Herschel/SPIRE

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SPIRE – STRUCTURE SUBSYSTEM SPECIFICATION

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Change Record

ISSUE	Date	Brief description of change
0.1	4 June 2000	Creation of the document
1.0	13 June 2000	Official issue
1.1	1 October 2000	Draft revision, based upon Review of SPIRE Sub-system Specification Documents by B. Swinyard, 10 August 2000
1.2	05-November-2000	Continued revising the document conform following generic sub system specification
1.3	29 November 2001	Update of the document
1.4	10 July 2002	Update of document for Thermal Busbar DDR
2.0	26 November 2002	Update of document to reflect design – update of pictures and removal of references to shutter.

Table of contents

1. Scope of the document

This specification defines the requirements applied to the performances, the design and the qualification of the SPIRE structure. It is applicable to the STM, CQM, PFM and the FS. This description gives an outline of the design of the instrument together with the specification of its capabilities. Furthermore, the compliance of this design with the various requirements as stated in the instrument requirements documents and the instrument interface document part A and B are compared. All interfacing subsystems are listed together with the applicable ICD's. This is for downward compatibility and traceability.

2. Documents

2.1. All documents are listed in the Figure 3.2 of the CIDL. Applicable documents

2.2. Glossary

All terms are listed in the CIDL.

3 Subsystem description

The contents of the various subsections are structured as per the following:

- **General Overview:** Explaining how the structure looks like and how it works. This includes how it fits in the overall system design, using block diagrams
- **Sub-system Design**: Gives a more detailed description of the design of each of the components within the sub-system.
- **Mission profile:** Gives the expected lifetime of the structure including numbers of operations (tests) it will go through for each of the models. This includes transportation.
- **Product Tree:** This tree lists all the components that are delivered and by whom for each instrument model.
- **The Requirements:** Down flow from AD01 and AD02.

3.1 General Overview

The SPIRE structure consists of a monocoque shell with a central optical bench. The structure is mounted on a fixed point (cone-shaped), suppressing translation in all directions. This fixed point is located on the corner of the optical bench. On the other side of the instrument (+Z direction) two A-frames are mounted suppressing each translation in the plane of the frame itself. All in all this results in a kinematic suspension with as a fixed reference with regard to the HERSCHEL optical bench, the cone.

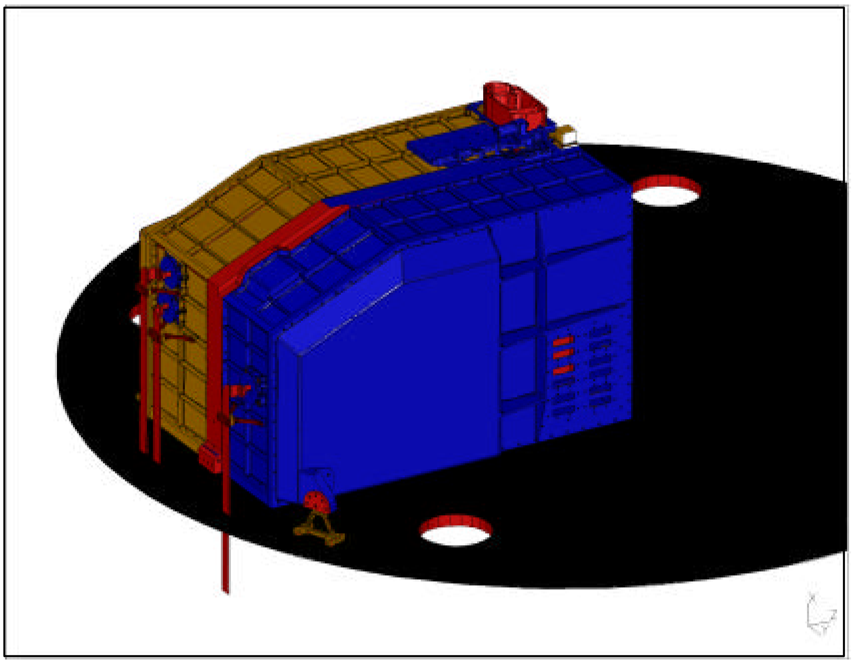


Figure 3.1-1: View of the outside of the instrument – Common Structure + Mounting

As said before the SPIRE instrument consists of a monocoque shell holding a bending stiff, internal, SPIRE optical bench. This optical bench supports a photometer and a spectrometer. All parts of these two sub-instruments are mounted on the SPIRE optical bench. See figure 3.1-2 for the photometer side of the optical bench, including IR-beams. The shutter is mounted at the bean entry of the instrument on the outside.

