Rutherford Appleton Laboratory

Procurement specification for the SPIRE calibration cryostat

Issue 1.2

August 10th 2001

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Document Change Record

Date	Issue	Pages	Comments
06/04/2001	1.1	All	Changes Bar marked Drawings renumbered Correction to lambda bath operating temperature. Relaxed thermometry requirements
10/08/2001	1.2	6-9	Temperature requirements inconsistencies corrected & refined and hold-times.

Contents

The SPIRE calibration Cryostat

1 Scope of the document

This document describes the requirements for the detailed design and manufacture of the SPIRE calibration cryostat.

2 Documents

2.1 Applicable documents

	Title	Author	Reference	Date
AD 1	SPIRE General arrangement drawing	M. Harman	A1-KG0710-001	
AD 2	SPIRE Test facility Cryostat drawing	M. Harman	A1-KG0710-002	
AD 3	SPIRE Instrument Interface drawing	M.Harman	A1- KG0710-010	
AD 4	SPIRE facility room layout	D. Smith	SPIRE-RAL-NOT-000515	08-NOV-2000
AD 5	Vacuum Windows Optical Filters and cold calibration interface details	M.Harman	A1- KG0710-003	06-April-2001

3 Glossary

AD	Applicable document	TBC	To be confirmed
CDR	Critical design review	TBD	To be defined
CQM	Cryogenic qualification model	TFCS	Test facility control system
DDR	Detailed design review	WE	Warm electronics
ESA	European space agency		
FIRST	Far infrared space telescope		
FIR	Far infrared		
FPU	Focal plane unit		
PFM	Prototype flight model		
NA	Not applicable		
NASA	National aeronautical space administration		
PFM	Protoflight model		
QMW	Queen Mary and Westfield college		
RAL	Rutherford Appleton laboratory		
RD	Reference document		
SPIRE	Spectral and photometric imaging receiver		

4 Introduction

In 2007, the European space agency mission named Herschel will be launched approximately 1.5 million km from the earth on an Ariane-5. Herschel is part of ESA's Horizons 2000 programme and will be implemented with the collaboration of NASA. The Herschel satellite will carry three Science Instruments called HIFI, PACS & SPIRE.

The Rutherford Appleton Laboratory is playing a key role in the development of the Instrument called SPIRE (Spectral and Photometric Imaging REceiver). SPIRE will utilise a super fluid helium cryostat similar to the technology used on the successful ISO mission and will have a lifetime of approximately 3 years.

Prior to the launch of SPIRE, several development models of the instrument will be built which will require testing & qualification in a terrestrial environment. Part of the test & qualification programme will commence in early 2002 at the Rutherford Appleton Laboratory and will require a cryostat to emulate the spacecraft cryogenic environment.

The SPIRE Calibration cryogenic system performs a critical role providing the necessary cooling for a low noise receiver instrument. It is vital for successful operation of the instrument that the cryogenic system provides appropriate thermal cooling capacity and stability, mechanical robustness and a high degree of reliability. Furthermore the design must be sufficiently simple to ensure minimum and straightforward instrument integration, operation and maintenance.

This specification provides a summary of the design requirements and although preliminary in a number of aspects, for example thermal heat loads, mechanical deflections tolerances and dimensional constraints need to be refined, it represents the envisaged structure and design methodology.

5 Requirements

The basis of the calibration cryostat can be divided into a number of key requirements as shown on drawing AD2 below &. Associated with each requirement heading are a series of objectives that require to be met.

5.1 General.

- *Accommodation:* - The calibration cryostat must accommodate the SPIRE instrument, cold calibration blackbody source, electronics units (JFET/Filter boxes), instrument wiring harness & associated mounting frame (Ref. document AD3).

- *Windows:* - The Rutherford Appleton Laboratory will provide a Vacuum window (signal input window). The heat load from the 300K environment will be intercepted at the different temperature stages utilising a series of infrared (IR) radiation blocking filters. Each filter will be optimised to ensure that it does not compromise receiver system sensitivity and hence observing performance. The filters will be designed and manufactured by the astrophysics dept. at Cardiff University (formerly Queen Mary and Westfield College, London). The Cryostat manufacture can assume that more than 90% of the thermal IR from the 300K environment will be filtered at 77K. More detailed estimates of the radiative heat load are available if required.

