SPIRE

SUBJECT:	**INSTRUMENT REQUIREMENTS DOCUMENT**		
PREPARED BY:	**Bruce Swinyard (Custodian)** **Ken King**		
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CHECKED BY:	**Berend Winter (MSSL)**	**Date:**	**…………………………..**
	Dominique Pouliquen (LAM)	**Date:**	**…………………………..**
	Peter Hargrave (QMW)	**Date:**	**…………………………..**
	Lionel Duband (CEA)	**Date:**	**…………………………..**
	Jamie Bock (JPL)	**Date:**	**…………………………..**
	Jean-Louis Augueres (CEA)	**Date:**	**…………………………..**
	Riccardo Cerulli-Irelli (IFSI)	**Date:**	**…………………………..**
	Gary Davis (USK)	**Date:**	**…………………………..**
	Hans-Goran Floren (Stockholm)	**Date:**	**…………………………..**
APPROVED BY:	**Matt Griffin**	**Date:**	**…………………………..**
	Ken King	**Date:**	**…………………………..**
	Laurent Vigroux	**Date:**	**…………………………..**
	Colin Cunningham	**Date:**	**…………………………..**
		Date:	**…………………………..**

Distribution

Matt Griffin	**Principal Investigator (QMW)**
Laurent Vigroux	**Co-Principal Investigator (CEA)**
Walter Gear	**Project Scientist**
Jean-Paul Baluteau	**Project Scientist**
Ken King	**Project Manager (RAL)**
Bruce Swinyard	**Instrument Scientist (RAL)**
Colin Cunningham	**FPU Systems Engineer (ATC)**
Jean-Louis Augueres	**CEA(Saclay)**
Lionel Duband	**CEA (Grenoble)**
Don Jennings	**GSFC**
Jamie Bock	**JPL/Caltech**
Jason Glenn	**University of Colorado**
Dominique Pouliquen	**LAM**
Berend Winter	**MSSL**
Kjetil Dohlen	**LAM**
Peter Hargrave	**QMW**
Gary Davis	**USK**
David Smith	**RAL**
Hans-Goran Floren	**Stockholm**
Riccardo Cerulli-Irelli	**IFSI**
Anna Di Giorgio	**IFSI**

Change Record

ISSUE	DATE	
1	2 July 1999	First proper issue just prior to PDR
2	September 1999	Radically re-arranged separate instrument and sub-system reqs.
2-1	November 1999	Updated following comments from Berend Winter – this issue sent out for Warm Electronics Review
3	May 2000	Revised following detector selection. Removed extraneous information that is better covered in other documents. Revised organisation of document and removed redundant requirements and renumbered some of the sub-systems requirements. Added simulator requirements Re-integrated Warm Electronics requirements
31	25 May 2000	Official release following comments on version 3. Changes made to requirements on WE testing to bring into line with development plans. Block diagram changed to put shutter electronics into DRCU Change made to cooler requirements to include parasitic load from 4-2 K via structure and heat switches.

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1. INTRODUCTION

1.1 Purpose

This document describes the capabilities required of the SPIRE instrument and the constraints placed upon its design and operation in the context of the FIRST mission.

The instrument requirements are derived from the scientific requirements placed on the instrument in the SPIRE Science Requirements Document (SRD); the constraints imposed upon the instrument design by the satellite interface specification as detailed in the Instrument Interface Document parts A and B (IID-A and IID-B) and the operational constraints on the instrument design given in the FIRST/Planck Operations Interface Requirements Document (OIRD).

This document goes beyond the general instrument level requirements to place specific requirements on individual sub-systems within the context of the instrument design specification. It thus forms the starting point for the SPIRE sub-system specification documents that will be written for each SPIRE sub-system.

The requirements set out in this document will be used to verify the performance of the instrument during instrument level Assembly, Integration and Verification (AIV). The sub-system requirements will be used as the bench mark for sub-system acceptance at instrument level.

1.2 Scope

This documents deals with the requirements on the SPIRE instrument hardware and software from the optical input from the FIRST telescope through to the interfaces with the spacecraft. It does not deal with the requirements on the SPIRE Instrument Control Centre or any other part of the instrument ground segment.

1.3 Glossary

AIV	Assembly Integration and Verification
AOCS	Attitude and Orbit Control System
ASIC	Application Specific Integrated Circuit
AVM	Avionics Model
BSM	Beam Steering Mechanism
CDMS	Command and Data Management System (on Spacecraft)
CQM	Cryogenic Qualification Model
CVV	Cryostat Vacuum Vessel
DCRU	Detector Control and Readout Unit
DPU	Digital Processing Unit
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
FINDAS	FIRST Integrated Network and Data Archive System
FOV	Field of View
FPU	Focal Plane Unit
FS	Flight Spare
FTS	Fourier Transform Spectrometer

HIFI	
IID-A	Instrument Interface Document part A
IID-B	Instrument Interface Document part B
JFET	Junction Field Effect Transistor
MGSE	Mechanical Ground Support Equipment
NEP	Noise Equivalent Power
OBDH	On Board Data Handling (on Spacecraft)
OGSE	Optical Ground Support Equipment
OPD	Optical Path Difference
PACS	
PDU	Power Distribution Unit (on spacecraft)
PFM	Proto-Flight Model
PLM	Payload Module
QLF	Quick Look Facility
S/C	Space Craft
SPIRE	Spectral and Photometric Imaging Receiver
SRD	Science Requirements Document
SVM	Service Module
TBD	To Be Determined
TBC	To Be Confirmed

Table A: Glossary of acronyms and abbreviations

1.4 References

Where there are differences in requirements or specification details, the applicable and reference documents enumerated here take precedence over the Instrument Requirements Document. This is particularly the case with the IID-A and IID-B which will contain the interface specification between the SPIRE instrument and the FIRST satellite.

1.4.1 Applicable Documents

Document Reference	Name	Number/version/date
AD1	FIRST/Planck Instrument Interface Document Part A (IID-A)	PT-IID-A-04624 Issue-Version 0-2 (working copy) 15 February 2000 SPIRE-ESA-DOC-000178
AD2	SPIRE Scientific Requirements Document (SRD)	Version 0.2 29 March 1999 SPIRE-UCF-DOC-000064
AD3	FIRST/PLANCK Operations Interface Requirements Document (FOIRD)	SCI-PT-RS-07360 Draft 5 03 May 2000 SPIRE-ESA-DOC-000188
AD4	FIRST Science Operations Implementation Requirements Document (SIRD)	PT-03646 Draft 3 30 September 1997 SPIRE-ESA-DOC-000198
AD5	FIRST/Planck Instrument Interface Document Part B	PT-SPIRE-02124 Issue-Rev.

	(IID-B) Instrument "SPIRE"	No. 0-2 01 August 1999 SPIRE-ESA-DOC-000275

Table B: Applicable Documents
The abbreviations in brackets are used throughout the present document.

1.4.2 Reference Documents

Document Reference	Name	Number/version
RD1	FIRST L-2 Radiation Environment	esa/estec/wma/he/FIRST/3 04 March 1997 SPIRE-ESA-NOT-000401
RD2	FIRST Telescope Specification	PT-RQ-04761 Issue 1/A January 1998 SPIRE-ESA-DOC-000195
RD3	ESA Packet Utilisation Standard	ESA-PSS-07-101 Issue 1 May 1994 SPIRE-ESA-DOC-000243
RD4	FIRST Satellite System Specification	PT-SP-00211 Issue 2 11 June 1997 SPIRE-ESA-DOC-000277
RD5	The document that describes the FIRST Orbit if this isnt the one above……	??
RD6	Fax from T. Passvogel 5/10/1998 – I think this is now in the IID-A	PT-05908
RD7	SPIRE Optics Alignment Requirements (title TBD – not written)	
RD8	FIRST Instrument I/F Study Final Report	FIRST-GR-B0000.009 Issue 1 02 February 2000 SPIRE-REF-DOC-000417
RD9	SPIRE Instrument AIV Plan	SPIRE-RAL-DOC-000410 Draft, 25 May 2000

Table C: Reference documents
The abbreviations in brackets are used throughout the present document.

1.5 Document Overview

The context within which the SPIRE instrument is to be operated and for which it is designed is outlined in section 2.1 together with an outline description of the conceptual design of the instrument. The requirements placed on the instrument performance in the Science Requirements Document are enumerated in section 2.2 and the requirements placed on the operation of the instrument in order to meet the scientific requirements are described in section 2.3. Sections 2.4-2.7 give the requirements placed upon the instrument design by the satellite launch and operations environments.

In chapter 3 the specific requirements placed on each sub-system of the SPIRE instrument are detailed. This starts from the generic requirements on all sub-systems for qualification and verification in sections 3.1 and 3.2. Each sub-system is then taken in turn, starting with the cold focal plane unit and ending with the warm electronics.

The details of various aspects of the qualification tests and the expected mass, power and thermal dissipation budgets available for the various sub-systems are given in the appendices.

2. INSTRUMENT AND SATELLITE LEVEL REQUIREMENTS

2.1 General Description

2.1.1 Instrument Description

SPIRE (Spectral & Photometric Imaging REceiver) is a bolometer instrument comprising a three-band imaging photometer covering the 200-600 µm range and an imaging Fourier Transform Spectrometer (FTS) with a spectral resolution of at least 0.4 cm^{-1} (corresponding to $\lambda/\Delta\lambda = 100$ at 250 µm), covering wavelengths between 200 and 670 µm. The detectors are bolometer arrays cooled to 300 mK using a ^{3}He refrigerator. The photometer is optimised for deep photometric surveys, and can observe simultaneously the same field of view of at least 4 x 4 arcminutes in all three bands.

2.1.2 Mission Context

SPIRE is one of three instruments to be placed on board the ESA Far InfraRed and Submillimetre Telescope (FIRST) satellite. This mission is dedicated to astronomical observations in the 85 to 700 µm waveband.

The FIRST satellite provides a 3.5 m telescope for receiving and imaging the FIR and submillimetre radiation from astronomical sources. The three instrument Focal Plane Units (FPUs) share the 0.25 degree focal plane of the FIRST telescope and each instrument provides re-imaging optics to take its the portion of the focal plane onto its detectors. The signals from the SPIRE instrument are, after suitable conditioning and conversion to digital format, sent to the ground via the spacecraft Command and Data Management System (CDMS).

In order to prevent the instrument detectors being swamped by self emission, the FPUs are located in the FIRST cryostat. This is a liquid helium (LHe) cryostat providing various temperature levels, the lowest of these is the super-fluid LHe tank at 1.7 K. There are also two cold gas vent lines – the actual temperatures these provide are dependent on the details of the instrument thermal dissipation and the cryostat design (see section 2.1.4.1). The three instrument FPUs mechanically interface to the cryostat via a common optical bench with separate thermal straps to the cryostat. The signal conditioning "warm electronics" units will be placed on the satellite service module (SVM). The electrical connections between the warm electronics and the cold FPU are made through a cryo-harness that will be provided as part of the satellite system.

The FIRST mission will be controlled from the Mission Operations Centre (MOC) via a remote ground station. The SPIRE instrument will be controlled from the SPIRE Instrument Control Centre (ICC) which communicates to the MOC via the FIRST Integrated Network and Data Archive System (FINDAS). The FIRST observers will interface to the mission via the FIRST Science Centre (FSC) which also communicates to the MOC via FINDAS.

