1u	1	1
9	TC Sig	TSIG	8/TBC	4/TBC	1k	1n	1u	1n	1	0.1
	Totals	1116	77							
	ID 10 - 20 not used									

SPIRE cryo-harness list for 15K to 100K BAU

3a : Detector Signals and control (CEA Option 4x8 arcminutes)

ID	Instrument: SPIRE 4.3-K to 15-K interface Signal definition	Name	No. of Cond.	No. of shields	Max. allowed Res. (Ω)	Current (A)	Duty Cycle (t*T)	Max. Line Volt (V)	Remarks
1	Detector signals	TBD	594	60	1000	1.0E-5	1	TBD	
	ID 2 - 20 not used								

3b : Detector Signals and control (GSFC TES Option 4x8 arcminutes)

Connections from 15K to 100K										
ID	Description	Name	No. of Conductors	No. of Shields	Max. Allowed Impedances			Current	Duty Cycle	Max. Volts
					R (Ω)	C (F)	L(H)	(A)		(V)
1-1	Row Address 0.625 mm	RADR P1	65	1 Bundle if Ribbon or 65 if Co-ax	70.2 TBC	1.0x10-9 TBC	2.4x10-6 TBC	3.2x10-3 TBC	1/64 of 50uS (781nS)	2
1-2	Row Address 0.625 mm	RADR P2	65	1 Bundle if Ribbon or 65 if Co-ax	70.2 TBC	1.0x10-9 TBC	2.4x10-6 TBC	3.2x10-3 TBC	1/64 of 50uS (781nS)	2
1-3	Row Address 1.25 mm	RADR P3	65	1 Bundle if Ribbon or 65 if Co-ax	70.2 TBC	1.0x10-9 TBC	2.4x10-6 TBC	3.2x10-3 TBC	1/64 of 50uS (781nS)	2
1-4	Row Address FTS 1	RADR F1	65	1 Bundle if Ribbon or 65 if Co-ax	70.2 TBC	1.0x10-9 TBC	2.4x10-6 TBC	3.2x10-3 TBC	1/64 of 50uS (781nS)	2
1-5	Row Address FTS 2	RADR F2	65	1 Bundle if Ribbon or 65 if Co-ax	70.2 TBC	1.0x10-9 TBC	2.4x10-6 TBC	3.2x10-3 TBC	1/64 of 50uS (781nS)	2
2-1	Det Bias 0.625 mm	DBIAS P1	8	1 Bundle	70.2 TBC	1.0x10-9 TBC	2.4x10-6 TBC	3.2x10-3 TBC	DC	1
2-2	Det Bias 0.875 mm	DBIAS P2	8	1 Bundle	70.2 TBC	1.0x10-9 TBC	2.4x10-6 TBC	3.2x10-3 TBC	DC	1
2-3	Det Bias 1.25 mm	DBIAS P3	8	1 Bundle	70.2 TBC	1.0x10-9 TBC	2.4x10-6 TBC	3.2x10-3 TBC	DC	1
2-4	Det Bias FTS 1	DBIAS F1	8	1 Bundle	70.2 TBC	1.0x10-9 TBC	2.4x10-6 TBC	3.2x10-3 TBC	DC	1
2-5	Det Bias FTS 2	DBIAS F2	8	1 Bundle	70.2 TBC	1.0x10-9 TBC	2.4x10-6 TBC	3.2x10-3 TBC	DC	1
3-1	SQUID Mux Output P1	MXO P1	62	1 Bundle if Ribbon or 65 if Co-ax	70.2 TBC	1.0x10-9 TBC	2.4x10-6 TBC	1.0x10-3 TBC	1/64 of 50uS (781nS)	1
3-2	SQUID Mux Output P2	MXO P2	28	1 Bundle if Ribbon or 65 if Co-ax	70.2 TBC	1.0x10-9 TBC	2.4x10-6 TBC	1.0x10-3 TBC	1/64 of 50uS (781nS)	1

3-3	SQUID Mux Output P3	MXO P3	16	1 Bundle if Ribbon or 65 if Co-ax	70.2 TBC	1.0x10-9 TBC	2.4x10-6 TBC	1.0x10-3 TBC	1/64 of 50uS (781nS)	1
3-4	SQUID Mux Output F1	MXO P4	14	1 Bundle if Ribbon or 65 if Co-ax	70.2 TBC	1.0x10-9 TBC	2.4x10-6 TBC	1.0x10-3 TBC	1/64 of 50uS (781nS)	1
3-5	SQUID Mux Output F2	MXO P5	14	1 Bundle if Ribbon or 65 if Co-ax	70.2 TBC	1.0x10-9 TBC	2.4x10-6 TBC	1.0x10-3 TBC	1/64 of 50uS (781nS)	1
4-1	SQUID Mux Feedback P1	MXFB P1	62	1 Bundle if Ribbon or 65 if Co-ax	70.2 TBC	1.0x10-9 TBC	2.4x10-6 TBC	1.0x10-3 TBC	1/64 of 50uS (781nS)	1
4-2	SQUID Mux Feedback P2	MXFB P2	28	1 Bundle if Ribbon or 65 if Co-ax	70.2 TBC	1.0x10-9 TBC	2.4x10-6 TBC	1.0x10-3 TBC	1/64 of 50uS (781nS)	1
4-3	SQUID Mux Feedback P3	MXFB P3	16	1 Bundle if Ribbon or 65 if Co-ax	70.2 TBC	1.0x10-9 TBC	2.4x10-6 TBC	1.0x10-3 TBC	1/64 of 50uS (781nS)	1
4-4	SQUID Mux Feedback F1	MXFB P4	14	1 Bundle if Ribbon or 65 if Co-ax	70.2 TBC	1.0x10-9 TBC	2.4x10-6 TBC	1.0x10-3 TBC	1/64 of 50uS (781nS)	1
4-5	SQUID Mux Feedback F2	MXFB P5	14	1 Bundle if Ribbon or 65 if Co-ax	70.2 TBC	1.0x10-9 TBC	2.4x10-6 TBC	1.0x10-3 TBC	1/64 of 50uS (781nS)	1
	Totals:		633	26 or 633 if Co-ax						
	ID 5 - 20 not used									