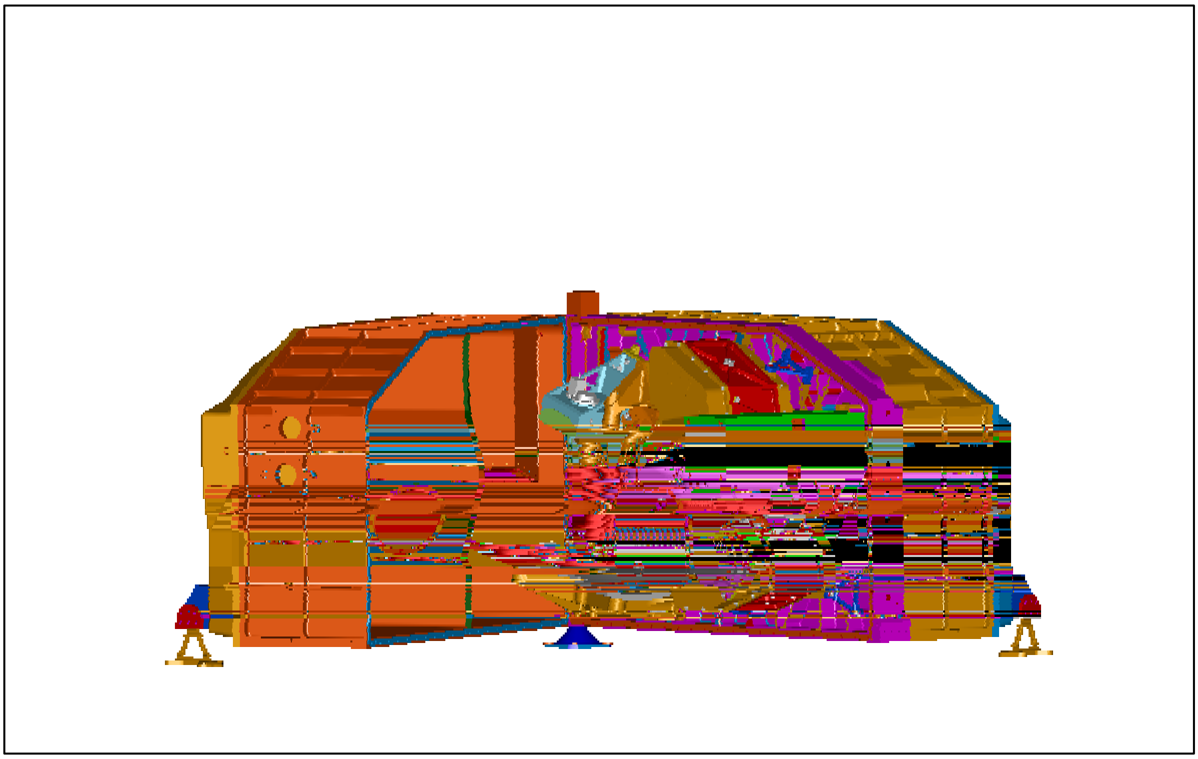


Figure 3.1-2: View of the inside of the instrument – photometer side, cover taken off