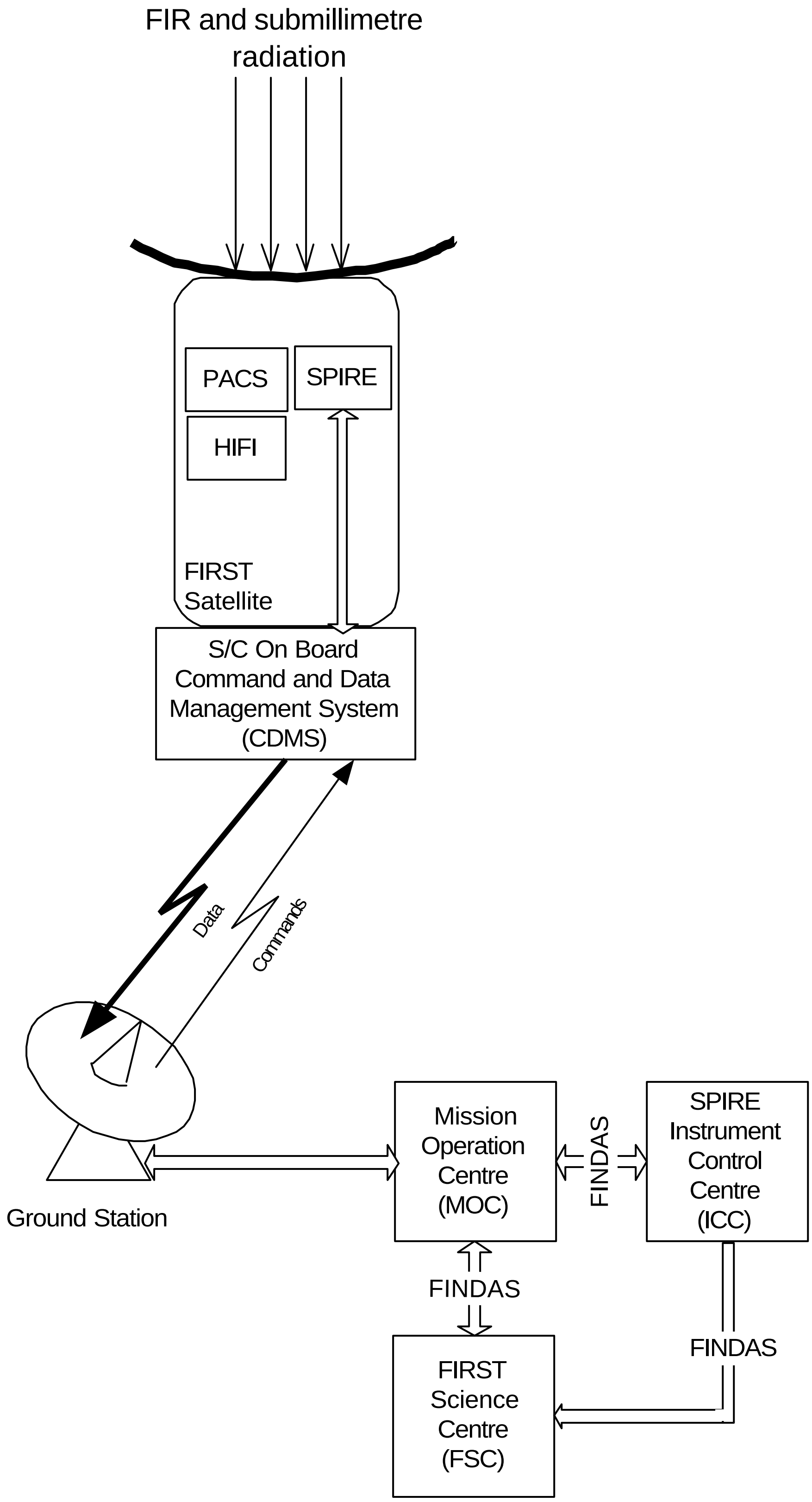


Figure 2-1: The FIRST Mission showing the communication between the various elements

2.1.3 Definition of Instrument Elements and Instrument Location

The SPIRE instrument consists of several "units" as defined in the IID-B and recapitulated in table 2.1-1 together with brief descriptions of their functions and their locations on the FIRST satellite. These are subject to revision as the detailed design of the instrument proceeds but are given here for reference.

Instrument unit	**Function**	**ESA code**	**Location**
Cold Focal Plane Unit (FPU)	Contains the optics; mechanisms and detectors.	FSFPU	On FIRST optical bench inside cryostat
Focal plane JFET box (FTB)	This unit contains the cold read-out electronics for the NTD germanium bolometers.	FSFTB	On FIRST optical bench inside cryostat
Detector Read-out and Control Unit (DRCU)	This warm electronics unit contains the circuitry necessary to read-out the detectors; control the various mechanisms and provide instrument control and data handling functions	FSDRC	On spacecraft service module (SVM)
Digital Processing Unit (DPU)	This warm electronics unit provides the instrument interface to the S/C CDMS sub-system; receives and interprets instrument commands and formats the instrument data for telemetry to the ground	FSDPU	On SVM
Warm interconnect harnesses (HARNESS)	This connects the warm electronics units.	FSHAR	On SVM

Table 2.1-1: Definition and location of the elements of the SPIRE instrument.

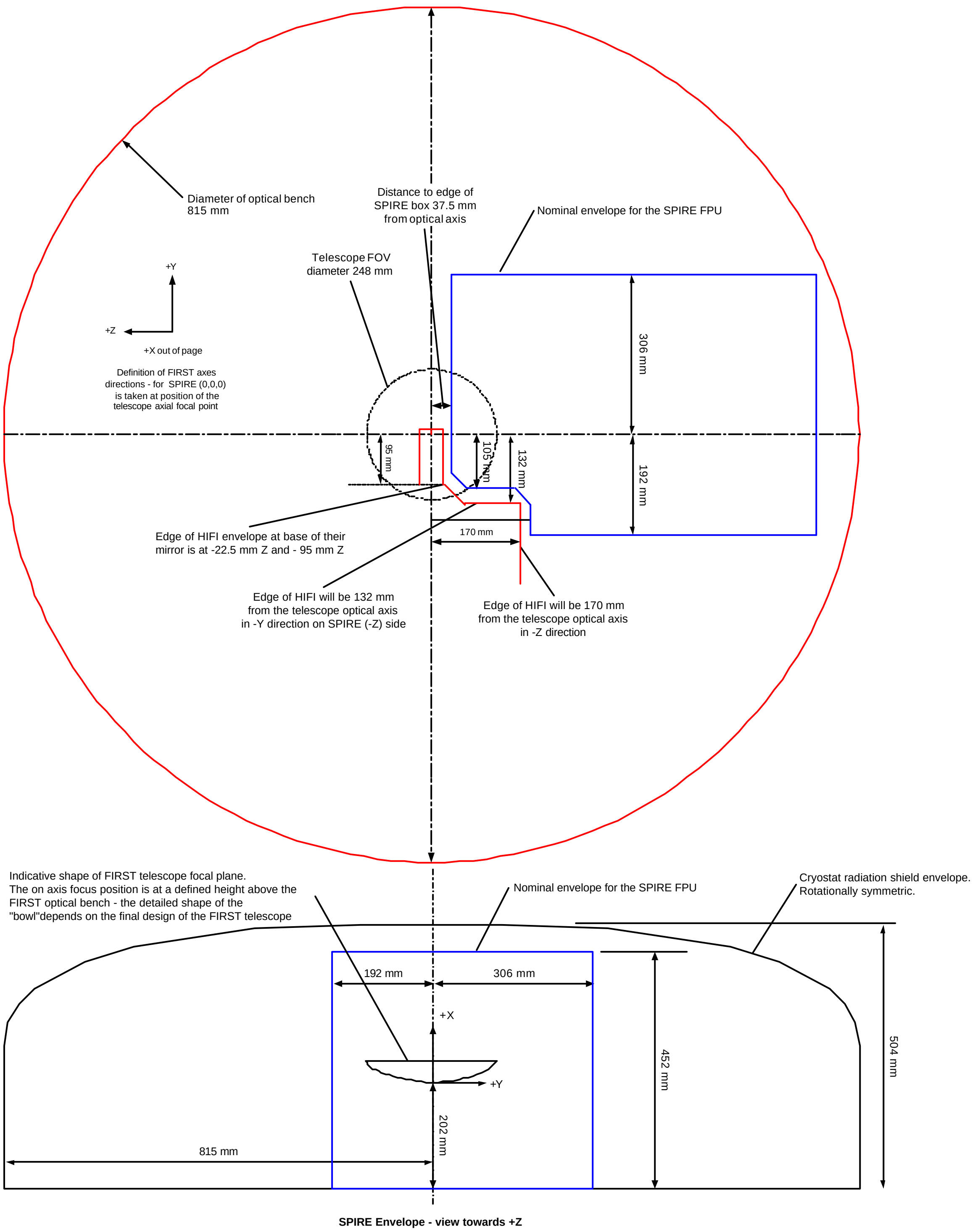


Figure 2-2: Cold FPU location and envelope constraints in the FIRST cryostat. The cryostat cover is rotationally symmetric and defines the X-Z envelope of the instrument box as well (not shown). The details of the box shape are subject to revision as the design evolves and the instrument dimensions are for illustrative purposes only.

2.1.3.1 Satellite Level Constraints and Assumptions

The specification and capabilities of the FIRST satellite are given in RD5 and the IID-A. As these two documents are under review and are unlikely to be finalised in the near term, the assumptions that should be made about the FIRST satellite for the purposes of the SPIRE instrument requirements are described in this section.

2.1.3.2 FIRST Cryostat

The thermal behaviour of the FIRST cryostat will be complex and depends btoh on its final design and that of the instruments. The results of a study into the expected temperatures that will be provided by the FIRST cryostat (RD8) shows that the temperatures of the three thermal interfaces are as given in table 2-2.

Description	Cooling Method and Comments	Nominal Temperature
LHe tank "Level 0"	The pumped LHe will be super-fluid and provide a very large thermal sink	1.7 K
Helium Vent Line "Level 1"	Cooled by cryostat boil off gas – temperature will depend on rate of boil off and instrument dissipation	5.2 K
Helium Vent Line "Level 2"	Strapped to helium gas vent line after level 1 connection. That is the temperature of the gas will depend on the thermal dissipation from the instruments at level 1.	11 K

Table 2-2: Temperature stages available from the FIRST cryostat.

The permissible dissipation from the FPU at the various temperatures is TBD but is likely to be no more than a few 10's mW total. An illustration of the expected levels of dissipation is given in the SPIRE Sub-system Budget Allocation (AD5).

The FIRST cryostat defines the available space envelope for the instruments. The SPIRE envelope is further restricted by the neighbouring HIFI instrument. Figure 2-2 shows the approximate location of the SPIRE instrument, the definition of the spacecraft axes and the available space envelope. The shape of the FIRST cryostat cover that defines the cold FPU space envelope is given in RD6 and repeated in table 2-3 for completeness.

X (mm)	Y (mm)	Z (mm)
0	0	815
271	0	815
315	0	807
350	0	787
379	0	758
431	0	662
461	0	563
497	0	337
504	0	135

Table 2-3: Dimensions of the FIRST cryostat shield that defines the envelope for the instruments. The shield is rotationally symmetric and, when this definition was provided, the hole in the top had a radius of 135 mm. This is subject to revision depending on the detailed design of the telescope.

2.1.3.3 Warm Electronics Power

The SPIRE instrument has requested up to 181 W total (see IID-B). How much power is actually available for the instruments is not defined at present.

2.1.3.4 Telemetry Rates

The average telemetry rate available to each instrument over the operational cycle of the FIRST satellite is 100 kbps.

2.1.3.5 FIRST Telescope

The FIRST telescope defines the optical "environment" in which the SPIRE instrument has to operate. In particular the field of view; the plate scale and speed of the beam. The current specification for the FIRST telescope is given in the 'FIRST Telescope Specification' (RD3). It is base lined as having the following optical specification:

Primary mirror diameter: 3.5 m
Focal length: 28.5 m
Focal Ratio: f/8.68
Back focal length: 975 mm – defined from the primary vertex
Field of view: circular - radius 0.25 degrees
Height of on-axis focus above optical bench: 202 mm
Plate scale: 7.237 arcsec/mm
Diameter of unvignetted field of view at the focal plane: 248.7 mm

The f/number of the primary and, therefore, the size of the secondary have not been finally decided. The telescope design is under review and the precise optical description is not finalised. I think this is finished – where is it documented? May 2000

2.1.3.6 Pointing

The pointing capabilities of the FIRST satellite are given in AD1 and RD5. The satellite has a requirement to "blind point" to within 3.7 arcsec and a goal to do this within 1.5 arcsec. Both these figures are 1-sigma values and are referred to the optical axis. If the goal is not achieved then a "peak-up" operation mode may be required.