3c : Detector Signals and control (Horn Option 4x8 arcminutes)

ID	Description	Name	No. of Conductors	No. of Shields	Max. Allowed Impedances			Current (A)	Duty Cycle	Max Volts (V)
					R (Ω)	C (F)	L(H)			
1	P250 Sig	P250S	447	1	1k	1n	1u	1n	1	0.1
2	P350 Sig	P350S	264	1	1k	1n	1u	1n	1	0.1
3	P500 Sig	P500S	129	1	1k	1n	1u	1n	1	0.1
4	S350 Sig	S350S	111	1	1k	1n	1u	1n	1	0.1
5	S600 Sig	S600S	21	1	1k	1n	1u	1n	1	0.1
6	Det. Bias	BIAS	64	32	1k	1n	1u	1u	1	0.1
7	JFET	JFET	64/TBC	32/TBC	1k	1n	1u	1m	0.3	10
8	TC Bias	TBIAS	8/TBC	4/TBC	1k	1n	1u	1u	1	1
9	TC Sig	TSIG	8/TBC	4/TBC	1k	1n	1u	1n	1	0.1
		Totals	1116	77						
	ID 10 - 20 not used									

SPIRE cryo-harness list for 100 K BAU to 300 K

4a : Detector Signals and control (CEA Option 4x8 arcminutes)

ID	Instrument: SPIRE 4.3-K to 15-K interface Signal definition	Name	No. of Cond.	No. of shields	Max. allowed Res. (Ω)	Current (A)	Duty Cycle (t*T)	Max. Line Volt (V)	Remarks
1	Detector signals	TBD	783	79	1000	1.0E-5	1	TBD	
2	Amplifier Power		TBD						
3	Thermistors		TBD						
	ID 4 - 20 not used								

4b : Detector Signals and control (GSFC TES Option 4x8 arcminutes)

Connections from 300K to 80K										
ID	Description	Name	No. of Conductors	No. of Shields	Max. Allowed Impedances			Current	Duty Cycle	Max. Volts
					R (Ω)	C (F)	L(H)	(A)		(V)
1-1	Row Address 0.625 mm	RADR P1	65	1 Bundle if Ribbon or 65 if Co-ax	146 TBC	1.1x10-9 TBC	5x10-6 TBC	3.2x10-3 TBC	1/64 of 50uS (781nS)	2
1-2	Row Address 0.625 mm	RADR P2	65	1 Bundle if Ribbon or 65 if Co-ax	146 TBC	1.1x10-9 TBC	5x10-6 TBC	3.2x10-3 TBC	1/64 of 50uS (781nS)	2
1-3	Row Address 1.25 mm	RADR P3	65	1 Bundle if Ribbon or 65 if Co-ax	146 TBC	1.1x10-9 TBC	5x10-6 TBC	3.2x10-3 TBC	1/64 of 50uS (781nS)	2
1-4	Row Address FTS 1	RADR F1	65	1 Bundle if Ribbon or 65 if Co-ax	146 TBC	1.1x10-9 TBC	5x10-6 TBC	3.2x10-3 TBC	1/64 of 50uS (781nS)	2
1-5	Row Address FTS 2	RADR F2	65	1 Bundle if Ribbon or 65 if Co-ax	146 TBC	1.1x10-9 TBC	5x10-6 TBC	3.2x10-3 TBC	1/64 of 50uS (781nS)	2
2-1	Det Bias 0.625 mm	DBIAS P1	8	1 Bundle	146 TBC	1.1x10-9 TBC	5x10-6 TBC	3.2x10-3 TBC	DC	1
2-2	Det Bias 0.875 mm	DBIAS P2	8	1 Bundle	146 TBC	1.1x10-9 TBC	5x10-6 TBC	3.2x10-3 TBC	DC	1
2-3	Det Bias 1.25 mm	DBIAS P3	8	1 Bundle	146 TBC	1.1x10-9 TBC	5x10-6 TBC	3.2x10-3 TBC	DC	1
2-4	Det Bias FTS 1	DBIAS F1	8	1 Bundle	146 TBC	1.1x10-9 TBC	5x10-6 TBC	3.2x10-3 TBC	DC	1
2-5	Det Bias FTS 2	DBIAS F2	8	1 Bundle	146 TBC	1.1x10-9 TBC	5x10-6 TBC	3.2x10-3 TBC	DC	1
3-1	SQUID Mux Output P1	MXO P1	62	1 Bundle if Ribbon or 65 if Co-ax	146 TBC	1.1x10-9 TBC	5x10-6 TBC	1.0x10-3 TBC	1/64 of 50uS (781nS)	1
3-2	SQUID Mux Output P2	MXO P2	28	1 Bundle if Ribbon or 65 if Co-ax	146 TBC	1.1x10-9 TBC	5x10-6 TBC	1.0x10-3 TBC	1/64 of 50uS (781nS)	1
3-3	SQUID Mux Output P3	MXO P3	16	1 Bundle if Ribbon or 65 if Co-ax	146 TBC	1.1x10-9 TBC	5x10-6 TBC	1.0x10-3 TBC	1/64 of 50uS (781nS)	1