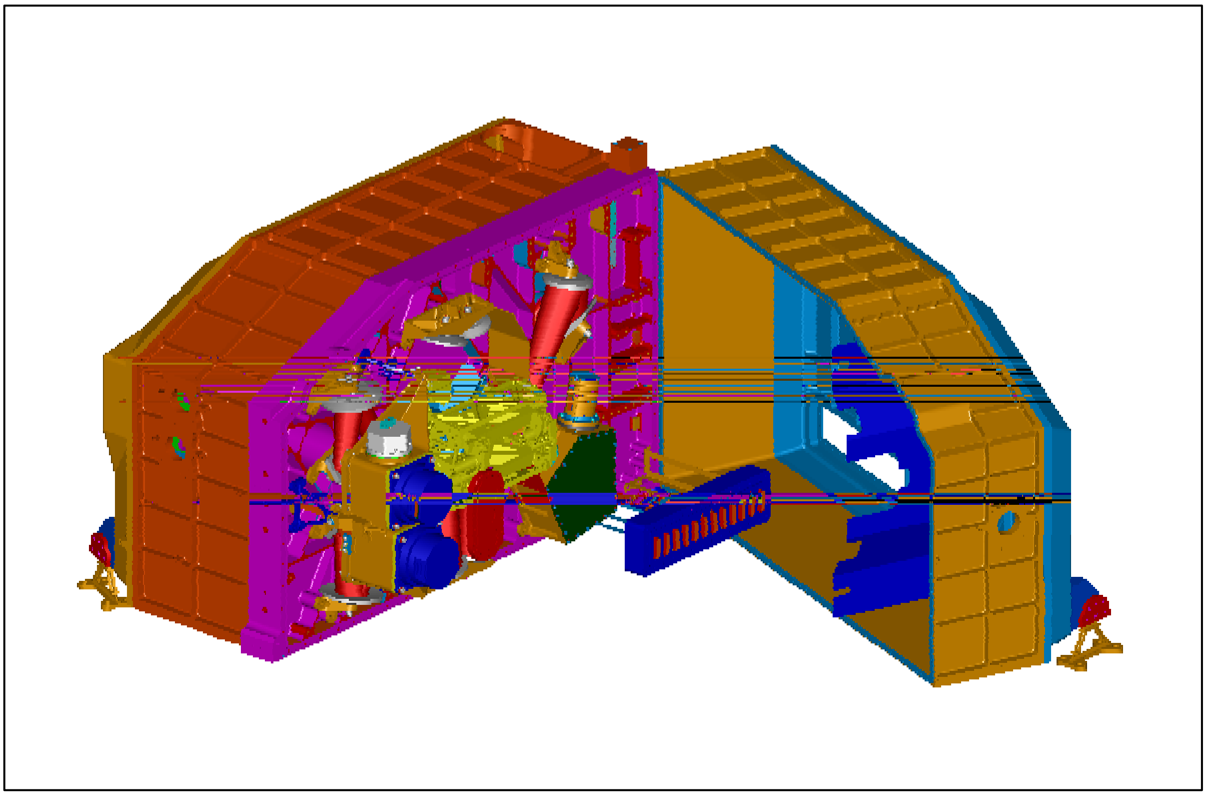
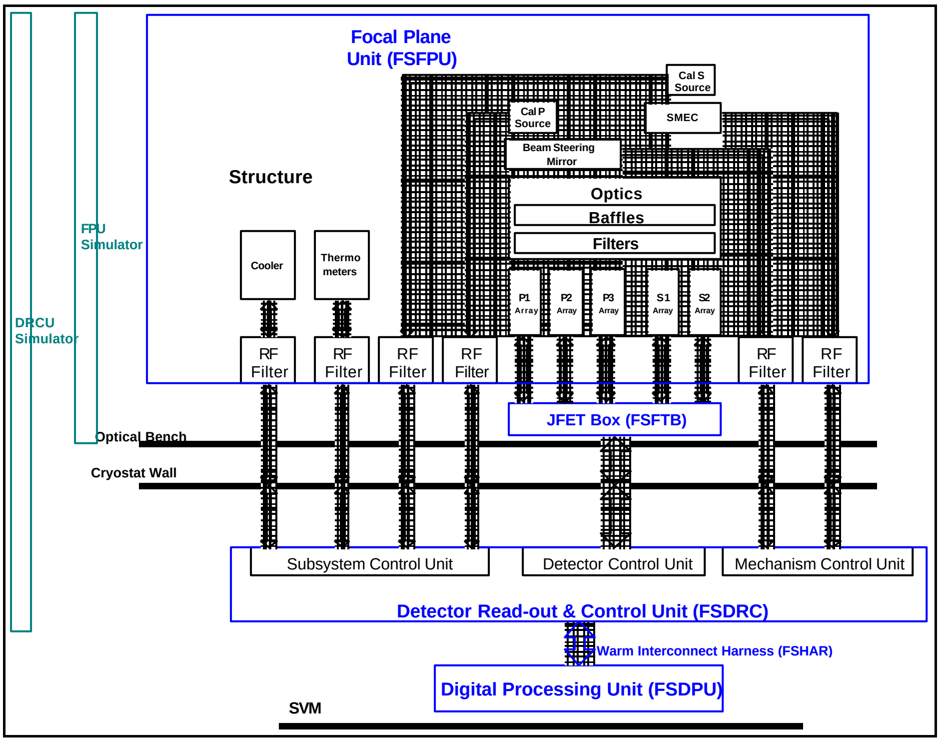


Figure 3.1-3: View of the inside of the instrument – spectrometer side, cover taken off

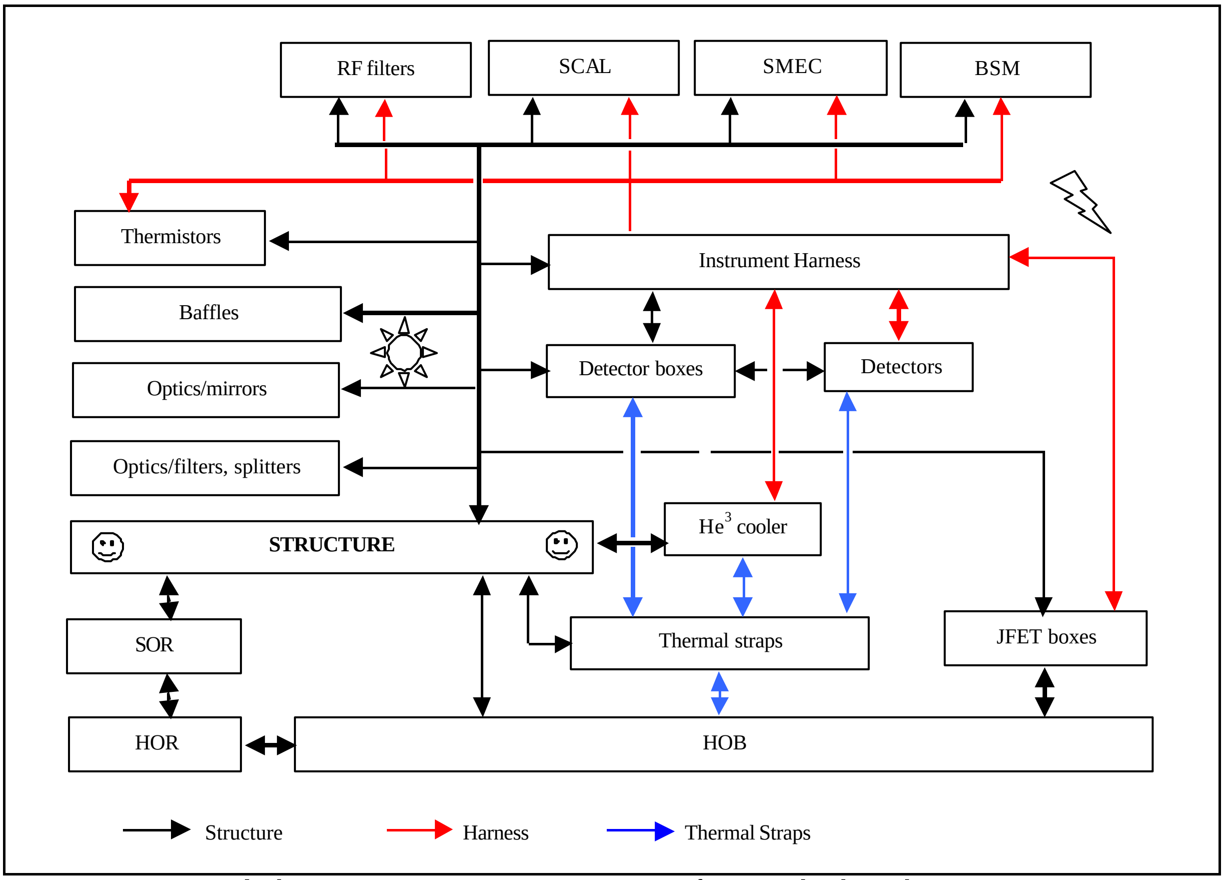
The instrument is divided into different temperature zones. The reason for this is the relative high interface temperature of the HERSCHEL optical bench and the low operating temperature of the detectors inside the instrument. The interface temperature is 6-10 Kelvin where the operating temperature of the detectors is ~0.3 Kelvin. The temperature zones in between are the temperature of the monocoque structure with the optical bench at ~4 Kelvin and the boxes holding the detectors, filters and dichroics at ~2 Kelvin.