The satellite has the ability to perform both pointed raster observations and fast scans across the sky. For the raster mode the relative accuracy between pointings will be better than 0.5 arcsec. In scan mode the satellite can be scanned over a large angular range from 0.1 arcsec/sec to 60 arcsec/sec with a resolution of 0.1 arcsec/sec. The satellite can be scanned from 1 arcmin to 110 degrees with a resolution of 1 arcmin. This mode can be used in "line scan" to build up maps of large areas of the sky.

The satellite can be nodded from one position to another with a duty cycle of at least 80% for a throw of 5 arcmin with a dwell time of 72 seconds at each position. The details of any actual SPIRE specific requirement on the nodding capability of the satellite are to be determined.

2.1.3.7 Launch Environment

The satellite will be launched on an Ariane V from Kourou. The expected environment is specified in the IID-A.

The cold FPU and JFET box (FTB) will be launched in vacuum and at cryogenic temperatures. The warm electronics units will be launched at ambient temperatures and atmospheric pressure.

2.1.3.8 Orbit

The FIRST satellite will be placed into a Lissajous orbit around the L2 libation point 1.5×10^6 km from the Earth on the Earth-Sun line. (Reference document?- May 2000)

2.1.3.9 Mission Lifetime

The expected mission lifetime is 4.25 years. This should be the figure used for estimation of number of operations and reliability of SPIRE sub-systems and the corresponding life tests that will be required.

2.1.3.10 Radiation environment

RD2 gives calculated fluence and doses for the mission. The integrated dose for silicon behind 2 mm of aluminium is estimated at 12 kRad and behind 5 mm of aluminium as 3.5 kRad. These figures will be taken as the radiation tolerance for components in the warm electronics boxes and inside the cryostat respectively (TBC).

2.1.3.11 Operational Environment

In normal operations the satellite is expected to have a 24-hour operational cycle with data being collected autonomously for 21 hours and a 3 hour ground contact period – the Data Transfer and Commanding Period (DTCP). During the DTCP the data will be telemetered to the ground and the commands for the next 24-hour period will be uplinked.

This operational environment requires the instrument to undertake autonomous health and safety monitoring and to be capable of reacting to safety critical situations in real time to prevent damage to the instrument. It is expected that some health and safety tasks will be undertaken by the satellite CDMS.

It is expected that the observing schedule will be carried out as a series of fixed time operations. It is also expected that the satellite CDMS will store the instrument commands and provide the commands at the appropriate time intervals to the instrument to carry out the fixed time observation schedule. This implies that the instrument does not need to store a large number of commands or to know the absolute time a command should be executed.

2.2 Instrument Level Requirements

2.2.1 Photometer Requirements

The basic scientific requirements for the SPIRE photometer are described in the SRD (AD2). The predicted instrument sensitivities, based on the current instrument design assumptions, and which are compatible with the scientific requirements, are given in Table 2.2-1. The assumptions used in the calculation of the sensitivities are given in the IID-B (RD1) Chapter 4.

		Wavelength Range			
Requirement ID	**Description**	**250 mm**	**350 mm**	**500 mm**	**Reference**
IRD-PHOT-R01	Nominal passband ($\lambda/\Delta\lambda$)	3	3	3	IID B Chap 4
IRD-PHOT-R02	Field of View (Arcmin) Req. Goal	4 x 4 4 x 8	4 x 4 4 x 8	4 x 4 4 x 8	IID B Chap 4
IRD-PHOT-R03	Beam FWHM (Arcsec)	18 (TBC)	25 (TBC)	36 (TBC)	IID B Chap 4
IRD-PHOT-R04	Point source sensitivity 1 σ -1 sec (mJy) 1 σ -1 hr (mJy)	34 (TBC) 0.6 (TBC)	35 (TBC) 0.6 (TBC)	41 (TBC) 0.7 (TBC)	IID B Chap 4
IRD-PHOT-R05	Mapping sensitivity for one FOV 1 σ -1 hr (mJy)	1.4 (TBC)	1.5 (TBC)	1.9 (TBC)	IID B Chap 4

Table 2.2-1: Summary of Photometer scientific requirements and sensitivities

In addition to the basic requirements, the SRD specifies “design” drivers and goals for the photometer design – these are described in Table 2.2-2.

Requirement ID	**Description**	**Reference**
IRD-PHOT-R06	Maximising 'mapping speed' at which confusion limit is reached over a large area of sky is the primary science driver. This means maximising sensitivity and field-of-view (FOV) but NOT at the expense of spatial resolution.	SRD Appendix item A1
IRD-PHOT-R07	Filling the FOV at three wavebands is more important than having more wavelength channels	SRD Appendix item A2
IRD-PHOT-R08	Chopping is highly undesirable for confusion-limited deep survey observations	SRD Appendix item A3
IRD-PHOT-R09	Small-scale "jiggling" or "micro-stepping" is essential.	SRD Appendix item A4
IRD-PHOT-R10	Field distortion must be <10% across the FOV	SRD Appendix item A5
IRD-PHOT-R11	Electrical crosstalk should be <0.4% between nearest-neighbour pixels and <0.05% between all other pixels. Achieving this goal would result in crosstalk being dominated by the telescope surface errors. This may not be achievable	SRD Appendix item A6

Requirement ID	Description	Reference
	in practice.	
IRD-PHOT-R12	NEP variation should be < 10% across each array.	SRD Appendix item A7
IRD-PHOT-R13	Instantaneous dynamic range should be > 12 bits.	SRD Appendix item A8
IRD-PHOT-R14	Absolute photometric accuracy should be ~10%.	SRD Appendix item A9
IRD-PHOT-R15	Detector linearity should be less than or calibratable to less than 10% across the full dynamic range of SPIRE, including any gain ranges.	SRD Appendix item A10
IRD-PHOT-R16	If the feedhorn arrays are selected then the three arrays need to be co-aligned to within 1 arcsecond.	SRD Appendix item A11

Table 2.2-2: Summary of Photometer design drivers from the SPIRE Science Requirements Document.

2.2.2 Spectrometer Requirements

The basic scientific requirements for the SPIRE FTS are described in the SRD. The predicted instrument sensitivities, based on the current instrument design assumptions, and which are compatible with the scientific requirements, are given in Table 2.2-3. The assumptions used in the calculation of the sensitivities are given in the IID-B Chapter 4.

Requirement ID	Description	Value	Reference
IRD-SPEC-R01	Wavelength range: Band A Band B	 200 – 300 μm (TBC) 300 – 700 μm (TBC)	IID B Chap 4
IRD-SPEC-R02	Maximum Resolution (cm^{-1}) Req. Goal	 0.4 0.04	IID B Chap 4
IRD-SPEC-R03	Minimum Resolution (cm^{-1}) Req. Goal	 2 4	IID B Chap 4
IRD-SPEC-R04	Field of View (Arcmin)	 2.6 diameter circular for feedhorns	IID B Chap 4
IRD-SPEC-R05	Beam FWHM (Arcsec) Band A (250 ? m) Band B (350 ? m)	 18 (TBC) 25 (TBC)	IID B Chap 4
IRD-SPEC-R06	Point source continuum sensitivity (mJy; 1 σ -1 hr; 0.4 cm^{-1} resolution) Point source unresolved line sensitivity	 Band A 200-300 μm 47 (TBC) Band B 300-400 μm 43 (TBC) Band B 400-700 μm TBD Band A 200-300 μm 5.6×10^{-18} (TBC)	IID B Chap 4

Requirement ID	Description	Value	Reference
	(W m^{-2}; 1 σ -1 hr)	Band B 300-400 μm 5.1 x 10^{-18} (TBC) Band B 400-700 um TBD	
IRD-SPEC-R07	Map continuum sensitivity (mJy; 1 σ -1 hr; 0.4 cm^{-1} resolution) Map line sensitivity (W m^{-2}; 1 σ -1 hr)	Band A 200-300 μm 108 (TBC) Band B 300-400 μm 104 (TBC) Band B 400-700 μm TBD Band A 200-300 μm 1.3 x 10^{-17} (TBC) Band B 300-400 μm 1.3 x 10^{-17} (TBC) Band B 400-700 μm TBD	IID B Chap 4

Table 2.2-3: Summary of Spectrometer scientific requirements and sensitivities.

In addition to the basic requirements, RD2 specifies “design” drivers and goals for the photometer design – these are given in Table 2.2-4.

Requirement ID	Description	Reference
IRD-SPEC-R08	Sensitivity is the primary science driver for the spectrometer, so that the maximum number of survey sources can be followed-up as rapidly as possible.	SRD Appendix item B1
IRD-SPEC-R11	The effective resolution should not vary more than 10% across the FOV of the spectrometer.	SRD Appendix item B4
IRD-SPEC-R12	Extending the short wavelength coverage of the FTS would be scientifically very useful and also assist cross calibration of SPIRE and PACS data.	SRD Appendix item B5
IRD-SPEC-R13	The telescope background should be compensated for using a calibration source in the second input port. This compensation should be as near to perfect as possible given the constraints of the knowledge of the telescope emission spectrum.	SRD Appendix item B6
IRD-SPEC-R14	Fringe contrast shall be greater than 80% for any point in the field of view for a resolution of 0.4 cm^{-1}.	?

Table 2.2-4: Summary of Spectrometer design drivers from the SPIRE Science Requirements Document.

2.3 Instrument Operations Requirements

2.3.1 Instrument Operations

Requirement ID	Description	Source
IRD-OPS-R01	It shall be possible to calculate the execution time of an instrument command to within 1 sec (TBC). *This will allow the calculation of the time taken to execute any observation.to be made, for example, when generating a timeline.*	
IRD-OPS-R02	The instrument shall be capable of limiting the average data rate to the CDMS, during a 24hr period, to 100kbps (TBC) *The on-board software should provide functionality to allow observing sequences to be generated that will keep the data rate within this limit. This functionality will include, general purpose data compression, data reduction by integration of science data over time and selection of subsets of science data (i.e. selected pixels).*	
IRD-OPS-R03	The SPIRE instrument shall be identified as a single subsystem within the satellite. *That is, the instrument will utilise a single APID (to be defined by the FIRST Project) to identify both telecommands to the instrument and telemetry from the instrument.*	OIRD

Table 2.3-1: Requirements on the instrument operations

2.3.2 Operating Modes

This section describes the expected operating modes for the SPIRE instrument.

Requirement ID	Description	Source
IRD-MODE-R01	The instrument shall be capable executing all operating modes described in the SPIRE Operating Modes Document (RD8)	

Table 2.3-2: Requirements on the instrument operating modes.

2.3.3 Commanding Requirements

Instrument operations will be controlled by commands passed from the CDMS to the instrument in the form of telecommand packets (see RD4). The CDMS will be responsible for handling the command timeline uplinked from the ground and issuing the commands to the instrument at the appropriate time. The instrument, therefore, is normally expected to execute the commands it receives from the CDMS (or CDMS simulator) in the order in which it receives them. Commands will be provided to modify the order of execution if required.