3-4	SQUID Mux Output F1	MXO P4	14	1 Bundle if Ribbon or 65 if Co-ax	146 TBC	1.1x10-9 TBC	5x10-6 TBC	1.0x10-3 TBC	1/64 of 50uS (781nS)	1
3-5	SQUID Mux Output F2	MXO P5	14	1 Bundle if Ribbon or 65 if Co-ax	146 TBC	1.1x10-9 TBC	5x10-6 TBC	1.0x10-3 TBC	1/64 of 50uS (781nS)	1
4-1	SQUID Mux Feedback P1	MXFB P1	62	1 Bundle if Ribbon or 65 if Co-ax	146 TBC	1.1x10-9 TBC	5x10-6 TBC	1.0x10-3 TBC	1/64 of 50uS (781nS)	1
4-2	SQUID Mux Feedback P2	MXFB P2	28	1 Bundle if Ribbon or 65 if Co-ax	146 TBC	1.1x10-9 TBC	5x10-6 TBC	1.0x10-3 TBC	1/64 of 50uS (781nS)	1
4-3	SQUID Mux Feedback P3	MXFB P3	16	1 Bundle if Ribbon or 65 if Co-ax	146 TBC	1.1x10-9 TBC	5x10-6 TBC	1.0x10-3 TBC	1/64 of 50uS (781nS)	1
4-4	SQUID Mux Feedback F1	MXFB P4	14	1 Bundle if Ribbon or 65 if Co-ax	146 TBC	1.1x10-9 TBC	5x10-6 TBC	1.0x10-3 TBC	1/64 of 50uS (781nS)	1
4-5	SQUID Mux Feedback F2	MXFB P5	14	1 Bundle if Ribbon or 65 if Co-ax	146 TBC	1.1x10-9 TBC	5x10-6 TBC	1.0x10-3 TBC	1/64 of 50uS (781nS)	1
	Total:		633	26 or 633 if Co-ax						
	ID 5 - 20 not used									

4c: Detector Signals and control (Horn Option 4x8 arcminutes)

ID	Description	Name	No. of Conductors	No. of Shields	Max. Allowed Impedances			Current (A)	Duty Cycle	Max Volts (V)
					R (Ω)	C (F)	L(H)			
1	P250 Sig	P250S	447	1	100	10n	1u	1n	1	0.1
2	P350 Sig	P350S	264	1	100	10n	1u	1n	1	0.1
3	P500 Sig	P500S	129	1	100	10n	1u	1n	1	0.1
4	S350 Sig	S350S	111	1	100	10n	1u	1n	1	0.1
5	S600 Sig	S600S	21	1	100	10n	1u	1n	1	0.1
6	Det. Bias	BIAS	64	32	100	10n	1u	1u	1	0.1
7	JFET	JFET	64/TBC	32/TBC	100	10n	1u	1m	0.3	10
8	TC Bias	TBIAS	8/TBC	4/TBC	100	10n	1u	1u	1	1
9	TC Sig	TSIG	8/TBC	4/TBC	100	10n	1u	1n	1	0.1
10	BAU Power	BAUP	6	3	10	10n	1u	120m	0.3	0.1
		Totals	1122	80						
	ID 11 - 20 not used									

SPIRE cryo-harness list for 15 K to 300 K interface level

Housekeeping and mechanism control (Independent of option)

	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	TBD

22	2- K therms (2)	TH-2	8	2	1000			1.0E-5	1	TBD
23	4- K therms (2)	TH-4	8	2	1000			1.0E-5	1	TBD
24	15- K therms (2)	TH-15	8	2	1000			1.0E-5	1	TBD
25	FTS temp sensors	F_Temp	8	2	1000			1.0E-5	1	TBD
26	FTS posn sensors (main)	F_Posn_M	5	1	1000			1.0E-4	0.5	TBD
27	FTS posn sensors (red)	F_Posn_R	5	1	1000			0.0E+0	1	TBD
28	FTS drive coils (main)	F_Drive_M	4	0 TBC	10 TBC			8.0E-3	0.5	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	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	TBD
33	Pump heater (main)	PH_M	2	0	10 TBC			2.0E-2	0.014	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	TBD
36	Pump therm. (red.)	PT_R	4	1	1000			1.0E-5	1	TBD
37	Evap. therm. (main)	ET_M	4	1	1000			1.0E-5	1	TBD
38	Evap. therm. (red.)	ET_R	4	1	1000			1.0E-5	1	TBD
39	Pump heat SW heater (main)	PHSWH_M	2	0	10 TBC			2.0E-3	0.96	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	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	TBD
44	Pump heat SW therm. (red.)	PHSWT_R	4	1	1000			1.0E-5	1	TBD
45	Evap. heat SW therm. (main)	EHSWT_M	4	1	1000			1.0E-5	1	TBD
46	Evap. heat SW therm. (red.)	EHSWT_R	4	1	1000			1.0E-5	1	TBD
47	BSM drive coil (main)	CH_DR_M	4	1	10 TBC			2.5E-3	0.5	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	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	TBD
52	BSM them (red.)	CH_T_R	4	1	1000			1.0E-5	1	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	TBD
56	Shutter therm (red.)	SH_T-R	4	1	1000			1.0E-5	1	TBD
57	Phot BB Calibrator (main)	P_BBC_M	2	0	10 TBC			3.0E-3	0.5	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	TBD
	Total		**180**	**39**						

Notes:
Allowed resistance values are at "operational temperatures"
In column Duty cycle t= part of T in which signal is active.
T= time for which SPIRE is in observe mode.

5.10.3 Grounding

The grounding scheme is TBD.

5.10.4 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)**	
Option:	4x8 arcmin filled array	4x8 arcmin horn array
Housekeeping data rate	2	2
Science data rate: Photometer only	322	26
Science data rate: Spectrometer only	139	97
Science data rate: Partner mode with PACS	TBD	TBD
Science data rate: Serendipity mode	TBD	TBD

The resultant housekeeping and science data rate requirements (after compression) for TM/storage, over the periods SPIRE is observing, are as follows:

Description	**Telemetry rate over 24 hours (kbps)**
Housekeeping data rate	2 (TBC) *
Science data rate: photometer only	100 **(TBC)
Science data rate: spectrometer only	139 *** (TBC)
Science data rate: in partner mode with PHOC	TBD
Science data rate: serendipity mode	TBD

* Housekeeping data shall not be compressed.

** Any increase in telemetry rate would have science benefits, as less on-board processing would be needed.

*** Any increase in telemetry rate would have science benefits, as raw interferograms could be transmitted. If the bit rate limit is maintained as 100 kbs the spectrometer will have to be used in conjunction with lower data rate FIRST operations to allow the full requirement of 139 kbs to be telemetered.

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 shill have the capability of handling a telemetry rate of > 500 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.

Note from ESA Project: In view of the selected 1553 interface at the CWG meeting held 02-07-1999 a rate of > 500 kbps will not be possible via this link.