Hereafter the block diagram is given, showing the structure as part of the whole system.



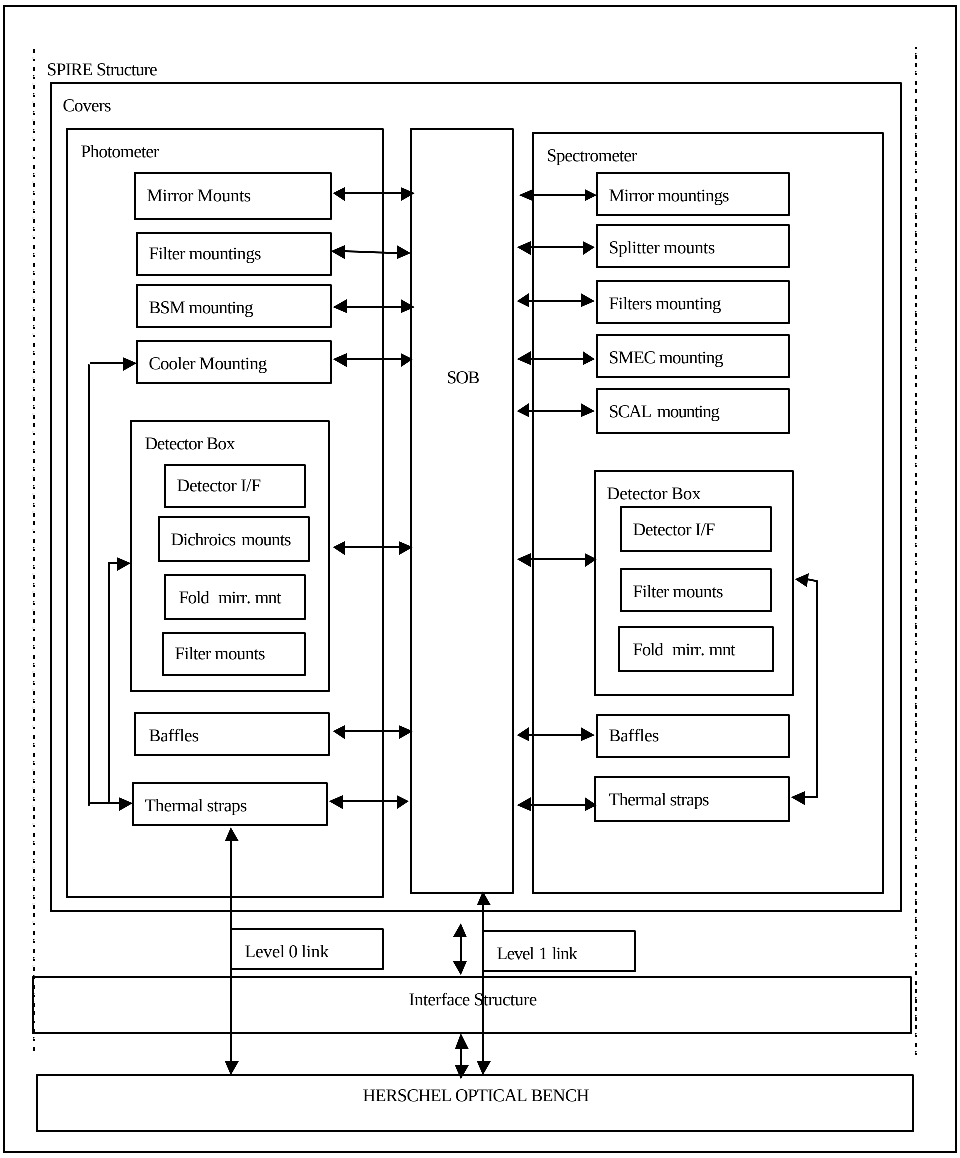
Block Diagram 3.1-1: SPIRE system

In the block diagram listed below the, many, interface with the various sub-systems is shown.