Requirement ID	Description	Source
IRD-CMD-R01	The instrument shall be capable of accepting telecommand packets from the CDMS at speeds up to the maximum rate delivered by the CDMS, without loss. *This implies that the instrument should be able to buffer a number of telecommands received from the CDMS while a command is being executed. However, it may be assumed that the timing of command distribution to the instrument will be managed so that the maximum number of commands in the buffer will be limited.*	
IRD-CMD-R02	The instrument shall validate each telecommand packet as it is received. *Telecommand packets will contain a checksum to allow validation.Invalid commands should be rejected*	
IRD-CMD-R03	The instrument shall verify execution of the telecommands in each packet. *Normally, each telecommand packet will contain only one instrument command* *Commands which take a long time to execute (longer than ~5 secs, TBC) should have their progress verified also.*	
IRD-CMD-R04	The instrument shall report the result of all telecommand validation/verification in telemetry *The format of these telecommand report packets are defined in RD4*	
IRD-CMD-R05	The instrument shall provide commands to allow control of all individual devices (e.g. switch, latch) within the instrument.	
IRD-CMD-R06	All commands to individual devices shall explicitly set the state of the device *I.e. there shall be no commands to 'toggle' the state of a switch or commands to step to the next location.*	
IRD-CMD-R07	The action of all commands affecting an individual device shall be verifiable by an independent parameter available in the nominal housekeeping packet. *For example the change of state of a switch shall be verified by the change in voltage at the output of the switch rather than the status of the latch controlling the switch*	
IRD-CMD-R08	The instrument shall provide commands to execute the functions required to implement the instrument operating modes *These functions are defined in the SPIRE Operating Modes document (RD8). They usually invoke one or more device*	

Requirement ID	Description	Source
	control actions in order to perform their function.	
IRD-CMD-R09	The instrument shall provide the facility to define and execute procedure commands. *These commands will invoke stored sequences of commands with appropriate control steps to allow a given task to be performed. They will be invoked with supplied parameters to modify the actions performed. The intention is to minimise the number of telecommand words required to execute a given command sequence.*	
IRD-CMD-R10	The instrument shall provide commands to modify the execution sequence of commands. *Normally, commands are executed in the order in which they are received. These commands should provide the facilty to interrupt the currently executing command, modify the command queue and continue execution of commands in the queue.*	
IRD-CMD-R11	The instrument shall provide commands to allow identification of the steps within an observation. *For processing of the data from the instrument it will be necessary to be able to identify the observation/step from which the data has come. These commands should modify software parameters onboard so that this information is reported in the telemetry*	
IRD-CMD-R12	The instrument shall provide commands to modify data values/tables held in the instrument memory. *The on-board software will use data tables to control the operations onboard. These tables may need to be maintained.*	
IRD-CMD-R13	The instrument shall provide commands to enable on-board software maintenance *It should be possible to update the on-board software code either as a whole, or replace a single subroutine/function.*	

Table 2.3-3: Instrument level requirements on telecommanding

2.3.4 Telemetry Requirements

All data generated by the instrument will be transmitted from the instrument to the satellite CDMS in the form of telemetry packets. These packets will be store onboard by the CDMS, until the opportunity arises to transmit them to the ground.

Requirement ID	Description	Source

Requirement ID	Description	Source
IRD-TLM-R01	The instrument shall be capable of transferring telemetry packets to the CDMS (or simulator) at up to the maximum rate allowed by the telemetry interface. *This is approximately 1Mbps*	
IRD-TLM-R02	The instrument shall be able to buffer telemetry packets until they are requested by the CDMS *The CDMS will poll each subsystem on the satellite in turn for data. The instrument should be able to buffer sufficient packets to not lose data waiting for the CDMS.*	
IRD-TLM-R03	It shall be possible to validate the content of each telemetry packet. *The telemetry packet standard identifies the location of a checksum of the data contained within the packet. This checksum may be used to validate the packet*	
IRD-TLM-R04	All telemetry packets shall contain information identifying the observation/step being executed. *This will allow data processing software to identify significant steps in an observation in order to apply the appropriate processing*	
IRD-TLM-R05	The instrument shall generate housekeeping data packets in all operating modes. *These data packets contain the values of both hardware and software parameters internal to the instrument.*	
IRD-TLM-R06	It shall be possible to define TBC alternative housekeeping packet structures with different rates of generation. *The normal housekeeping packet will be generated once per second (TBC) and contain, at the least, all hardware parameters.* *Housekeeping packets generated at higher rates (up to 1000 per second (TBC) may contain a subset of the instrument parameters*	
IRD-TLM-R07	The instrument shall generate science data packets in all observing modes. *These packets shall contain data from the detector arrays associated with the observing mode, plus all instrument parameters that may be required to enable the processing of the detector data (e.g mechanism positions, temperatures of units which may affect the detector data, monitoring parameters for the subsystems being used).*	

Requirement ID	Description	Source
IRD-TLM-R07	It shall be possible to define TBC alternative science data packets structures. *This will allow the set of detector data and instrument parameters included in the science data to be optimised for different observation modes.*	
IRD-TLM-R08	The instrument shall generate event packets in all operating modes. *These packets notify the CDMS and/or ground monitoring equipment of instrument anomalies and significant actions taken by the instrument. The ESA packet Utilisation Standard identifies many of thesereport packet types.* *These packets should identify the type of anomaly and the data used to identify it.*	

Table 2.3-4: Instrument level requirements on the data packets

2.3.5 Data Handling Requirements

Requirement ID	Description	Source
IRD-DATA-R01	All data transferred between the CDMS and the instrument shall be contained in packets conforming to the ESA Packet Utilisation Standard (RD4) *It is assumed that in the interests of commonality with other spacecraft systems and scientific instruments the data handling of the SPIRE instrument will follow this standard. The detailed definition of the contents of each packet will formally be defined in a FIRST Space/Ground Interface Document to be written and agreed later.*	OIRD
IRD-DATA-R02	The instrument shall provide all mandatory packet handling services defined for the mission. *The OIRD (AD3) defines the list of mandatory services*	OIRD
IRD-DATA-R03	The instrument shall be capable of buffering data generated during an observation. *It is possible that data will be generated during an observation, at a rate greater than that which can be transferrred to the CDMS. The instrument should buffer this data and transfer it to the CDMS at a later time (even if a new observation has begun). The size of the buffer is TBD*	
IRD-DATA-R04	The instrument shall be capable of reducing the average data rate to the CDMS to 20kbps. *This may be required to cope with a reduced telemetry downlink rate or 'partner mode' observations. The science content of the telemetry may be degraded.*	

IRD-DATA-R05	The packing of science data into science data packets shall minimise loss of information if packet is lost or corrupted. *Science data packets could include data from one or more detectors over a given time period (or for a single interferogram) rather than one sample from all detectors. In this way if a data packet is lost the impact on the science is reduced.*	

Table 2.3-5: Instrument level data handling requirements

2.4 Instrument Model Philosophy

The instrument models to be built are as follows:

STM – Structural Thermal Model. This will be used to give early verification of the structural design of the instrument. It will consist of the CQM structure with mass dummies for the sub-systems. It is intended that it will be vibrated warm as a test of the frequency response of the structure and to verify the FEA analysis.
AVM – Avionics Model. The IID-A states that this is: "…to validate electronics and software for its interface with the S/C, including anything that exchanges information with, for example, the AOCS. In addition all tasks relevant to SPIRE autonomy shall be verified." We have interpreted this as being a DPU plus a simulator of the DRCU and the cold FPU – the latter is termed the DRCU Simulator.

CQM - Cryogenic Qualification Model. For both the cold FPU and the warm electronics it is assumed 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.

Requirement ID	Description	Source
IRD-INST-R14	The SPIRE instrument shall provide the instrument models as specified in the IID-A	IID-A

Table 2.4-1: Instrument level model requirements.

2.5 Instrument level Qualification

It is required that the instrument be qualified at unit level – i.e. the cold FPU; warm electronics boxes etc must undergo individual qualification testing and be shown to be flight worthy. The tests that are required for each model and unit are outlined in Table 2.5-1 and described in more detail in the SPIRE Instrument AIV Plan (RD9).

Test Matrix

	CQM Cold Focal Plane Units	QM Warm Electronics Units	PFM Cold Focal Plane Units	PFM Warm Electronics Units	FS Cold Focal Plane Units	FS Warm Electronics Cards
Vibration:	**Q**	**Q**	**QA**	**A**	**A**	**A**
Thermal cycle:	**Q**	**Q**	**QA**	**A**	**A**	**A**
Vacuum cycle	**x**	**x**	**x**	**x**	**x**	**x**
Thermal range:	**x**	**x**	**x**	**x**	**-**	**-**
EMC (Instrument Level)	**x**	**x**	**x**	**x**	**-**	**-**
EMC (Satellite Level):	**-**	**-**	**x**	**x**	**-**	**-**

Table 2.5-1: Test matrix for the instrument level testing.
Q indicates a test carried out at qualification level for qualification times; QA a test carried out at qualification levels for acceptance test times and A a test carried out at acceptance level for acceptance times. An x indicates that this test is carried out and is a characterisation type test or the level is irrelevant. A dash indicates that no test will be done on this model/unit.

Requirement ID	Description	Source
IRD-INST-R15	The instrument units are required to undergo an environmental test programme that demonstrates the design and build standard of the flight model is compatible with the launch and operational environment of the FIRST satellite.	

Table 2.5-1: Instrument level qualification requirements.

2.6 Verification

For the purposes of verification requirements, the instrument models consist of the units specified in section 2.4. It is also assumed that there will be present some form of EGSE to allow testing of the instrument models in the absence of the spacecraft and that there will be some computer hardware and software to allow the receipt; storage and analysis of the test data.

Requirement ID	Description	Source
IRD-VER-01	The STM verification testing shall demonstrate that the proposed structure design is capable of meeting the environmental conditions specified for the FIRST launch. The STM vibration shall be used to verify the FEA model of the instrument.	
IRD-VER-R02	The AVM verification testing shall demonstrate that the instrument will fulfil the requirements on the following: 1. Communication between the satellite CDMS and the DPU. 2. Correct transfer and receipt of instrument commands from the satellite 3. Correct transfer and receipt of instrument data packets form the instrument to the satellite 4. Correct execution of instrument commands 5. Correct transfer of instrument data from the FPU simulator to the DPU 6. Correct execution of DPU on-board software for any data compression algorithms and packet generation for all instrument data packet types.	
IRD-VER-R03	The CQM verification testing shall, in addition to the requirements on the AVM verification, demonstrate the following: 1. Correct operation of all FPU sub-systems at cryogenic temperatures for all instrument operation modes for both prime and redundant systems. 2. Correct operation of all instrument sub-systems with warm electronics units operating over a range of temperatures 3. The instrument cold FPU and JFET box thermal dissipation is within requirements for all instrument operation modes. 4. The warm electronics thermal dissipation at room temperature is within requirements. 5. Correct operation of CQM version of all on-board software. 6. The instrument straylight environment is within requirements	

Requirement ID	Description	Source
	7. The instrument optics performance is within requirements 8. The performance of the instrument meets the scientific requirements expected for the CQM for all instrument observing modes 9. Development and test of all functional test sequences required for Integrated Systems Testing (IST) at satellite level. 10. The correct functioning of the instrument for all Astronomical Observing Templates (AOTs) and calibration sequences. 11. Development and test of all in-flight functional and performance test sequences	
IRD-VER-R04	The PFM and FS verification testing shall, in addition to the requirements on the CQM and AVM verification, demonstrate the following: 1. The performance of the flight and flight spare instruments meets the scientific requirements for all instrument observing modes. 2. Correct operation of flight version of all on-board software. 3. The characterisation of the PFM and FS instrument performance for all instrument observing modes – including generation of data for instrument calibration and functional testing both during IST and in-flight. 4. The characterisation of the instrument performance with the warm electronics operating over a range of temperatures 5. Final test of all functional test sequences for IST. 6. Final test of all AOTs 7. Final test of all in-flight functional and performance test sequences.	

Table 2.6-1: Requirements on the instrument level verification.

2.7 Safety

Requirement ID	Description	Source
IRD-SAFE-R01	During all mission phases, there shall be no requirement for commands to be sent from the ground to the instrument with an immediate response time (i.e. less than 2 minutes TBC). *Any such situations must be handled on board.*	OIRD-CTRL-1
IRD-SAFE-R02	Situations which require response from the ground within a short time (i.e. less than 30 mins) shall be reduced to a minimum, be well identified and agreed by ESA	OIRD-CTRL-2
IRD-SAFE-R03	Situations which require response from the ground within a short time (i.e. less than 30 mins) shall be unambiguously recognisable in the instrument housekeeping telemetry, without complex processing	OIRD-CTRL-3
IRD-SAFE-R04	Housekeeping telemetry shall be generated during all nominal modes of the instrument. *This includes any instrument Safe Modes*	OIRD-CTRL-4
IRD-SAFE-R05	The instrument shall be able to accept all telecommand packets sent to it at the nominal transfer rate from the CDMS	OIRD-CTRL-5 OIRD-CTRL-6
IRD-SAFE-R06	It shall not be possible by command, or lack of command, to place the instrument into a configuration that will, or is likely to cause damage to any subsystem	
IRD-SAFE-R07	All telecommands received by the instrument shall be checked to be correctly formatted and complete before execution. *Incorrect telecommands will be rejected by the instrument*	
IRD-SAFE-R08	Failure of any sub-system, or one of its components, shall not affect the health of any other subsystem, the instrument or the interface with the satellite.	
IRD-SAFE-R09	Failure of any component in a subsystem shall not damage any redundant or backup component designed to replace that component in the subsystem	
IRD-SAFE-R10	No electronics sub-unit shall be capable of affecting instrument operations until it is in a defined state. This state shall be confirmed in the housekeeping telemetry.	
IRD-SAFE-R11	No commands shall be sent to an electronics sub-unit until they are in a defined state confirmed by the on-board software	

Table 2.7-1: Instrument level safety requirements.