5.11.1.3 Data Packets

In order to prevent data overflow in the SPIRE on-board data storage units, the S/C OBDH 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.

Voltage to instrument
Current to instrument
Power status – i.e. which SPIRE units are on i.e. FSDPU and FSDRC.
Instrument Temperatures (Section 5.7.5 lists the instrument temperature channels together with their relevant TM allocations)

5.11.3 Timing and synchronisation signals

The S/C shall provide SPIRE with a timing synchronisation packet 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 with a timing precision of better than 5 milliseconds. This is required so that the SPIRE data can be correctly processed.

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 S/C shall be capable of responding to an error flag from the SPIRE on-board software indicating that a command has not been correctly received by re-sending the appropriate telecommand packet. TBC.

The maximum rate of sending commands from the OBDH to the SPIRE instrument is TBD.

The maximum telecommand packet length is TBD

5.11.5 Interface circuits

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

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. If the feedhorn detector option is chosen, then the AOCS 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 AOCS 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 TBD arcmin and TBD 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 TBD seconds

- Line scan mode. To map large areas of the sky, the telescope must be capable of being scanned up to TBD 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. The rate of scanning must be stable to within TBD arcsec per second and 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 TBD 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 5 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, never-the-less, be capable of providing a rectangular raster with steps of between 1.7 and 30 arcsec (TBC) 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. Depending on the detector type that is implemented 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 TBD arcsec r.m.s. per minute.

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)

5.13 ON-BOARD HARDWARE/SOFTWARE AND AUTONOMY FUNCTIONS

5.13.1 On-board hardware

There are two separate on-board computers in the SPIRE instrument each with separate on-board software.

5.13.2 On-board software

The SPIRE instrument requires that the FIRST OBDH stores an image of both sets of instrument on-board software to be loaded automatically at the start of each operational cycle.

The SPIRE instrument requires that the FIRST OBDH stores an “instrument context” data image to be loaded automatically at the start of each operational cycle.

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 an “Autonomous Housekeeping Data” packet 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 5g (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 TBD K/hour. The rate of depressurisation/pressurisation P/T shall not exceed 50 mB/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 5g (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 (FSBAU; FSDRC; FSDPU; FSHAR) 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 5g (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; BAU 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 and FSBAU, to enable integration of the FSDRC; FSDPU and FSHAR
- TBD EGSE for integration of the FSBAU and 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.

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

5.16.10 Technical Documentation

The following documents will be delivered:

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

TBD

6.3 COMMONALITY

It is a fundamental design feature of the FIRST/Planck mission that commonality shall be pursued, to the maximum extent possible, for all the instruments.
Complete in response to relevant chapter of IID-A.

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

TBD

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.

7.3 Operations

Covered in other applicable documentation as follows:

AD1-14	FIRST/Planck Ground Segment Interface Document (GSID)
AD1-15	FIRST/Planck Operations Interface Requirements Document (OIRD)
AD1-16	FIRST Science-operations Implementation Requirements Document (FIRST-SIRD)
AD1-17	Planck Science-operations Implementation Requirements Document (Planck-SIRD)

7.4 Commonality

For the activities in chapters 7.2 and 7.3 commonality shall be pursued to the maximum extent possible.

Complete in response to relevant chapter of IID-A.

8 PRODUCT ASSURANCE

The instrument will comply with PT-RQ-044100, ‘Product Assurance Requirements for FIRST/Planck Scientific Instruments’.

Details are to be found in SPIRE Product Assurance Plan (RD2: BOL/RAL/D/0017)

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.

- A cold vibration facility will be built that will simulate the launch temperatures for the bolometer instrument and provide the specified vibration levels.

- 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 procedures is given in reference document BOL/RAL/N/0020.

- This document will form the basis of the *FIRST Bolometer 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 and submitted for project/ESA approval.

- 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 FIRST bolometer instrument will be in accordance with the requirements of the FIRST IID part A. The instrument models to be produced are:

- EM - Electrical Model.
- EQM - Engineering 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

10.1 PRODUCT TREE (PT)

Instrument Option	Baseline			Backup		
Instrument Model	EM	EQM	PFM	EM	EQM	PFM
Product Item						
Cold FPU (SPIRE1)						
Structure						
"15 K" Box		x	x		x	x
"4 K" Box		x	x		x	x
"2 K" Box		x	x		x	x
"300 mK" Box		x	x		x	x
MGSE		x	x		x	x
Transport containers		x	x		x	x
Optics						
Photometer optical chain and fore optics						
M3 - "field" mirror		x	x		x	x
M4 - chopper mirror		x	x		x	x
Beam conditioning and folding mirrors (TBD)		x	x		x	x
Re-imaging mirrors (TBD)		x	x		x	x
Optics mounts		x	x		x	x
Spectrometer optical chain						
Beam conditioning mirrors (TBD)		x	x		x	x
Fold mirrors (TBD)		x	x		x	x
Moving mirror(s)		x	x		x	x
Mirror movement measurement system (may be integrated with mechanism)		x	x		x	x
Re-imaging mirrors (TBD)		x	x		x	x
Optics mounts		x	x		x	x
Photometer filters, fore optics filters and dichroics						
"15 K" fore optics filter		x	x		x	x
"4 K" filter		x	x		x	x
"2 K" filter		x	x		x	x
Dichroics		x	x		x	x
Pass band filters		x	x		x	x
Filter and dichroic mounts		x	x		x	x
Spectrometer filters, dichroics and grids						
"4 K" filter		x	x		x	x
"2 K" filter		x	x		x	x
Dichroics		x	x		x	x
Passband filters		x	x		x	x
Filter and dichroic mounts		x	x		x	x
Polarising grids		x	x		x	x
Grid mounts		x	x		x	x
Photometer optical baffling and fore optics baffling						