- *SPIRE instrument wiring requirements:* - A wiring harness will be supplied by RAL for the Instrument wiring. The routing of the wiring harness is still to be specified. All connections from the SPIRE Instrument, JFET boxes, & calibration black body will be thermally heat sunk onto 9K Thermal Shield. The Harness will contain 14 off 100 pin Vacuum compatible electrical connectors that will be terminated on the vacuum case. The wiring Harness may not be available at the time of Cryostat acceptance testing so a list of estimated heat loads can be provided if required.

5.2 Design

- *Detailed design:* - RAL has performed preliminary design analysis to ensure that the conceptual cryostat design proposed in document AD2 is feasible, although it will be the suppliers' responsibility to satisfy themselves that all the requirements of this specification can be met. The supplier will provide RAL detailed manufacturing drawings. Manufacturing will not commence without the written approval of RAL.

- *Detailed design review:* - A detailed design review shall take place prior to the manufacture with the supplier & members of the RAL SPIRE team present. Detailed manufacturing drawings will be supplied to RAL 1 week prior to the detail design review RAL will have the opportunity to comment & change the design as required.

- *Pressure Vessel design & construction code of practice:* - All vessels will be designed & constructed in accordance with BS5500 cat II although approval is not mandatory.

- *Over pressure device:* -An over pressure device (burst disc or drop off plate) must be installed on the 4.2K vessel & vacuum vessel to prevent the chamber exceeding design pressures and invoking a catastrophic failure of any vessel.

- *Vacuum connections:* -All vacuum fitting must be compliant with standard KF or ISO vacuum flange fitting.

- *External Finish:* - The cryostat external faces will be left natural. The chamber should be cleaned prior to delivery.

- *Internal Finishes:* - All internal surfaces must be clean and where appropriate the emisivity of these surfaces is to be reduced to enhance cryogenic performance.

5.3 Cooling.

Cooling the instrument to ≤ 4.2 K & ≤ 1.7K and achieving appropriate temperature stability is a critical objective if optimum instrument performance if to be attained and maintained and is a function of the overall system efficiency. In order to achieve good cooling efficiency we must first identify all sources of significant heat input. With the SPIRE cryostat the areas that contribute to the system thermal loading are:

- Radiation from the surrounding environment.
- Conductive heat flux from mechanical support structures, electrical wiring.
- Power dissipation from electronic components that form part of the instrument.
- Power dissipation from Instrument sorption cooler & associated components.

To satisfy the above parameters for the successful calibration of the instrument cryostat with the proposed construction.

- *Baseline 77K cooling:* -A Vessel will be provided for the interception of conductive & radiative heat loads. This vessel will be filled with liquid Nitrogen via an external tank. A suitable method of restricting the ingress of air into the tank must be provided on the tank vent. I.e. non return valve on vent.

- *Baseline 9K cooling:* A 9K shield must be provided that encloses instrument. The function of this shield is to emulate the cold environment that the instrument will see whilst on the spacecraft during orbit. This shield will be actively cooled utilising the exhaust gas from the 4.2K Vessel. The shield temperature must be maintained to within a temperature of ±5K of the operational temperature. A heater may be required in the 4.2K vessel to provide the adequate gas flow to achieve the specification.

- *Baseline 4.2K cooling:* - A helium vessel will be provided with a flexible heat pipe mounted onto the base. The helium source will be provided from an external 200 litre Dewar located on the floor (ref document AD4) via a vacuum insulated syphon tube, which will be supplied with the cryostat. The connection for the syphon tube will be ø12.7mm min to the main 4.2K helium bath. During operation, the heat pipe will be filled with helium. The flexible heat pipe will be compliant to allow attachment onto the SPIRE Instrument during cryostat integration. The heat load onto the 4.2K heat pipe from SPIRE can be provided if required. The Heat pipe will also be compliant enough so as not to affect the alignment of SPIRE during cool down.