2.8 Autonomy

The instrument is required to be "autonomous" when not in ground contact. This implies that the warm electronics must monitor critical housekeeping parameters to ensure that any sub-system failure is detected and the appropriate action taken. It is assumed that the basic action will be to switch the instrument to a safe mode with only the DPU on and housekeeping telemetry.

Requirement ID	Description	Source
IRD-AUT-R01	The SPIRE instrument shall have a defined safe mode. *The configuration of this mode shall be agreed with ESA*	
IRD-AUT-R02	The SPIRE instrument shall define housekeeping parameters to be used for autonomous health and safety monitoring	
IRD-AUT-R03	The SPIRE instrument shall provide a method of monitoring the defined housekeeping parameters and taking appropriate action in the case of error or failure.	
IRD-AUT-R04	The SPIRE instrument shall provide a method of alerting the S/C CDMS of any failure requiring the instrument to be controlled by the CDMS (e.g. switched off). *Actions to be taken in the case of failure will b defined by the instrument and stored as procedures in the CDMS*	
IRD-AUT-R05	The instrument shall continuously monitor the integrity of the on-board software and take appropriate action in case of error. *The on-board software can itself calculate a checksum over the OBS code and compare this to a stored value.*	
IRD-AUT-R06	The instrument shall monitor the operational status of the instrument on-board computers and take appropriate action in case of error. *A watchdog function will be implemented to identify if the on-board computer(s) have crashed.*	

Table 2.8-1: Requirements for autonomous health and safety monitoring.

2.9 Reliability and Redundancy

It is assumed that reliability will be maintained by use of a combination of hardware redundancy and flexibility in the onboard software such that a failure of a single hardware device will not lead to a loss of instrument capability, although it may lead to loss of instrument performance.

Requirement ID	Description	Source
IRD-REL-R01	As far as possible the total failure of a single sub-system shall not lead to the total loss of instrument operations.	
IRD-REL-R02	Backup modes of operation should be available for all nominal observing modes. These shall be designed to allow the continued use of that mode, albeit with degraded performance or efficiency.	
IRD-REL-R03	Cold redundant hardware shall be provided wherever practicable within the instrument design.	
IRD-REL-R04	As far as possible all control loops shall be implemented through the use of on-board software.	
IRD-REL-R05	It shall be possible to break all control loops implemented in hardware. *This will allow the control of the loop through the on board software (this may be a degraded mode of operation)*	

Table 2.9-1: Instrument level reliability and redundancy requirements.

2.10 EMC

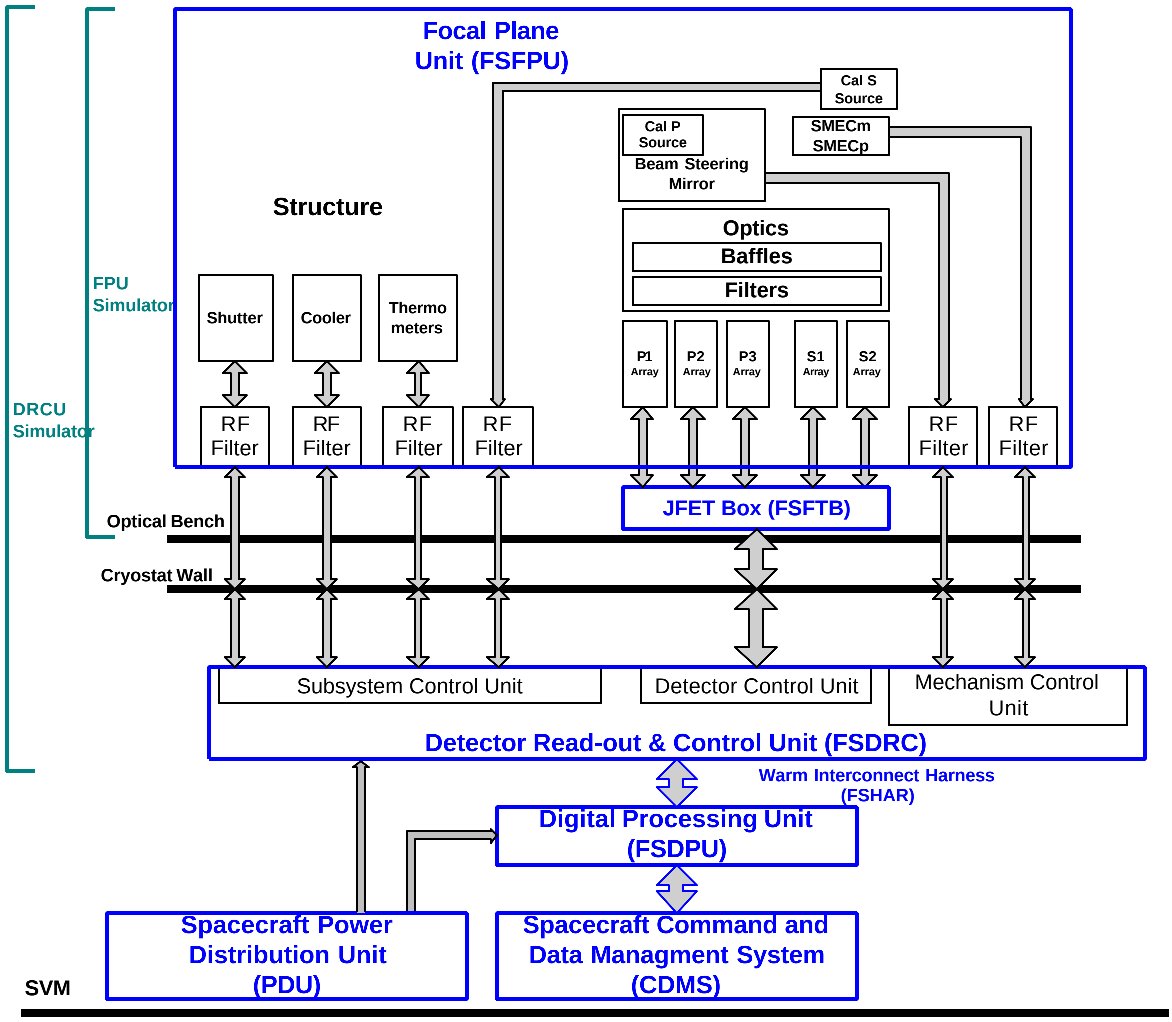
To be written

The EMC environment – and hence the requirements – will be the subject of a joint study between the instrument teams and ESA at some future date (30/11/99)

3. SUBSYSTEMS REQUIREMENTS

3.1 Assumptions

The SPIRE instrument will consist of the sub-systems indicated in figure 3.1-1 and table 3.1-1. Figure



3.1-1 also shows the interface relationship between the SPIRE sub-systems; harnesses etc.

Figure 3.1-1: SPIRE sub-system block diagram

Subsystem Name	Description	Unit	Number
Structure	Focal plane unit structure to hold all cold sub-systems in the focal unit. This includes all thermometers necessary to monitor the instrument during cool down and operation.	FSFPU	1.1
Optics	All mirrors for the photometer and spectrometer channels	FSFPU	1.2
Filters	All filters; beam splitters and dichroics for the photometer and spectrometer channels The requirements on these are included with those for the	FSFPU	1.2.1

	optics.		
Baffles	Straylight control baffles for the photometer and spectrometer channels	FSFPU	1.2.2
Cooler	^{3}He cooler unit cools the photometer and spectrometer detector arrays to 300 mK	FSFPU	1.3
Detector Arrays	Bolometer array modules for the photometer and spectrometer	FSFPU	1.4
Beam Steering Mechanism	This mechanism allows the photometer and spectrometer fields of view to be stepped or chopped across the sky.	FSFPU	1.5.1
FTS Mechanism (SMECm)	The FTS moving mirrors drive mechanism and position measurement system. SMECm designates the mechanism and position encoder	FSFPU	1.5.2
FTS encoder amplifier (SMECp)	SMECp the cold pre-amplifier that may be required for the encoder detectors.	FSFPU	1.5.3
Shutter Mechanism	A shutter is required in the instrument for ground test to allow the detectors to see the correct radiation environment.	FSFPU	1.5.4
Photometer Calibration Source	Calibration source for photometer	FSFPU	1.6.1
Spectrometer Calibration Source	Calibration source for the spectrometer	FSFPU	1.6.2
RF Filter Modules	Each sub-system harness into the cold FPU must have an electrical RF filter to prevent EMI problems with the bolometers. These will be mounted in standard RF filter modules on the wall of the FPU box.	FSFPU	1.7
JFET Box	JFET pre-amplifiers for NTD germanium bolometers. This box will also contain the RF filters required for all detector options.	FSFTB	1.8
Detector Read-out & Control	Detector amplifier and digitisation chain and instrument control electronics.	FSDRC	2.2
Digital Processing Unit	Instrument on board computer – forms interface to CDMS	FSDPU	2.3
Warm Interconnect Harness	Harness between warm boxes	FSHAR	2.4
On Board Software	All on board software that controls the function of the instrument. This is all contained in the DPU	FSOBS	2.5
FPU Simulator	A set of electronic components, either passive or active, that mimics the analogue response of the FPU sub-systems to the warm electronics.	FSFPS	3.1
DRCU Simulator	A set of interface hardware and computer software that mimics the response of the DRCU and FPU to the DPU and on board software.	FSDRS	3.2

Table 3.1-1: Listing of SPIRE sub-systems.

The unit column refers to the ESA designation for the unit in which the sub-system is located. The sub-system number is that allocated for the purposes of interface control. (Do the simulators need acronyms – are these o.k.? May 2000)

3.2 Scope

This chapter details the requirements on the cold focal plane unit sub-systems; the JFET box and the instrument simulators.

3.3 Subsystem Qualification Requirements

Assumptions

It is assumed that all sub-systems will have been through a type approval programme of one or more models before the Cryogenic Qualification version of the sub-system is delivered for the instrument AIV. This implies:

1. The testing carried out on the CQM instrument should <u>NOT</u> be considered to be the qualification test for each individual sub-system. The tests carried out on the instrument CQM will be neither exhaustive nor at the correct level for sub-system qualification.
2. It is intended that the tests listed here be carried out on a specific type approval model or models. It is expected that acceptance tests will be done on each delivered model (CQM, Flight and Flight Spare) as part of the general instrument AIV – these will be detailed in the instrument AIV plan. The type approval test programme does not replace the need for acceptance testing of each model.

Test Matrix:

	Structure	Optics	FTS Mechanism	Shutter	BSM	Detector arrays	Cooler	Filters/grids/dichroics	Calibration Sources	DCRU	DPU
Vibration:	X	X	X	X	X	X	X	X	X	X	X
Thermal cycle:	X	X	X	X	X	X	X	X	X		
Vacuum cycle			X	X	X	X	X	X	X	X	X
Lifetime:		P	X	P	X	X	X	X	X	X	X
Soak/cycle:			X	P	X	X	X		X	X	X
Radiation tolerance:			P	P	P	X	P	X	X	X	X
Thermal range:			X	P	X	X	X	X	X	X	X
Thermal stability:		P	X	P	X	X	X	P	X	X	X
Microphonics:		P	X	X	X	X	X	P	P		
Ionising radiation:						X					
EMI:			X	X	X	X	P		P	X	X

EMC:			**X**	**X**	**X**	**X**	**P**		**P**	**X**	**X**

Table 3.3-1: Test matrix for the SPIRE sub-systems qualification programme.
Tests marked with an X are mandatory, those marked with a P are possibly required depending on the detailed design of the sub-system and/or the new of novel materials. A full description of each test is given in the SPIRE Instrument AIV Plan (RD9). For some sub-systems the qualification and lifetime testing will be more appropriately carried out at component or test item level rather than at the level of the integrated sub-system. At what stage and under what conditions the tests are to be carried out is a matter for detailed consideration by the groups responsible for the sub-systems delivery.