Instrument Option	Baseline			Backup		
Instrument Model	EM	EQM	PFM	EM	EQM	PFM
Product Item						
Baffles (TBD)		x	x		x	x
Baffle mounts		x	x		x	x
Spectrometer baffling						
Baffles (TBD)		x	x		x	x
Baffle mounts		x	x		x	x
Cooler						
^{3}He Cooler Unit		x	x		x	x
Cold harness and connectors		x	x		x	x
Mechanical interface structure		x	x		x	x
Cold finger interface structure		x	x		x	x
Focal Plane						
Photometer Bolometer arrays						
Bolometer pixels					x	x
Feed Optics					x	x
Bolometer arrays		x	x			
Cold readout electronics		x	x			
Focal plane structure including filter mounts		x	x		x	x
Cold harness and connector(s)		x	x		x	x
Spectrometer Bolometer array						
Bolometer pixels					x	x
Feed Optics					x	x
Bolometer arrays		x	x			
Cold readout electronics		x	x			
Focal plane structure including filter mounts		x	x		x	x
Cold harness and connector(s)		x	x		x	x
Mechanisms						
Chopper						
Chopper motor		x	x		x	x
Interface structure		x	x		x	x
Cold harness and connector		x	x		x	x
Spectrometer Mechanism						
Spectrometer motor		x	x		x	x
Moving mirror support structure		x	x		x	x
Interface structure		x	x		x	x
Cold harness and connector		x	x		x	x
Calibration Sources						
Photometer calibration source						
Temperature controlled radiation source		x	x		x	x
Interface structure		x	x		x	x

Instrument Option	Baseline			Backup		
Instrument Model	EM	EQM	PFM	EM	EQM	PFM
Product Item						
Cold harness and connector		x	x		x	x
Spectrometer calibration source						
Temperature controlled radiation source		x	x		x	x
Interface structure		x	x		x	x
Cold harness and connector		x	x		x	x
JFET Module						
JFETs and asscoiated components					x	x
RF Filters and associated components					x	x
Box and interface structure					x	x
Cold harness and connectors					x	x
Warm Electronics						
Detector Buffer Amplifiers (SPIRE2)						
Box	x	x	x	x	x	x
Buffer amplifiers	x	x	x	x	x	x
Connectors	x	x	x	x	x	x
Savers	x	x	x	x	x	x
Detector Read Out and Control Electronics (SPIRE3)						
Box	x	x	x	x	x	x
Analogue amplification chain	x	x	x	x	x	x
Bias electronics	x	x	x	x	x	x
ADCs and associated components	x	x	x	x	x	x
Instrument Control electronics	x	x	x	x	x	x
Chopper drive electronics	x	x	x	x	x	x
Spectrometer mechanism drive electronics	x	x	x	x	x	x
Cooler control electronics	x	x	x	x	x	x
Calibration source control electronics	x	x	x	x	x	x
Temperature monitor electronics	x	x	x	x	x	x
Digital interface electronics	x	x	x	x	x	x
Connectors	x	x	x	x	x	x
Savers	x	x	x	x	x	x
Signal Processing Unit - SPU (SPIRE4)						
Box	x	x	x	x	x	x
Signal processing module	x	x	x	x	x	x
Memory module	x	x	x	x	x	x
DC/DC converters	x	x	x	x	x	x
Connectors	x	x	x	x	x	x
Savers	x	x	x	x	x	x
Digital Electronics - DPU (SPIRE5)						
Box	x	x	x	x	x	x

Instrument Option	Baseline			Backup		
Instrument Model	EM	EQM	PFM	EM	EQM	PFM
Product Item						
CPU	x	x	x	x	x	x
Mass memory	x	x	x	x	x	x
Digital interface electronics	x	x	x	x	x	x
Power supplies (PSU)	x	x	x	x	x	x
Connectors	x	x	x	x	x	x
Savers	x	x	x	x	x	x
Warm Interconnect Harness (SPIRE6)						
DPU to SPU harness	x	x	x	x	x	x
SPU to detector read and control electronics harness	x	x	x	x	x	x
Detector readout and control electronics to detector buffer amplifiers harness	x	x	x	x	x	x
Analogue Instrument Simulator	x			x		
On Board Software						
Data handling and instrument command software	x	x	x	x	x	x
Real time instrument control software	x	x	x	x	x	x
Data processing software	x	x	x	x	x	x

10.2 WORK BREAKDOWN STRUCTURE (WBS)

BOL Instrument

1. Project management

1.1 Support to ESA
1.2 Project Control
1.3 Project Office
1.4 Product Assurance

2. Instrument Hardware

2.1 Design ⇒
2.2 Ground Support Facilities ⇒
2.3 Development and Manufacture ⇒
2.4 Test and Calibration Preparation ⇒
2.5 On Board Software

3. ICC Development

3.1 Management ⇒
3.2 Instrument Operations ⇒
3.3 Software Development ⇒
3.4 ICC Preparation ⇒

4. ICC Operations

4.1 Management ⇒
4.2 Software Maintenenace ⇒
4.3 ICC Operations ⇒
4.4 Facilities Maintenance ⇒

5. Post-Operations

5.1 Run-Down Activities
5.2 Archive Definition
5.3 Improvement of Archive Contents
5.4 Archive Users Support
5.5 Facilities Maintenance

6. Archive Phase

TBD

7. Science Exploitation

7.1 FIRST Science Programme Support
7.2 Instrument Science Programme
7.3 Open-Time Observations
7.4 Science Analysis

2.1 Design

2.1.1 System Design

- 2.1.1.1 Scientific Requirements
- 2.1.1.2 Instrument System requirements
- 2.1.1.3 Mechanical System Design
- 2.1.1.4 Optical System Design
- 2.1.1.5 Thermal System Design
- 2.1.1.6 Electrical System Design
- 2.1.1.7 Instrument Science Verification Review
- 2.1.1.8 Provision of Mathematical Optical Model
- 2.1.1.9 Provision of Mathematical Thermal Model