Block Diagram 3.1-2: SPIRE structure interfacing with other subsytems

In the block diagram listed below, the various components making up the structure are listed with the internal relationships.



Block Diagram 3.1-3: SPIRE structure, relations between structural components

3.2 Sub-system Design

The SPIRE structure is part of the SPIRE FPU and its place within the FPU is outlined in the block diagram 3.1-2. Here after the various components, together forming the design of the structure are listed and briefly addressed.

3.2.1 SPIRE structure - RF sealing

As stated in section 3.1 the structure uses a monocoque shell and an optical bench to hold all different parts of the instrument. The monocoque shell also serves as RF-attenuator/shield. For this all openings/seams in the instrument need to be closed such that the instrument works as a Faraday cage attenuating the RF radiation sufficiently in the specified frequency bands. For the signal and control wiring filters will be used to ensure proper operation/functionality of the electronics. An example of an RF-seal to be used in between the joints of the common structure panels. There will be a one piece seal strip that is sandwiched into grooves in the cover walls and in the cover tops. MSSL is responsible for implementing the RF-attenuation with regard to the structure. In principle the consortium as a whole is responsible for the RF-shielding of the instrument

3.2.2 Straylight

The straylight will be attenuated as much as possible by utilising filters, black material, labyrinths and baffles where needed. The joints will have a small tight labyrinth as shown in figure 3.2.1-1. At the entry of the instrument the incoming IR beam will be filtered, excluding as much as possible the unwanted wave lengths. Inside the instrument (4 K environment) the beam will pass baffles, filters and finally, after being reflected via mirrors, end inside the detector boxes falling onto the detector noses. The proposed stray-light baffles around the thermal straps entering the common structure or the detector boxes will look like the one outlined in figure 3.2.2-1. (See for more details RD7 and RD8). MSSL is responsible for implementing the straylight shielding. RAL is responsible for the straylight modelling and advises MSSL on the implementation.

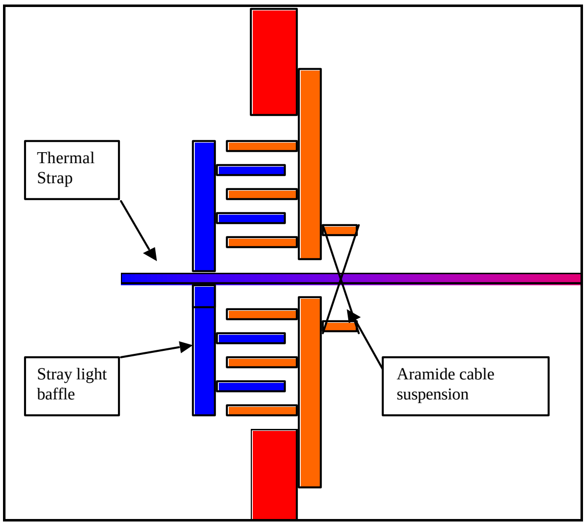
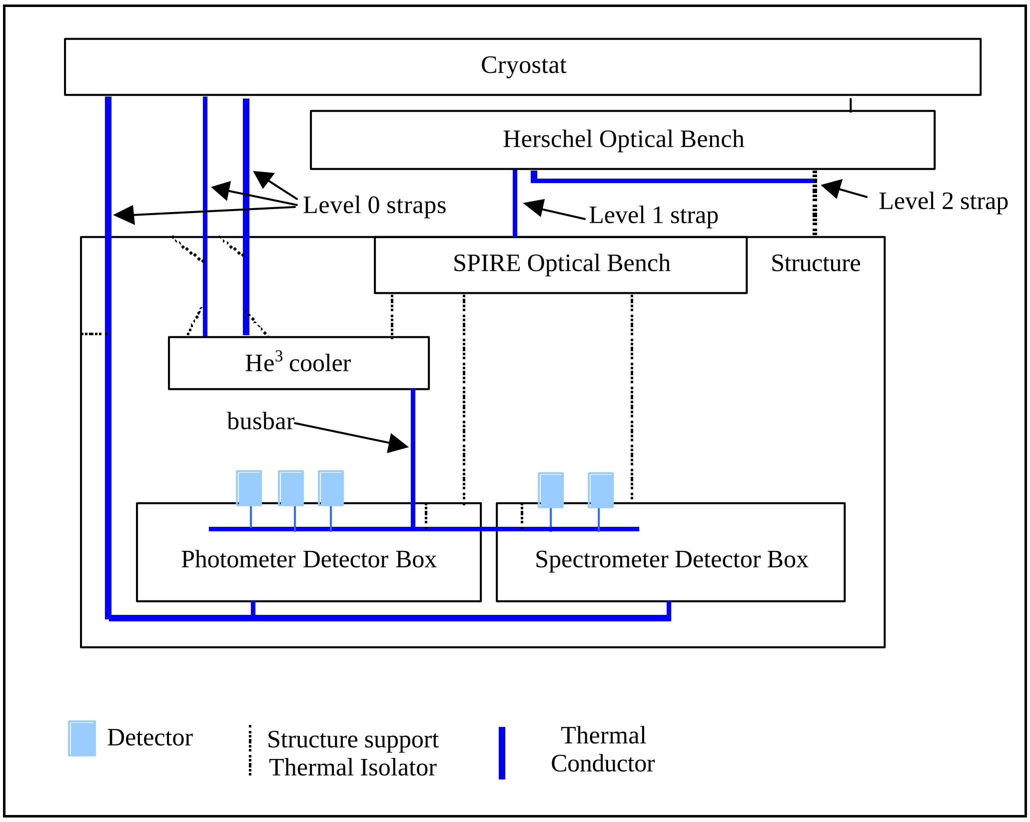