- *Baseline 1.7K cooling:* - A super fluid helium vessel will be provided with a flexible heat pipe. The super fluid helium source will be provided from the main 4.2K-helium bath, which will be generated using a lambda point pumping arrangement. During operation, the heat pipe will be filled with super fluid helium. The flexible heat pipe will be compliant to allow attachment onto the SPIRE Instrument during cryostat integration. Estimated heat load budget from SPIRE onto the 1.7K can be supplied if required. The heat pipe will also be compliant enough so as not to affect the alignment of SPIRE during cool down. The supplier must ensure a filter is installed to protect the 4.2K He feed into the needle valve to prevent blockage. The cryostat supplier will specify a suitable manufacturer & manufacturing specification of a suitable pump & any other device for the generation of the super fluid helium.

- *Stability:* - Provide a 1.7K stage temperature stability of < 17mKhr^{-1} with a goal of 1.14mKhr^{-1}. Ensure that temperature drift rates at the 4.2 K cold connections do not exceed 0.26Khr^{-1}. Ensure that temperature drift rates at the 9 K cold connections do not exceed 70mKhr^{-1}.

5.4 Physical mass and size compliance.

- *Size:* - The cryostat must be able to fit though the test facility door. This limits the total package to an envelope size of 1.8m width x 2.5m height.

- *Max head height:* - The cryostat must be able be commissioned & operate fully when installed in the test facility (e.g. removal of fill tubes, He probe etc) the max head in the test facility room is 2.7m.

5.5 Operational issues.

- *Cleanliness:* - The cryostat will be delivered to RAL clean & compatible for use in a class 1000 clean room. The internal surfaces of the cryostat should be cleaned using an approved process. All vacuum testing of the cryostat must use an oil-free system to prevent hydrocarbon contamination.
- *Sorption:* -A carbon sorption trap & sorption heater will be provided which is mounted to the base of the 4.2K vessel. for the active absorption of vacuum contaminates
- *Evacuation and cool down:* - Total cryostat evacuation and cool down time (from room temperature) should not exceed 3 days. The cryostat must have the ability to be evacuated to a pressure of 10^{-6}mbar before filling with cryogen. It is expected that the cryostat will run continuously for up to three months without letting up to ambient pressure.
- *Precool:* - If the supplier recommends the use of LN2 to pre-cool the 4.2K vessel a suitable means of evacuating LN2 from the vessel must be provided i.e. blow out tube/heaters.
- *Cryogen Hold Time* - The cryogen tanks should be sized to allow the following hold times as a minimum:
  - 72 hours with the instrument switched off at operating temperatures (i.e.4.2K and 1.7K).
  - 48 hours to allow full operational cycle of the ^{3}He cooler i.e. recharge, followed by 2 hours recovery, followed by 46 hours operation. The 1.7K Pot will be refilled prior to the cooler recharge.
- *Reliability:* Repeated thermal and vacuum cycling of the cryostat structural components (cooling pipes, vacuum vessel, windows etc.), should not cause catastrophic system failure. The system should allow 1000 cycles.
- *Transportation:* - The cryostat must be capable of being safely transported, e.g., from construction location to operational site. The system should be able to withstand and survive a 3g-shock loading. The use of warm transit fixing to support cryogenic tanks during transportation is acceptable.
- *Cryostat Warm up:* Heaters will be provided on the 4.2K and LN2 vessels to minimise the time taken to remove SPIRE from the cryostat.

5.6 Cryostat Control & Instrumentation

- *Instrument electrical interfaces:* 3 fabricated flanges will be provided on the vacuum vessel & associated closure plate will be provided for the Instrument electrical connectors.
- *Cryostat Instrumentation electrical interfaces:* - WWW Fisher, DBEE series connectors should be used for electrical connectors for the cryostat control & instrumentation. The supplier shall provide both mating halves.
- *Shielding requirements RF:* - To prevent electromagnetic interference to the SPIRE instrument, all instrumentation wiring within the cryostat must consist of twisted pairs and/or screened.
- *N2 level sensing:* 2 capacitive LN2 level probes will be supplied which will be permanently fixed inside the vessel.
- *4.2K Cryogenic He level sensing:* -Level sensing will be performed using a demountable, superconducting resistive probe.
- *1.7K Cryogenic vessel level sensing:* - Temperature sensors will be used. See below.
- *Temperature sensing* : Appropriate cryogenic thermometers will be used to allow the temperature to be monitored from 300K to the operating temperature. The minimum number and locations of the sensors will be specified by RAL in table 1. Additional sensors may be fitted by the supplier, as required.