2.1.2 Detailed Design

- 2.1.2.1 Definition of Subsystem Requirements
- 2.1.2.2 Instrument Internal Interfaces
- 2.1.2.3 Structure Design
- 2.1.2.4 FTS Subsystem Design
- 2.1.2.5 Optics Design
- 2.1.2.6 Cooler Subsystem Design
- 2.1.2.7 Chopper Subsystem Design
- 2.1.2.8 Calibration Source(s) Design
- 2.1.2.9 Focal Plane Arrays Design
- 2.1.2.10 Filters Design
- 2.1.2.11 Analogue Electronics Design
- 2.1.2.12 Digital electronics Design
- 2.1.2.13 Preliminary Baseline Design Review
- 2.1.2.14 Design Consolidation
- 2.1.2.15 Instrument Baseline Design Review
- 2.1.2.16 Provision of Instrument Design Doc.
- 2.1.2.17 Definition of Electrical Model
- 2.1.2.18 Provision of EMC Model

2.2 Ground Support Facilities

- 2.2.1 EGSE
- 2.2.2 Quick Look Facility
- 2.2.3 Test Equipment ⇒
- 2.2.4 FPU Integration Facilities
- 2.2.5 Alignment Check Cryostat and OGSE
- 2.2.6 Instrument level Test Cryostat and OGSE
- 2.2.7 EMC Test Facility
- 2.2.8 Thermal Vacuum Test Facility
- 2.2.9 Calibration Test Facility
- 2.2.10 Cold Vibration Test Facility
- 2.2.11 Warm Vibration Test Facility

2.2.3 Test Equipment

- 2.2.3.1 Optical Alignment Jig
- 2.2.3.2 Provision of Analogue Instrument Simulator
- 2.2.3.3 Provision of Digital Instrument Simulator
- 2.2.3.4 Provision of Throughput Test Detector Assembly

2.3 Development and Manufacture

2.3.1 Electrical Model

- 2.3.1.1 EM Manufacture and Assembly ⇒
- 2.3.1.2 EM Integration and Verification ⇒
- 2.3.1.3 EM Delivery
- 2.3.1.4 EM System Level Testing

2.3.2 Qualification Model

- 2.3.2.1 QM Manufacture and Assembly ⇒
- 2.3.2.2 QM Integration and Verification ⇒
- 2.3.2.3 QM Delivery
- 2.3.2.4 QM System Level Testing

2.3.3 Proto-Flight Model

- 2.3.3.1 PFM Manufacture and Assembly ⇒
- 2.3.3.2 PFM Integration and Verification ⇒
- 2.3.3.3 PFM Delivery
- 2.3.3.4 PFM System Level Testing
- 2.3.3.5 Launch Campaign

2.3.4 Flight Spare

- 2.3.4.1 FS Manufacture and Assembly ⇒
- 2.3.4.2 FS Integration and Verification ⇒
- 2.3.4.3 FS Delivery

2.3.1.1 EM Manufacture and Assembly

- 2.3.1.1.1 Provision of EM Digital Electronics + OBS
- 2.3.1.1.2 Provision of EM Analogue Electronics

2.3.1.2 EM Integration and Verification

- 2.3.1.2.1 EM Digital Electronics Functional and Interface Tests
- 2.3.1.2.2 EM Analogue Electronics Functional and Interface Tests
- 2.3.1.2.3 EM Functional Tests and QLF I/F Check
- 2.3.1.2.4 EM EMC Tests
- 2.3.1.2.5 Instrument Hardware Design Review

2.3.2.1 QM Manufacture and Assembly

2.3.2.1.1 Provision of QM Digital electronics + OBS
2.3.2.1.2 Provision of QM Analogue Electronics
2.3.2.1.3 Provision of QM Structure
2.3.2.1.4 Provision of QM FTS Assembly
2.3.2.1.5 Provision of QM Optics
2.3.2.1.6 Provision of QM Cooler Assembly
2.3.2.1.7 Provision of QM Chopper
2.3.2.1.8 Provision of QM Calibration Source(s)
2.3.2.1.9 Provision of QM Focal Plane Arrays
2.3.2.1.10 Provision of QM Filters

2.3.2.2 QM Integration and Verification

2.3.2.2.1 QM Digital Electronics Functional and Interface Tests
2.3.2.2.2 QM Analogue Electronics Functional and Interface Tests
2.3.2.2.3 QM Mechanical Integration
2.3.2.2.4 QM Bakeout
2.3.2.2.5 QM Optical Alignment Check
2.3.2.2.6 QM FPU Integration
2.3.2.2.7 QM Thermal Balance Tests
2.3.2.2.8 QM Pre-Vibration Cold Functional Test
2.3.2.2.9 QM Pre-Vibration Performance Test
2.3.2.2.10 QM Qualification Vibration Test
2.3.2.2.11 QM Warm Electronics Vibration Test
2.3.2.2.12 QM QM Warm Electronics EMC Test
2.3.2.2.13 QM Post-VIbration Cold Functional Test
2.3.2.2.14 QM Post-Vibration Performance Test
2.3.2.2.15 QM Thermal Vacuum Test
2.3.2.2.16 Instrument Hardware Design Review

2.3.3.1 PFM Manufacture and Assembly

2.3.3.1.1 Provision of PFM Digital electronics + OBS
2.3.3.1.2 Provision of PFM Analogue Electronics
2.3.3.1.3 Provision of PFM Structure
2.3.3.1.4 Provision of PFM FTS Assembly
2.3.3.1.5 Provision of PFM Optics
2.3.3.1.6 Provision of PFM Cooler Assembly
2.3.3.1.7 Provision of PFM Chopper
2.3.3.1.8 Provision of PFM Calibration Source(s)
2.3.3.1.9 Provision of PFM Focal Plane Arrays
2.3.3.1.10 Provision of PFM Filters