Figure 3.2.2-1: Outline of the stray-light baffle concept for thermal straps.

3.2.3 Thermal design

The various parts of the instrument will be connected with thermal straps to heat sinks inside the cryostat (~2 K and ~4 K). The detectors, mounted on the detector boxes, will be cooled using a thermal busbar connected to a helium-3 fridge. MSSL responsibility is manufacture and integration of the straps. The design and development responsibility is shared between CEA, RAL, QMW and MSSL.

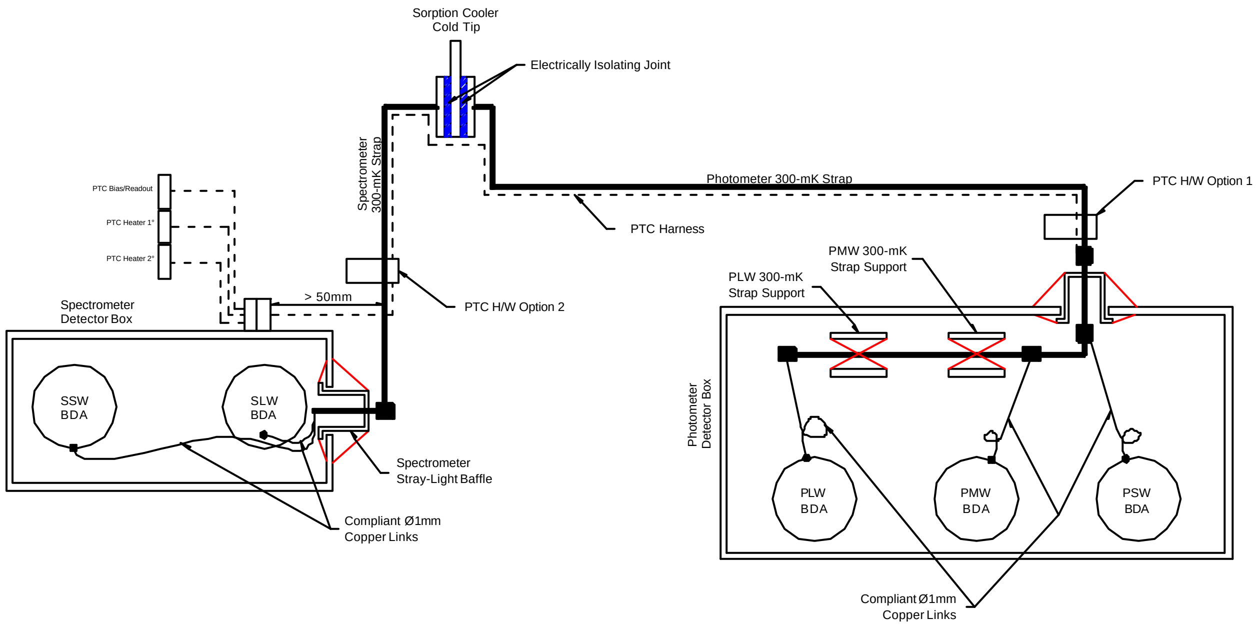
The block diagram, listing the various thermal components in more detail than 3.1-3 does is listed hereafter in 3.2.3-1.



Block diagram 3.2.3-1: All thermal control hardware (except surface finishes)

3.2.3.1 300mk Strap System

The 300mK strap subsystem links the ^{3}He cooler tip with all five detector arrays in the SPIRE instrument. The straps must have a high degree of thermal isolation fro m warmer structure while at the same time be able to withstand high levels of launch vibration with complete reliability. In order to fulfill these requirements, a Kevlar suspension system has been developed to support the 300mK straps. The thermal interfa ces for the 300mK straps to the detectors are inside the 2K detector boxes. The 300mK straps must be fed from the 4K environment of the cooler tip, through the 2K detector box walls, into the 2K environments of the photometer and spectrometer detector boxe s. Therefore a light baffle has been developed, based on the Kevlar support idea, which supports the bus bars as they pass through the detector box walls, while at the same time providing a high degree of stray light attenuation.



Block diagram 3.2.3-2 Block diagram of 300mK strap sub-system.

The straps are shown in bold black lines in block diagram 3.2.3-2.

3.2.4 Grounding

The instrument will be electrically isolated from the HERSCHEL optical bench. The thermal straps will be electrically isolated from the cryostat. See for an outline of the baseline grounding scheme figure 3.2.4-1.