Table 1: Location of cryostat temperature sensors

Ref. No.	Location	Position	No Off	Min Temp Required (K)	Temp Range (K) Min	Temp Range (K) Max	Cold Temperature Accuracy (+/-K)
1	77K Shield	End cap 1	1	*70*	60	325	1
2		End cap 2	1	*70*	60	325	1
3		Filter Flange	1	*70*	60	325	1
4	9K Shield	Inlet Pipe	1	*8*	4.2	325	0.25
5		Outlet Pipe	1	*8*	4.2	325	0.25
6		End cap 1	1	*8*	4.2	325	0.25
7		End cap 2	1	*8*	4.2	325	0.25
8		Cylinder End 1	1	*8*	4.2	325	0.25
9		Cylinder Centre	1	*8*	4.2	325	0.25
10		Cylinder End 2	1	*8*	4.2	325	0.25
11		Filter Flange	1	*8*	4.2	325	0.25
12	9K Support Frame	Vacuum Vessel Standoff 1	1	*8*	4.2	325	0.25
13		Vacuum Vessel Standoff 2	1	*8*	4.2	325	0.25
14		Vacuum Vessel Standoff 3	1	*8*	4.2	325	0.25
15		Vacuum Vessel Standoff 4	1	*8*	4.2	325	0.25
16	9K Interface Plate	Photo JFET Enclosure	1	*8*	4.2	325	0.25
17		Spec JFET Enclosure	1	*8*	4.2	325	0.25
18		FPU Foot 1Interface	1	*8*	4.2	325	0.25
19		FPU Foot 2 Interface	1	*8*	4.2	325	0.25
20		FPU Foot 3 Interface	1	*8*	4.2	325	0.25
21		Harness Sink - RF Filters	1	*8*	4.2	325	0.25
22		Harness Sink - Photo JFET	1	*8*	4.2	325	0.25
23		Harness Sink - Spec JFET	1	*8*	4.2	325	0.25
24	4.2K Stage	Vessel Top	1	*3*	1.4	325	0.05
25		Vessel Bottom	1	*3*	1.4	325	0.05
26		FPU Level 1 Strap interface	1	*3*	1.4	325	0.05
27	1.7K Stage	Vessel - Bottom	1	*1.6*	1.4	325	0.01
28		FPU Box Strap interface	1	*1.6*	1.4	325	0.01
29		FPU Pump Strap interface	1	*1.6*	1.4	325	0.01
30		FPU Evap Strap interface	1	*1.6*	1.4	325	0.01
31		Vessel - Top	1	*1.6*	1.4	325	0.01
TOTAL NUMBER OF SENSORS:			31				

6 Acceptance testing

6.1 Vacuum testing

- The supplier should demonstrate that the cryostat is capable of reaching 10^{-6}mbar from atmospheric pressure within 24 hours with the SPIRE instrument in place.

6.2 Cryogenic testing

- *Demonstration of cryogenic endurance:* - The supplier must be able to demonstrate that the cryostat will hold temperature for the specified times without refilling the cryogen tanks with specified loads on each stage.

6.3 Installation

- The supplier will deliver the cryostat to the SPIRE test facility clean room at RAL where it will be installed by the RAL test facility team.

6.4 Commissioning

- RAL will conduct commissioning trials after installation to be satisfied that the cryostat as delivered meets the required performance.

7 Schedule

The SPIRE project has formally agreed milestone dates that have to be met if a launch in 2007 is to be achieved. Testing of the SPIRE instrument is planned to start in early 2002 and cannot proceed without a completed and commissioned cryostat. It is therefore necessary that the cryostat be delivered to RAL by autumn 2001. The contractor should be able to demonstrate that they can meet this delivery date. A schedule showing the key activities and milestones will be provided with the quotation.

8 Quality Assurance

SPIRE is an ISO9000 project and has to demonstrate that its quality control procedures are being followed as defined by the RAL product assurance dept. The SPIRE project does not require that the contractor is ISO9000 accredited, although the contractor should be able to demonstrate that quality control procedures are in place and being followed. The SPIRE project may wish to review the reports from key inspection points. The SPIRE project should be notified of all major non-conformances and changes to the agreed design. A certificate of conformance will be required as part of the delivery to RAL.