2.3.3.2 PFM Integration and Verification

2.3.3.2.1 PFM Digital Electronics Functional and Interface Tests
2.3.3.2.2 PFM Analogue Electronics Functional and Interface Tests
2.3.3.2.3 PFM Mechanical Integration
2.3.3.2.4 PFM Bakeout
2.3.3.2.5 PFM Optical Alignment Check
2.3.3.2.6 PFM Optical Throughput Test
2.3.3.2.7 PFM FPU Integration
2.3.3.2.8 PFM Thermal Balance Checks
2.3.3.2.9 PFM Pre-Vibration Cold Functional Test
2.3.3.2.10 PFM Pre-Vibration Performance Test
2.3.3.2.11 PFM Acceptance Vibration Test
2.3.3.2.12 PFM Warm Electronics Vibration Test
2.3.3.2.13 PFM Warm Electronics EMC Test
2.3.3.2.14 PFM Post-VIbration Cold Functional Test
2.3.3.2.15 PFM Post-Vibration Performance Test
2.3.3.2.16 PFM Calibration
2.3.3.2.17 PFM Thermal Vacuum Test
2.3.3.2.18 Instrument Critical Design Review

2.3.4.1 FS Manufacture and Assembly

2.3.4.1.1 Provision of FS Digital electronics + OBS
2.3.4.1.2 Provision of FS Analogue Electronics
2.3.4.1.3 Provision of FS Structure
2.3.4.1.4 Provision of FS FTS Assembly
2.3.4.1.5 Provision of FS Optics
2.3.4.1.6 Provision of FS Cooler Assembly
2.3.4.1.7 Provision of FS Chopper
2.3.4.1.8 Provision of FS Calibration Source(s)
2.3.4.1.9 Provision of FS Focal Plane Arrays
2.3.4.1.10 Provision of FS Filters

2.3.4.2 FS Integration and Verification

2.3.4.2.1 FS Digital Electronics Functional and Interface Tests
2.3.4.2.2 FS Analogue Electronics Functional and Interface Tests
2.3.4.2.3 FS Mechanical Integration
2.3.4.2.4 FS Bakeout
2.3.4.2.5 FS Optical Alignment Check
2.3.4.2.6 FS Optical Throughput Test
2.3.4.2.7 FS FPU Integration
2.3.4.2.8 FS Thermal Balance Checks
2.3.4.2.9 FS Pre-Vibration Cold Functional Test
2.3.4.2.10 FS Pre-Vibration Performance Test
2.3.4.2.11 FS Acceptance Vibration Test
2.3.4.2.12 FS Warm Electronics Vibration Test
2.3.4.2.13 FS Warm Electronics EMC Test
2.3.4.2.14 FS Post-VIbration Cold Functional Test
2.3.4.2.15 FS Post-Vibration Performance Test
2.3.4.2.16 FS Calibration
2.3.4.2.17 FS Thermal Vacuum Test

2.4 Test and Calibration Preparation

2.4.1 AIV Preparation
2.4.2 Calibration Preparation
2.4.3 Test Team

3.1 Management

- 3.1.1 Support to ESA
- 3.1.2 Control and maintenance of ICC Schedule
- 3.1.3 Product Assurance
- 3.1.4 Team Setup and Management

3.2 Instrument Operations

- 3.2.1 Provision of Instrument Users Manual
- 3.2.2 Provision of Instrument Database
- 3.2.3 Provision of Calibration Database
- 3.2.4 Definition of Instrument Observations ⇒
- 3.2.5 Definition of Operating Procedures

3.2.4 Definition of Instrument Observations

- 3.2.4.1 Definition of Instrument Modes
- 3.2.4.2 Definition of AOTs
- 3.2.4.3 Implementation of AOTs

3.3 Software Development

- 3.3.1 Provision of Instrument Time Estimator
- 3.3.2 Provision of Instrument Command Translator
- 3.3.3 Provision of RTA/QLA
- 3.3.4 Provision of Trend Analysis System
- 3.3.5 Provision of Calibration Analysis System
- 3.3.6 Provision of Interactive Analysis System
- 3.3.7 Provision of Science Processing Software
- 3.3.8 Provision of Science Analysis Software
- 3.3.9 Provision of Diagnostic Tools

3.4 ICC Preparation

- 3.4.1 ICC Planning ⇒
- 3.4.2 ICC Implementation ⇒
- 3.4.3 Integration and Test ⇒
- 3.4.4 FINDAS Support
- 3.4.5 Operations Planning ⇒
- 3.4.5 Training ⇒

3.4.1 ICC Planning

- 3.4.1.1 Provision of SIP
- 3.4.1.2 Definition of PV Phase Test Plan
- 3.4.1.3 Provision of Science Validation Plan
- 3.4.1.4 ICC Design

3.4.2 ICC Implementation

- 3.4.2.1 ICC Infrastructure ⇒
- 3.4.2.2 ICC Hardware ⇒
- 3.4.2.3 Commissioning Phase System
- 3.4.2.4 Provision of Instrument Simulator
- 3.4.2.5 Provision of OBS Maintenance Facility

3.4.2.1 ICC Infrastructure

- 3.4.2.1.1 ICC Ops centre Infrastructure
- 3.4.2.1.2 DAPSAS(UK) Infrastructure
- 3.4.2.1.3 DAPSAS(Fr) Infrastructure

3.4.2.2 ICC Hardware

- 3.4.2.2.1 ICC Ops Centre Hardware
- 3.4.2.2.2 DAPSAS(UK) Hardware
- 3.4.2.2.3 DAPSAS(Fr) Hardware

3.4.3 Integration and Test

- 3.4.3.1 ICC Ops centre Integration and Test
- 3.4.3.2 DAPSAS(UK) Integration and Test
- 3.4.3.3 DAPSAS(Fr) Integration and Test
- 3.4.3.4 ICC Internal Interface Test
- 3.4.3.5 ICC Ops Test
- 3.4.3.6 Ground Segment Testing

3.4.5 Operations Planning

- 3.4.5.1 Provision of ICC Operations Plan
- 3.4.5.2 Definition of ICC Operations Procedures
- 3.4.5.3 Definition of ICC/FSC Operational I/Fs
- 3.4.5.4 Definition of ICC/MOC Operational I/Fs

3.4.6 Training

- 3.4.6.1 ICC Ops Team Training
- 3.4.6.2 FSC and MOC Training
- 3.4.6.3 DAPSAS(UK) Training
- 3.4.6.4 DAPSAS(Fr) Training