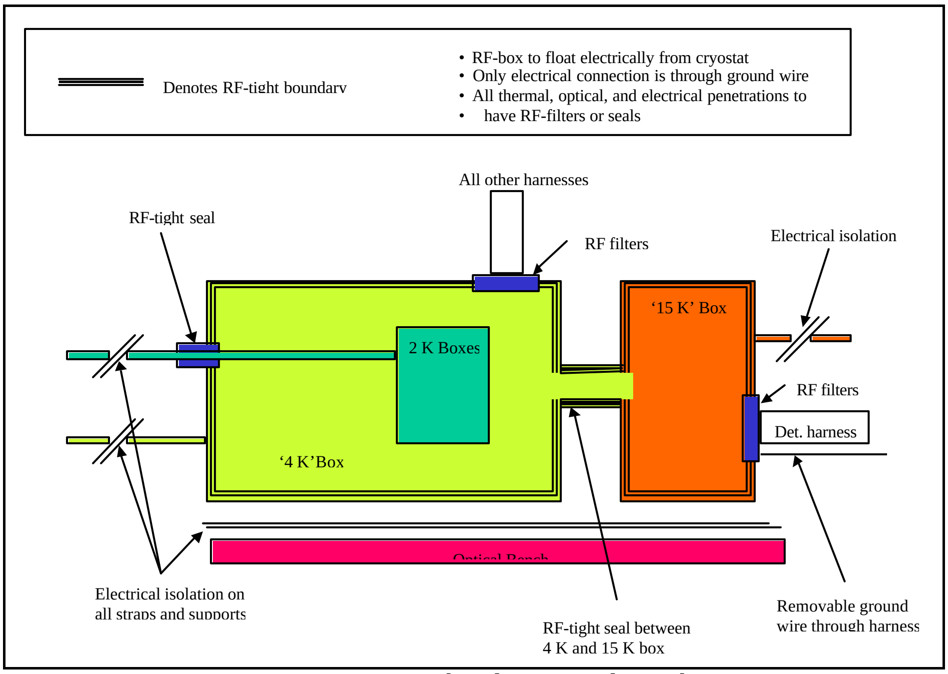


Figure 3.2.4-1: SPIRE baseline grounding scheme.

The grounding scheme is a consortium responsibility. The electrical isolation requirements will be defined by a consortium (RAL, ATC, QMW, JPL, LAM leading), and implemented by the sub-systems.

3.2.5 SPIRE optical design

Hereafter the topology of the optical layout of the instrument is given. First, the photometer side of the instrument is outlined (Figure 3.2.5-1), followed by the spectrometer side (Figure 3.2.5-2). The optical design is not a MSSL responsibility its design however defines in many ways the structure. Therefore all optical components are pictured in the two below listed figures. All relative positions of the components (following the light path) are correct.

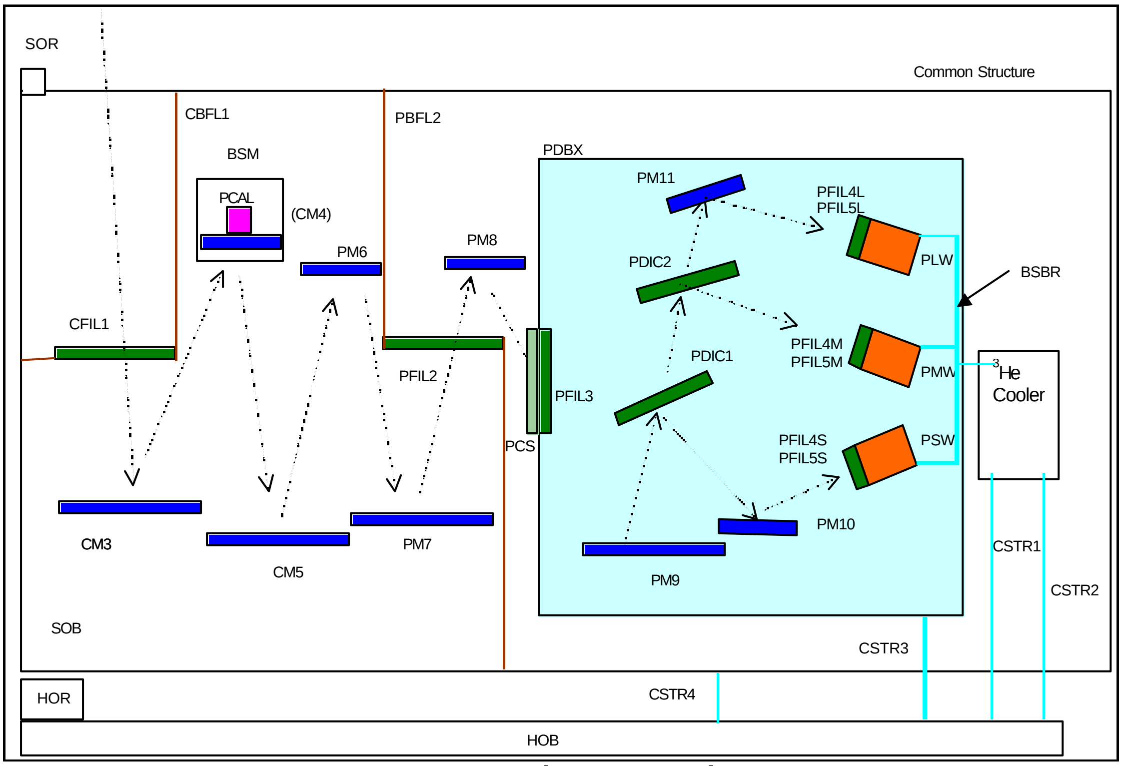


Figure 3.2.5-1: Photometer topology

Where :