Requirement ID	Description	Source
IRD-SUBS-R01	All subsystems are required to undergo an environmental test programme that demonstrates the design and build standard of the sub-system models will be compatible with the environmental test programme to be carried out on the appropriate integrated instrument model.	
IRD-SUBS-R02	All sub-systems are required to demonstrate that they will operate successfully over the 4.25 years of expected mission operations.	

3.4 Assumptions for the Focal Plane Unit

3.4.1 Plate Scale

The nominal optical design of the SPIRE optics for both the photometer and spectrometer has a final focal ratio onto the detectors of f/5. This implies, given the design of the FIRST telescope (see section 2.1.4.4), that the nominal plate scale at the SPIRE focal plane is 12.564 arcsec/mm. This value will be used throughout this section to determine the required size of the focal plane arrays.

3.4.2 Vacuum

The cold focal plane unit will be launched and operated in a vacuum of TBD mBar.

3.4.3 Mass

Requirements are not directly placed on the mass of each sub-system in this document (issue 3) as this is felt to be unnecessarily prescriptive. However, the mass of the focal plane units is of deep concern and all sub-systems are required to be as mass efficient as possible. A mass allocation for each sub-system in set out in AD5.

Requirement ID	Description	Source
IRD-SUBS-R03	All subsystems are required to be within the mass allocation given in AD5	

3.5 Sub-system requirements

3.5.1 Structure

3.5.1.1 Common Structure

Performance Requirements

Requirement ID	Description	Value	Source
IRD-STRC-R01	Alignment of the instrument w.r.t. the FIRST optical axis	The SPIRE common structure shall allow the alignment of the instrument and telescope optical axes to within +-2.5 (TBC) mm lateral and +- TBD arcmin rotational about any axis.	
IRD-STRC-R02	Attenuation of RF by 4-K Common Structure covers	The covers as fitted on the instrument will attenuate all frequencies lower than 8 GHz by TBD dB. (Needs confirmation May 2000)	
IRD-STRC-R03	Items requiring support from the 4-K Common Structure	**Photometer and common sub-systems** Photometer 4-K optics Photometer filters 4-K Thermal Strap ^{3}He Cooler 4-K Baffles All sub-system harnesses BSM Mechanism and structure Shutter mechanism and mount Photometer 2-K enclosure **Spectrometer** All spectrometer optics Beam splitters Mechanism structure Mechanism motor Calibration source and mount Spectrometer 2-K enclosure	
IRD-STRC-R04	Optics and associated sub-system alignment	The common structure shall be capable of maintaining the alignment of the photometer and spectrometer optics and associated components (i.e. filters; 2-K enclosures; BSM etc) to within the specifications given in RD7 both at room temperature and during cryogenic operation.	
IRD-STRC-R05	Surface finish of the 4-K Common	The inside and outside of the box shall have a finish with a low emissivity. At	

Requirement ID	Description	Value	Source
	Structure cover	least ε=0.2. Some parts of the structure walls may be blackened as part of the straylight control.	
IRD-STRC-R06	Pumping port	The total effective pumping conductance of the 4-K enclosure must be greater than or equal to 7.8 l/s (TBC)	
IRD-STRC-R07	Thermometry	The structure subsystem shall provide thermistors and associated wiring to allow the temperature of critical parts to be monitored during in-flight operations.	
IRD-STRC-R08	Attenuation of radiation from cryostat environment	Requirement $<2x10^{-5}$ (TBC) To illustrate this, the requirement is the equivalent of a ~4 mm diameter hole in a total area of the box cover of 1 m^2 (TBC)	

Table 3.5-1: Performance requirements for the instrument common structural elements.

System Requirements

Requirement ID	Description	Value	Source
IRD-STRC-R09	First natural frequency of the instrument assembly	The first eigenfrequency of the integrated instrument assembly shall be greater than 100 Hz (TBC) with a goal of greater than 120 Hz	
IRD-STRC-R10	Instrument mechanical interface	The mechanical interface of the instrument will be directly to the FIRST optical bench and the instrument will be in direct thermal contact at that interface.	
IRD-STRC-R12	Grounding	All parts of the SPIRE structure shall be electrically connected one to another. Resistance to be no more than 0.1 Ω (TBC) between any two parts of the structure	
IRD-STRC-R13	Electrical isolation from FIRST	All parts of the SPIRE structure shall be electrically isolated from the FIRST optical bench and cryostat. Resistance to be greater than TBD Ω.	
IRD-STRC-R14	Thermal isolation	The conductance from the level 2 to level 1 stage is required to be no more than 6 mW (TBC) assuming level 2 is 9 K and level 1 is 4 K.	

Table 3.5-2: System requirements on the instrument common structural elements

3.5.1.2 Photometer Structure

Performance Requirements

Requirement ID	Description	Value	Source
IRD-STRP-R01	Items requiring support	The photometer 2-K structure shall support: Photometer 2-K optics; dichroics and filters Detector array modules; Detector thermal straps	
IRD-STRP-R02	Optics and filters alignment	The 2-K photometer structure shall be capable of maintaining the alignment of the photometer 2-K optics; filters and dichroics to within the requirements set out in RD7 at room temperature and during cryogenic operation.	
IRD-STRP-R03	Array module alignment	The 2-K photometer structure shall be capable of maintaining the position of the detector array modules to within the requirements set in RD7 about any axis during cryogenic operation of the instrument.	
IRD-STRP-R04	Surface finish	The outside of the box shall have a finish with a low emissivity. At least ε=0.2 The inside of the box shall have a low reflectivity finish on all non-optical surfaces.	
IRD-STRP-R05	Pumping port	The total effective pumping conductance of the 2-K box must be greater than or equal to 5.6 l/s (TBC)	
IRD-STRP-R06	Attenuation of radiation from 4-K environment	Requirement 5×10^{-7}; goal is 5×10^{-8} (TBC) To illustrate this, the requirement is the equivalent of a 0.5 mm diameter hole in a total area of the box cover of 0.5 m^2 *This, of course, excludes the hole that lets the beam in.*	

Table 3.5-3: Performance requirements on the photometer 2-K structure.

System Requirements

Requirement ID	Description	Value	Source
IRD-STRP-R07	First natural frequency	The first eigenfrequency of the photometer 2-K structure on its mounts shall be greater than 100 Hz (TBC) with a gaol of > 150 Hz	
IRD-STRP-R09	Thermal isolation	The conductance of from the 4-K to 2-K stage shall be no more than 0.75 mW (TBC)	

Table 3.5-4: System requirements on the photometer 2-K structure

3.5.1.3 Spectrometer Structure

Performance Requirements

Requirement ID	Description	Value	Source
IRD-STRS-R01	Items requiring support	The spectrometer 2-K structure shall support: Cold Stop filters Fold mirrors	
IRD-STRS-R02	Optics alignment requirements	The spectrometer 2-K structure shall be capable of maintaining the alignment of the spectrometer 2-K optical components to within the requirements set out in RD7	
IRD-STRS-R03	Surface finish	The outside of the box shall have a finish with a low emissivity. At least ε=0.2 The inside of the box shall have a low reflectivity finish on all non-optical surfaces.	
IRD-STRS-R04	Pumping port	The total effective pumping conductance of the 2-K box must be greater than or equal to 5.6 l/s (TBC)	
IRD-STRS-R05	Attenuation of radiation from 4-K environment	Requirement 5×10^{-7}; goal is 5×10^{-8} (TBC) To illustrate this, the requirement is the equivalent of a 0.5 mm diameter hole in a total area of the box cover of 0.5 m^2 *This, of course, excludes the holes that let the beams in.*	

Table 3.5-5: Performance requirements on the spectrometer 2-K structure.

System Requirements

Requirement ID	Description	Value	Source
IRD-STRS-R06	First natural frequency	The first eigenfrequency of the spectrometer 2-K structure on its mounts shall be greater than 100 Hz (TBC) with a gaol of > 150 Hz	
IRD-STRS-R08	Thermal isolation	The conductance of from the 4-K to 2-K stage shall be no more than 0.25 mW (TBC)	

Table 3.5-6: System requirements on the spectrometer 2-K structure.

3.5.2 ^{3}He Cooler and detector temperature control

Performance Requirements

Requirement ID	Description	Value	Source
IRD-COOL-R01	Temperature at the detectors	Nominal 300 mK	
IRD-COOL-R02	Operating temperature control	Desirable to be able to vary the temperature of the detectors up to 320 mK and below 300 mK *if this is permitted by the temperature drop across the thermal link.* *The evaporator cold tip temperature can be varied by heating the sorption cooler. Electronic control shall be provided to do this in the flight electronics.*	
IRD-COOL-R03	Temperature drop across thermal link between detectors and evaporator cold tip	Maximum of 25 mK	
IRD-COOL-R04	Temperature drift	The temperature of the evaporator cold tip should not drift by more than 10 mK/h	
IRD-COOL-R05	Temperature fluctuations at the evaporator cold tip	No more than 150 nK $Hz^{-1/2}$ in a frequency band from 0.1-100 Hz.	
IRD-COOL-R06	System low frequency temperature stability with active temperature control	150 nK at 0.015 Hz at a maximum power dissipation of 1 µW	
IRD-COOL-R07	Heat lift at evaporator cold tip	Minimum of 10 µW at 300 mK	
IRD-COOL-R08	Hold time	Minimum 46 hours	
IRD-COOL-R09	Recycle time	Maximum 2 hours	

Table 3.5-7: Performance requirements on the sorption cooler.

System Requirements

Requirement ID	Description	Value	Source
IRD-COOL-R10	Mechanical interface	Preferred interface is with the instrument 4-K structure	
IRD-COOL-R11	Thermal Interface with FIRST cryostat	Pumped liquid helium tank at 1.8 K for both sorption pump and evaporator	

Requirement ID	**Description**	**Value**	**Source**
IRD-COOL-R12	Parasitic thermal load onto He bath during cold operation	Maximum 1.2 mW is allowed for the conduction from 4 K to 2 K through the support structure and heat switches.	
IRD-COOL-R13	Time averaged thermal load onto He bath for 48 hour cycle	Maximum 3 mW (includes 20% margin)	
IRD-COOL-R15	Maximum envelope	200x100x100 mm	
IRD-COOL-R17	Sorption pump heater	The baseline design has a heater resistance of 400 Ω implying a current of up to 20 mA for recycling. It is desirable that this heater resistance is increased so that the allowable resistance of the cryo-harness wiring can, in turn, be increased. The maximum resistance of the heater that can be driven by 28 V is about 5 kΩ.	
IRD-COOL-R18	Thermometers	Thermometers shall be provided on the cooler as necessary to monitor its behaviour and operation. The absolute temperature measurement on the evaporator cold tip shall be 0.5% (<1.5 mK) with a resolution of TBD mK. Thermometers of the same specification shall also be provided on each detector array (*q.v.*).	
IRD-COOL-R19	Gas gap heat switches	It is noted that these are a potential single point failure in the instrument operation. Provision of some redundancy (i.e. doubling them up) is desirable *but not at the expense of severe limitations on the cooler performance.*	
IRD-COOL-R20	Ground Operation	The cooler must be capable of full operation on the ground, including recycling, when the instrument is in its normal orientation in the test facility. This will be arranged so that the evaporator is below the pump. The cooler must be capable of operating with the instrument rotated to up to 90^{o} about either the S/C Y or Z axes.	

Requirement ID	Description	Value	Source
IRD-COOL-R21	Warm electronics power dissipation	Less than TBD W during cold operation Less than TBD W during recycling	

Table 3.5-8: Systems requirements on the sorption cooler

3.5.3 Shutter

All specifications and requirements on the shutter are under review. (30/11/99)

Performance Requirements

Requirement ID	Description	Value	Source
IRD-SHUT-R01	Beam blanking	When the shutter vane is in place the throughput of the photometer optics shall be no more than 0.5% (TBD) of the nominal throughput. Goal is to provide the same for the spectrometer	
IRD-SHUT-R02	Vane temperature	The temperature of the shutter vane shall be variable between 5 and 20 K	

Table 3.5-9: Performance requirements on the shutter

System Requirements

Requirement ID	Description	Value	Source
IRD-SHUT-R03	Failure mode	Any failure of the shutter mechanism must be with the vane out of the beam	
IRD-SHUT-R04	Operating temperature	Maximum 300 K Minimum 4 K	
IRD-SHUT-R05	Thermal dissipation of actuator in operation	< 1 mW	
IRD-SHUT-R06	Electrical resistance of heater	Of order 10 kΩ	
IRD-SHUT-R07	Max. thermal dissipation of heater < 5 mW	<5 mW	
IRD-SHUT-R08	Nominal envelope for actuator	TBD	

Table 3.5-10: System requirements on the shutter

3.5.4 Harness

Performance Requirements

All harness requirements are under review and TBW (30/1199)

System Requirements

Requirement ID	Description	Value	Source
IRD-FPHR-R01	Generic implementation	All sub-system electrical connections shall be routed through an RF filter module mounted on the outside cover of the FPU. The detector harnesses will be routed through the JFET box which will form part of the Faraday cage.	