4.1 Management

- 4.1.1 Operations Management
- 4.1.2 Product/Quality Assurance

4.2 Software Maintenence

- 4.2.1 OBS Maintenance
- 4.2.2 ICC Software Maintenance
- 4.2.3 Science Processing Software ⇒
- 4.2.4 Science Analysis Software ⇒

4.2.3 Science Processing Software

- 4.2.3.1 Update SPS
- 4.2.3.2 SPS Acceptance Testing
- 4.2.3.3 SPS Validation
- 4.2.3.4 SPS Delivery to FSC

4.2.4 Science Analysis Software

- 4.2.4.1 Update SAS
- 4.2.4.2 SAS Acceptance Testing
- 4.2.4.3 SAS Validation
- 4.2.4.4 SAS Delivery to FSC

4.3 ICC Operations

- 4.3.1 Support to MOC
- 4.3.2 Support to FSC
- 4.3.3 Health and Status Monitoring
- 4.3.4 Performance Monitoring
- 4.3.5 Calibration
- 4.3.6 Trend Analysis
- 4.3.7 Science Processing Quality Checking
- 4.3.8 Performance Maintenance
- 4.3.9 Ground Segment Interaction
- 4.3.10 Parallel Mode Analysis
- 4.3.11 Serendipity Mode Analysis
- 4.3.12 Support to the Community ⇒
- 4.3.13 Consortium Support to the ICC

4.3.12 Support to theCommunity

- 4.3.12.1 Consortium Support
- 4.3.12.2 National Community Support

4.4 Facilities Maintenance

- 4.4.1 Infrastructure Maintenance
- 4.4.2 Hardware Maintenance
- 4.4.3 System Mangement

10.3 INTERFACE CONTROL

The Systems Engineering team will be responsible for definition of all the technical requirements, including interfaces, for each sub-system and equipment for the SPIRE. Within the Systems Team will be a Hardware Systems Engineer who will co-ordinate, manage and control all internal and external interfaces via an interface panel.

Each major sub-system and equipment supplier will nominate an Interface Engineer who's responsibility will be to attend interface panels and assist and negotiate with the Systems Engineer on all interface matters relating to his/hers sub-system.

Under the leadership of the Systems Engineer, it is the goal of the interface panel to achieve frozen technical interface requirements consistent with schedule design activities. Prior to project kick-off an Interface Exchange Plan will be issued which identifies the various interface items with required freeze dates, these dates will be overlaid onto the programme schedule as Interface exchange dates. It will be the responsibility of each Interface Engineer to ensure that the interface exchange data that he or she is responsible for is delivered on time. All interface data should be frozen at the start of QM manufacture.

For each separate sub-system or major equipment there will be an Interface Requirements Document. This document contains and defines all relevant interface data for design purposes. As various interface data is agreed it should be reflected in the Interface Requirements Document and signed by all relevant parties (Systems Engineer, Equipment/Sub-System Interface Engineer and ESA for external Interfaces.

10.4 REVIEWS

The following instrument reviews have been defined to achieve the aims of the reviews identified in the IID part A, taking into account the current model philosophy including provision of an Electrical Model and no Engineering Model. They follow the standard review stages for hardware development;

Instrument Preliminary Design Review
Held at the end of the instrument system design phase
Purpose:

- To verify that the instrument system design fulfills the instrument scientific requirements.
- To assess whether the instrument design will meet the instrument engineering requirements.
- To approve the instrument system interfaces and budgets.
- To approve the Interface Control Plan
- To approve the on-board software User’s Requirements Documents.

Tasks:

- To review the instrument scientific requirements.
- To review the instrument system design.

- To review the instrument engineering requirements.
- To review the instrument system interfaces and budgets.
- To review the instrument subsystems design concepts.
- To review the Interface Control Plan.
- To review User's Requirements Documents for the Digital Processing Unit and the Signal Processing Unit software.

Instrument Critical Design Review
Held at the end of the instrument detailed design phase
Purpose:

- To verify the instrument design fulfills the instrument engineering requirements and release for manufacture of the Electrical Model and Qualification Model.
- To approve the on-board software Software Specification Documents.

Tasks:

- To review the instrument system design.
- To review the instrument subsystems designs.
- To review the Software Specification Documents for the Digital Processing Unit and the Signal Processing Unit software.

Electrical Model Delivery Review
Held at the end of the instrument Electrical Model AIV phase
Purpose:

- To accept the instrument Electrical Model for delivery to ESA for integration into the spacecraft Electrical Model
- To approve the Instrument Users' Manual (Draft)

Tasks:

- To review the results of the Electrical Model instrument-level tests.
- To review the Electrical Model delivery documentation.
- To review the Instrument Users' Manual (Draft).

Qualification Model Delivery Review
Held at the end of the instrument Qualification Model AIV phase.
Purpose:

- To accept the Qualification Model for delivery to ESA for system-level testing.
- To verify the instrument design as qualified and to approve the release for manufacture of the Proto-Flight Model.
- To approve the Instrument Users' Manual (Issue 1)

Tasks:

- To review the results of the instrument Electrical Model system-level tests.
- To review the results of the Qualification Model instrument-level tests..
- To review the Qualification Model delivery documentation.
- To review the results of the Qualification Model instrument-level qualification testing.
- To review the Instrument Users' Manual (Issue 1)

Flight Model Delivery Review
Held at the end of the Flight Model instrument-level AIV phase.
Purpose:

- To accept the instrument Flight Model for delivery to ESA for integration on the spacecraft.
- To accept the Instrument Users' Manual for delivery to ESA.

Tasks:

- To review the results of the Qualification Model system-level tests.
- To review the results of the Flight Model instrument-level tests .
- To review the results of the Flight Model calibration.
- To review the Flight Model delivery documentation.
- To review the Instrument Users' Manual (Issue 2).

Flight Spare Model Delivery Review

Held at the end of the Flight Spare Model instrument-level AIV phase.

Purpose:

- To accept the instrument Flight Spare Model for delivery to ESA.

Tasks:

- To review the results of the Flight Spare Model instrument-level tests .
- To review the results of the Flight Spare Model calibration.
- To review the Flight Spare Model delivery documentation.

10.5 SCHEDULE

TBD