Table 3.5-11: Requirements for the internal SPIRE harnesses.

3.5.5 Optics and Filters

3.5.5.1 Photometer Optics and Filters

Performance Requirements

Requirement ID	Description	Value	Source
IRD-OPTP-R00	Compatibility with FIRST telescope	The optical design of the photometer fore-optics shall be compatible with the FIRST telescope optical design.	
IRD-OPTP-R01	Nominal final focal ratio	As close to F/5 as practical	
IRD-OPTP-R02	Variation in focal ratio	The focal ratio at any point in the must be within 20% (TBC) of that of the on-axis point.	
IRD-OPTP-R03	Distortion	The image of the telescope field of view is nominally rectangular. The position of any point within the image of the FOV at the detectors must be within 10% (TBC) of the actual position of the point at the telescope focal plane.	
IRD-OPTP-R04	Anamorphism	The anamorphic ratio of the image of a point source at the detectors must be no more than 6:5 (TBC) in any pair of orthogonal directions at any point in the FOV.	
IRD-OPTP-R05	Throughput	The throughput of the photometer mirrors, filters, dichroics and baffles shall be greater than 0.27 (TBC) over the instrument waveband. This includes losses due to manufacturing defects; surface finish and alignment tolerances.	
IRD-OPTP-R06	Image quality	The photometer optics shall give a Strehl ratio of greater than 0.9 (TBC) over the 4x8 arcmin FOV at 250 μm including all losses due to alignment; mirror quality etc	
IRD-OPTP-R07	Out of band radiation	The end to end filtering of the photometer shall control the out of band radiation to be no more than 10^{-3} for 40 cm-1 to 200 cm-1 10^{-6} for 200 cm-1 to 1000 cm-1 10^{-9} for 1000 cm-1 to 100000 cm-1 of the in-band telescope background radiation.	
IRD-OPTP-R08	In-band straylight	The background power falling on the detectors with the optical beam blocked shall be no more than 5% (TBC) of the in-band background power from the telescope over	

Requirement ID	Description	Value	Source
		the 200-300 µm band; 5% (TBC) over the 300-400 µm band and 5% (TBC) over the 400-670 µm band.	

Table 3.5-12: Performance requirements on the photometer optics.

3.5.5.2 Spectrometer Optics and Filters

Performance requirement

Requirement ID	Description	Value	Source
IRD-OPTS-R01	Nominal final focal ratio	As close to F/5 as practical	
IRD-OPTS-R02	Variation in focal ratio	The focal ratio at any point in the must be within 20% (TBC) of that of the on-axis point.	
IRD-OPTS-R03	Distortion	The position of any point within the image of the FOV at the detectors must be within 10% (TBC) of the actual position of the point at the telescope focal plane.	
IRD-OPTS-R04	Anamorphism	The anamorphic ratio of the image of a point source at the detectors must be no more than 6:5 (TBC) in any pair of orthogonal directions.	
IRD-OPTS-R05	Theoretical throughput	The theoretical throughput of the spectrometer mirrors; filters; beam splitters and baffles shall be greater than 0.2 (TBC) over the total instrument waveband (TBC) including all losses due to manufacturing defects; surface finish and alignment tolerances.	
IRD-OPTS-R06	Image quality	The spectrometer optics shall give a Strehl ratio of greater than 0.9 (TBC) over the 2.6 arcmin FOV at 250 µm including all losses due to alignment; mirror quality etc	
IRD-OPTS-R07	Balancing of ports	In order that the two output ports shall have the same performance and to facilitate accurate compensation of the zero path difference maximum, the beam splitters shall have 2RT equal to R^2+T^2 to within 90% (TBC) over the waveband of the instrument.	
IRD-OPTS-R08	Out of band radiation	The end-to-end filtering of the spectrometer shall control the out of band radiation to be no more than 10^{-3} for 40 cm-1 to 200 cm-1 10^{-6} for 200 cm-1 to 1000 cm-1 10^{-9} for 1000 cm-1 to 100000 cm-1	

Requirement ID	Description	Value	Source
		of the in band telescope background radiation.	
IRD-OPTS-R09	In band straylight	The background power falling on the detectors with the optical beam blocked shall be no more than 5% (TBC) of the in band background power from the telescope over the 200-400 µm band and 5%(TBC) over the 400-670 µm band.	
IRD-OPTS-R10	Off axis resolution	The FWHM of the resolution element at any point in the FOV shall be no more than 10% greater than the on-axis value for a nominal resolution of 0.4 cm^{-1}.	

Table 3.5-13: Performance requirements for the spectrometer optics.

3.5.6

3.5.6 Detectors

3.5.6.1 Photometer Detectors

Performance Requirements

Requirement ID	Description	Value	Source
IRD-DETP-R01	Detective Quantum Efficiency at 2 Hz at nominal incident power levels	> 0.6	
IRD-DETP-R02	Time constant	16 milliseconds (Equivalent to 10 Hz)	
IRD-DETP-R03	Uniformity	NEP spec. shall be met over the whole array Responsivity variations shall be lass than 10% across the array and calibrated to an accuracy of <1%	
IRD-DETP-R04	Yield (good pixels)	≥90% for each array	
IRD-DETP-R05	Electrical crosstalk for near neighbour pixels.	Less than the optical cross talk at the output of the cold JFET amplifiers.	
IRD-DETP-R06	Electrical crosstalk any pair of pixels	Requirement is less than 0.1% (TBC) at the output of the cold JFET preamplifiers. Goal is to be less than the optical cross talk.	
IRD-DETP-R07	Detector angular response	2Fλ Feedhorns : Single moded	
IRD-DETP-R08	Spectral response	≥ 90% at the nominal edge frequencies of the appropriate passband	

Table 3.5-14: Performance requirements on the photometer detectors.

System Requirements

Requirement ID	Description	Value	Refers to:

Requirement ID	Description	Value	Refers to:
IRD-DETP-R09	Microphonic susceptibility	TBD	
IRD-DETP-R10	EMI susceptibility	TBD	
IRD-DETP-R11	Sensitivity to ionising radiation	TBD	
IRD-DETP-R12	Volume envelope	The detector modules shall fit within a cylinder of diameter 75 mm (goal 60 mm) and length 100 mm.	
IRD-DETP-R13	300 mK thermal load	The thermal dissipation and parasitic load at 300 mK shall be no more than 1.6 µW for each array module	
IRD-DETP-R14	Mechanical interface	The detector modules shall mechanically interface to the photometer 2-K structure	

System requirements on the photometer detectors.

3.5.6.2 Spectrometer Detectors

Performance Requirements

Requirement ID	Description	Value	Source
IRD-DETP-R01	Detective Quantum Efficiency at 20 Hz at nominal incident power levels	SW 200-300 µm > 0.6 LW 300-400 µm > 0.6 LW >400 µm as large as possible	
IRD-DETP-R02	Time constant	8 milliseconds (Equivalent to 20 Hz)	
IRD-DETP-R03	Uniformity	NEP spec. shall be met over the whole array Responsivity variations shall be lass than 10% across the array and calibrated to an accuracy of <1% (TBC)	
IRD-DETP-R04	Yield (good pixels)	≥90% for each array	
IRD-DETP-R05	Electrical crosstalk for near neighbour pixels.	Less than the optical cross talk at the output of the cold JFET amplifiers.	
IRD-DETP-R06	Electrical crosstalk any pair of pixels	Requirement is less than 0.1% (TBC) at the output of the cold JFET preamplifiers. Goal is to be less than the optical cross talk.	
IRD-DETP-R07	Detector angular response	SW array: single mode 2Fλ horns LW array : 2Fλ aperture size at 350 µm with oversized wave guide to allow use up to 670 µm. Over-moding is permitted at 350 µm: single mode at 670 µm with 1Fλ aperture.	
IRD-DETP-R08	Spectral response	SW 200-300 µm ≥ 90% LW 300-400 µm ≥ 90% LW>400 µm as large as possible.	

Requirement ID	Description	Value	Source
IRD-DETS-R01	Sampling frequency	The spectrometer bolometer pixels shall be capable of being readout at the rate required by the FTS mechanism and position control system – nominally 80 Hz (TBC)	

Table 3.5-15: Spectrometer detectors performance requirements

System Requirements

Requirement ID	Description	Value	Source
IRD-DETS-R02	Microphonic susceptibility	TBD	
IRD-DETS-R03	EMI susceptibility	TBD	
IRD-DETS-R04	Sensitivity to ionising radiation	TBD	
IRD-DETS-R06	Volume envelope	The detector modules shall fit within a cylinder of diameter 75 mm (goal 60 mm) and length 100 mm.	
IRD-DETS-R07	300 mK thermal load	The thermal dissipation and parasitic load at 300 mK shall be no more than 1.6 μW per module	
IRD-DETS-R08	Mechanical interface	The detector modules shall mechanically interface to the spectrometer 2-K structure.	

Table 3.5-16: Spectrometer detectors system requirements

3.5.7 Beam Steering Mechanism

Performance Requirements

Requirement ID	Description	Value	Source
IRD-BSMP-R01	Maximum throw in chop axis	The BSM shall move the imaged field of view of the detectors by a maximum of ± 2 arcmin on the sky in the ± Y axis of the satellite	
IRD-BSMP-R02	Maximum throw in jiggle axis	The BSM shall move the imaged field of view of the detectors by a maximum of ±30 arcsec (TBC) in the ± Z axis of the satellite	
IRD-BSMP-R03	Minimum step in both axis	The minimum step size in either chop or jiggle axes shall be 2 arcsec	
IRD-BSMP-R04	Frequency of chop	The chop frequency in the chop axis shall be continuously variable or selectable in 16 steps from 0 to 2 Hz for nominal operation and power dissipation. The chop frequency should be capable of reaching 5 Hz with increased power dissipation and settling time.	
IRD-BSMP-R05	Frequency of jiggle	Goal of 1 Hz. Requirement of at least 0.5 Hz	
IRD-BSMP-R06	Holding Position	The BSM shall be capable of moving to and holding indefinitely at any commanded position within its range of movement	
IRD-BSMP-R07	Stability	The angle on the sky must not vary by more than 0.2 arcsec r.m.s (TBC) over 60 sec at the commanded mirror position in the frequency range 0.03 to 25 Hz.	
IRD-BSMP-R08	Repeatability in successive positions	0.2 arcsec	
IRD-BSMP-R09	Position Measurement	The absolute knowledge of the mirror position shall be equivalent to less then 0.1 arcsec (TBC).	
IRD-BSMP-R10	Duty Cycle	The mirror shall settle to within 1 arcsec of its commanded position in less than 25 milliseconds in the chop axis. (90% duty cycle for 2 Hz) Goal is 50 milliseconds for the jiggle axis equivalent to 90% duty cycle.	

Table 3.5-17: Performance requirements on the beam steering mirror.

System Requirements

Requirement ID	Description	Value	Source
IRD-BSMP-R11	Volume envelope	The BSM shall fit within a volume of 130x130x30 mm (TBC) not including its bracket.	
IRD-BSMP-R12	Operating temperature	Nominal operating 4 K. The mechanism shall be capable of operating in a temperature range of 4-300 K	
IRD-BSMP-R13	Thermal isolation	The beam steering mirror structure or mirror temperature shall rise by no more than 1 K (TBC) from the nominal temperature of the surrounding structure after one hour operation in any mode.	
IRD-BSMP-R14	Cold power dissipation	The power dissipation at 4 K shall be no more than 4 mW (TBC) in any operating mode.	
IRD-BSMP-R15	Warm power dissipation	The power dissipation in the warm electronics shall be no more than TBD W when chopping at 2 Hz in any operating mode.	

Table 3.5-18: System requirements on the beam steering mirror.

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3.5.8 Spectrometer Mirror Mechanism and Position Measurement System

Performance Requirements

To illustrate the maximum requirements on the systems design, the goal resolution of 0.04 cm^{-1} is used throughout the rest of this section.

Requirement ID	Description	Value	Source
IRD-SMEC-R01	Linear Travel	*Assumed folding factor of 4 for baseline design and single sided interferograms with short travel beyond zero path difference for phase correction.* Total OPD required 14 cm. Maximum mirror travel required (wrt ZPD position): – 0.32 to +3.2 cm	
IRD-SMEC-R02	Minimum movement sampling interval	Short wavelength band minimum measurement interval of 5 µm is required (equivalent to 20 µm OPD) For long wavelength band the requirement is 7.5 µm (equivalent to 30 µm OPD)	
IRD-SMEC-R03	Sampling step control	The measurement interval must be variable between 5 and 25 µm.	
IRD-SMEC-R04	Scan length	The system shall be capable of starting and stopping a scan at any position within the required scan range	
IRD-SMEC-R05	Dead-time	A goal is to have a dead-time of no more than 10% per scan when taking data at resolution of 0.4 cm^{-1}	
IRD-SMEC-R06	Mirror velocity	For assumed detector response of 20 Hz the maximum required rate of change of the OPD is 0.4 cm s^{-1}. Required max. mirror velocity 0.1 cm s^{-1}. A capability to have mirror velocity of 0.2 cm s^{-1} is desirable and is set as a goal.	
IRD-SMEC-R07	Velocity control	The mirror velocity should be selectable from 0.02 to 0.1 cm s^{-1} – or 0.2 cm s^{-1} if the goal performance is achieved.	
IRD-SMEC-R08	Velocity stability	The mirror velocity shall be within 0.001 cm/s r.m.s. within a band width of 0.03 to 25 Hz over the entire scan range. The velocity from scan to scan shall not vary by more than 1% over a period of 24 hours under nominal operating conditions.	
IRD-SMEC-R09	Position measurement	Required OPD position accuracy is 1/50 of the smallest step size. Simulation confirms that this adds minimal system noise to the	

Requirement ID	Description	Value	Source
		resultant interferogram. Required mirror position measurement accuracy 0.1 µm over +- 0.32 scan range and 0.3 µm thereafter.	
IRD-SMEC-R10	Sampling frequency	The position is sampled at the frequency required for the short wavelength array – i.e.(mirror velocity)/(measurement step size for short wavelength array)	

Table 3.5-19: Performance requirements on the FTS mirror mechanism.

System Level Requirements

Requirement ID	Description	Value	Source
IRD-SMEC-R11	Maximum thermal load onto 4 K during cold operation – mechanism and cold position measurement system.	Under zero-g maximum TBD mW Under 1-g maximum TBD mW	
IRD-SMEC-R12	Maximum envelope	TBD	
IRD-SMEC-R13	Thermometers	At least one thermometer shall be provided on the FTS mechanism. The temperature range of the thermometer shall be 2 to 20 K (TBC). The absolute temperature measurement accuracy shall be 5% (TBC) with a resolution of TBD mK.	
IRD-SMEC-R14	Ground Operation	The mechanism and position measurement system must be capable of full operation on the ground when the instrument is in its normal orientation in the test facility cryostat.	

Table 3.5-20: System requirements on the FTS mirror mechanism

3.5.9 Calibration Sources

3.5.9.1 Photometer Calibration Source

Performance Requirements

Requirement ID	Description	Value	Source
IRD-CALP-R01	Nominal operating output	Equivalent to εT=40 K for 200<λ<700 μm	
IRD-CALP-R02	Operating range	4-80 K for 200<λ<700 μm commandable in 256 (TBC) steps.	
IRD-CALP-R03	Equivalent obscuration of aperture through BSM mirror	<0.2%. Actual size is referred to the telescope secondary mirror image at the position of the beam steering mirror.	
IRD-CALP-R04	Speed of response	Requirement 150 ms Goal 30 ms	
IRD-CALP-R05	Repeatability	RMS better than 1% over 20 operations Drift less than10% over lifetime of the mission.	
IRD-CALP-R06	Operation	Nominally once per hour for no more than 10 seconds	
IRD-CALP-R07	Frequency	Continuously or pseudo continuously variable between 0 and 5 Hz.	

Table 3.5-21: Performance requirements for photometer calibration source

System Requirements

Requirement ID	Description	Value	Source
IRD-CALP-R08	Interface	The calibrator will be integrated into the beam steering mechanism.	
IRD-CALP-R09	Volume envelope	30 x 15 x 10 mm	
IRD-CALP-R10	Thermal isolation	The temperature of the surrounding structure (including the beam steering mirror) shall rise by no more than 1 K after 10 seconds when the calibrator is operated unmodulated at nominal power output.	
IRD-CALP-R11	Operating temperature	4-K	
IRD-CALP-R12	Cold power dissipation	Less than 2 mW when operated unmodulated at nominal power output.	
IRD-CALP-R13	Warm power dissipation	Less than TBD W when operated unmodulated at nominal power output	

Requirement ID	Description	Value	Source
IRD-CALP-R14	Operating voltage	Less than 28 V at input power level of 5 mW	
IRD-CALP-R15	Redundancy	Cold redundancy for the thermal source	

Table 3.5-22: System Requirements for the photometer calibration source

3.5.9.2 Spectrometer Calibration Source

Performance Requirements

Requirement ID	Description	Value	Source
IRD-CALS-R01	Radiated spectrum:	Null the central maximum to accuracy of 5% (goal 2%) [TBC] Replicate the dilute spectrum of the telescope to an accuracy of better than 20% (goal 5%) [TBC] over 200-400 µm.	
IRD-CALS-R02	Beam pattern	Replicate the appropriate beam pattern at the second input port pupil image	
IRD-CALS-R03	Adjustability:	Zero - maximum in 256 steps	
IRD-CALS-R04	Uniformity	The uniformity of the intensity from the calibration source across the second input port pupil image shall be better than TBD%	
IRD-CALS-R05	Repeatability and drift	The output intensity of the calibration source shall drift by no more than 1% over one hour of continuous operation. The absolute change in the output intensity of the source shall be no more than 15% over the mission lifetime	
IRD-CALS-R06	Operation	The calibration source shall be capable of continuous operation for periods of up to 2 hours with no loss of operational performance.	
IRD-CALS-R07	Number of operations	The calibration source shall be capable of up to 12000 operational cycles	

Table 3.5-23: Spectrometer calibrator performance requirements

System Requirements

Requirement ID	Description	Value	Source
IRD-CALS-	Operating Voltage	No more than 28 V DC	

R08		
IRD-CALS-R09	Power dissipation in the focal plane	No more than 5 mW with a goal of 2 mW
IRD-CALS-R11	Envelope	50x50x70 mm (TBC)
IRD-CALS-R12	Thermal Isolation	The surrounding structure of the calibrator shall rise in temperature by no more than TBD K after one hour of continuous operation
IRD-CALS-R13	Operating Temperature	4 K
IRD-CALS-R14	Redundancy	Fully redundant systems shall be provided for the active elements.

Table 3.5-24: Spectrometer calibrator systems requirements

3.5.10 JFET Box

Performance Requirements

Requirement ID	Description	Value	Source
IRD-FTB-R01	Amplifier noise	Requirement better than 10 nV $Hz^{-1/2}$ over a bandwidth of 100 to 1400 Hz Goal 7 nV $Hz^{-1/2}$	
IRD-FTB-R02	RF rejection	The RF filters, as fitted in the box and with the correct harness, connectors and back-shells; shall reject all frequencies from 500 MHz to 10 GHz at –60 dB.	

Table 3.5-25: JFET box performance requirements

System Requirements

Requirement ID	Description	Value	Source
IRD-FTB-R04	Envelope	The JFET/Filter box shall be no more then 300x100x100 mm (TBD)	
IRD-FTB-R05	Dissipation	The dissipation of JFET amplifiers shall be heat sunk to the level 2 cryostat stage. The dissipation shall be no more than 33 mW (TBC) average for all operating modes with the level 2 temperature at 11 K. *Any change in the system design – i.e. changes in the cryostat specification - will lead to a revision of this requirement.*	
IRD-FTB-R06	Operating temperature range	The JFET amplifiers and RF filters shall be capable of operating in with the temperature of the mounting point of the box in the range 4 to 300-K	
IRD-FTB-R07	Mechanical Interface	The FTB shall mount directly to the FIRST optical bench.	
IRD-FTB-R08	Nominal operating temperature	The JFET amplifier and RF filter performance requirements shall be maintained with the temperature of the mounting point of the box within the range 4 to 20 K.	
IRD-FTB-R09	First natural frequency	The first eigenfrequency of the FTB on its mounts shall be greater than 100 Hz (TBC) with a gaol of > 150 Hz	

Table 3.5-26: JFET box system requirements

3.5.11 RF Filter Modules

Performance Requirements

Requirement ID	Description	Value	Source
IRD-RFM-R01	RF rejection	The RF filters, as fitted in the box and with the correct harness, connectors and back-shells; shall reject all frequencies from 500 MHz to 10 GHz at –60 dB.	

Table 3.5-27: RF Module performance requirements

System Requirements

Requirement ID	Description	Value	Source
IRD-RFM-R02	Envelope	The filter modules shall be no more than TBD	
IRD-RFM-R03	Dissipation	The RF filters will be passive components with no dissipation.	
IRD-RFM-R04	Operating temperature range	The RF filters shall be capable of operating in with the temperature of the mounting point of the box in the range 4 to 300-K	
IRD-RFM-R05	Nominal operating temperature	4 K	
IRD-RFM-R06	Mechanical interface	The RF modules shall be mounted from the 4-K common structure.	
IRD-RFM-R07	First natural frequency	The first eigenfrequency of the filter modules shall be greater than 200 Hz (TBC) with a gaol of > 300 Hz	

Table 3.5-28: RF Module system requirements

3.5.12 Instrument Simulators

3.5.12.1 FPU Simulator

Performance Requirements

Requirement ID	Description	Value	Source
IRD-FSIM-R01	Function	The FPU simulator shall allow the Warm Electronics to be switched on and operated in the absence of the cold FPU unit.	
IRD-FSIM-R02	Analogue Outputs	The simulator shall return to the Warm Electronics analogue signals within the range expected for each signal channel to allow the basic function of the analogue Warm Electronics and the instrument commanding to the verified	
IRD-FSIM-R03	Control loops	The simulator shall return to the Warm Electronics the appropriate signals to allow the basic function of any control loops to be verified.	

Table 3.5-29: FPU simulator performance requirements

System Requirements

Requirement ID	Description	Value	Source
IRD-FSIM-R04	Harness	The FPU simulator shall provide a dedicated harness that interfaces directly to the appropriate Warm Electronics unit	
IRD-FSIM-R05	Prime and Redundant Interfaces	The FPU simulator shall provide simulation and interfaces to both the prime and redundant channels of the Warm Electronics.	

Table 3.5-30: FPU simulator system requirements

3.5.12.2 DRCU Simulator

Performance Requirements

Requirement ID	Description	Value	Source
IRD-DSIM-R01	Function	The DRCU simulator shall allow the DPU to be operated in the absence of the DRCU and cold FPU.	
IRD-DSIM-R02	Outputs	The simulator shall return to the DPU the appropriate digital responses to allow the verification of the instrument commanding and all on board software functions including autonomy modes.	

Table 3.5-31: DRCU simulator performance requirements

System Requirements

Requirement ID	Description	Value	Source
IRD-DSIM-R03	Harness	The DRCU simulator shall provide a dedicated harness that interfaces directly to the DPU	
IRD-DSIM-R04	Prime and Redundant Interfaces	The DRCU simulator shall provide simulation and interfaces to both the prime and redundant channels of the DPU.	

Table 3.5-32: DRCU simulator system requirements

3.6 Warm Electronics

To Be Written