CFIL1	Common Filter 1 (entry 4 K enclosure)
CM3-5	Common Mirror 3-5
HOB	Herschel Optical Bench
HOR	Herschel Optical Reference
PCAL	Photometer CALibrationsource
PCS	Photometer Cold Stop
PDBX	Photometer Detector BoX
PDIC1	Photometer DIChroic 1
PDIC2	Photometer DIChroic 2
PFIL2	Photometer FILter (entrance PDBX)
PFIL3	Photometer FILter 2 (4 K-2 K enclosure)
PFIL4L/5L	Photometer FILter 4 and 5 at nose PLW
PFIL4M/5M	Photometer FILter 4 and 5 at nose PMW
PFIL4S/5S	Photometer FILter 4 and 5 at nose PSW
PLW	Photometer Long Wave detector
PM6-11	Photometer Mirror 6 to 11
PMW	Photometer Medium Wave detector
PSW	Photometer Short Wave detector
SOB	Spire Optical Bench Panel
SOR	Spire Optical Reference

Not included in the overview are the shutter, baffles and the cooler.

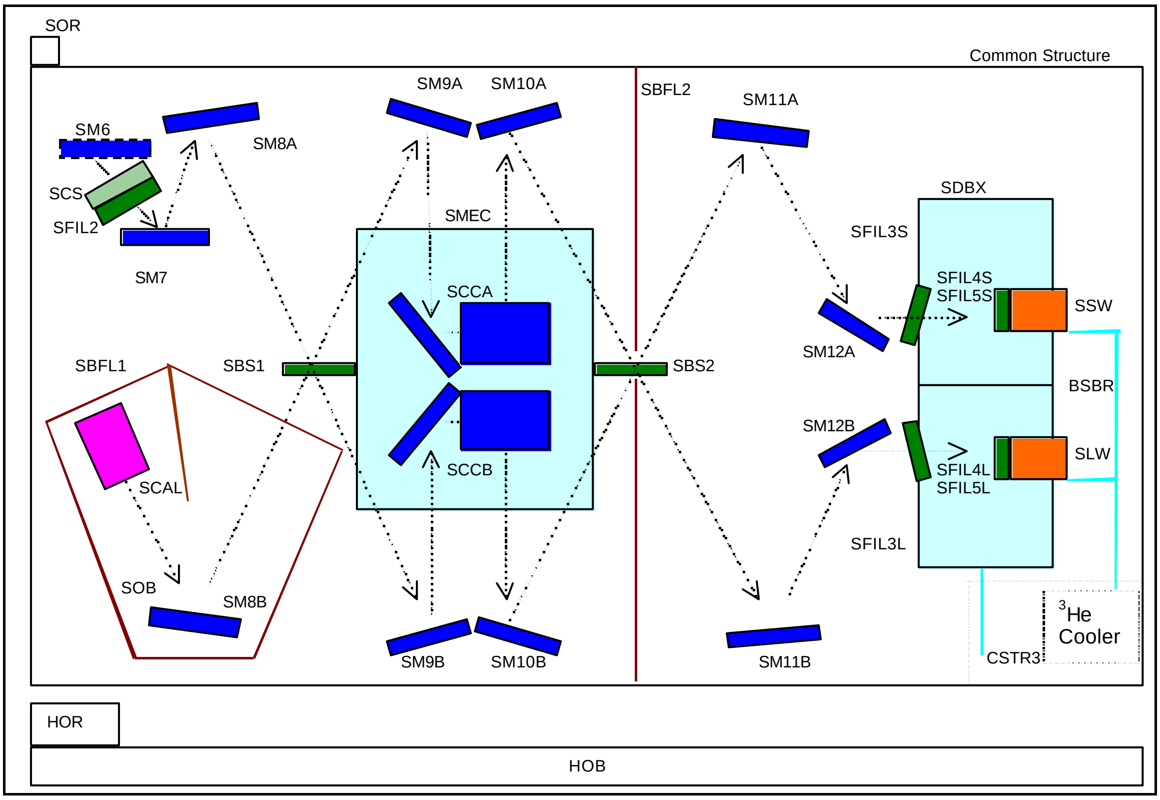


Figure 3.2.5-2: Spectrometer topology

Where:

HOB	Herschel Optical Bench
HOR	Herschel Optical Reference
SBS1	Spectrometer Beam Splitter 1
SBS2	Spectrometer Beam Splitter 2
SCCA	Spectrometer Corner Cube +X
SCCB	Spectrometer Corner Cube –X
SCAL	Spectrometer CALibration source
SCS	Spectrometer Cold Stop
SDBX	Spectrometer Detector BoX
SFIL2	Spectrometer FILter 2 (4 K - 2 K enclosure)
SFIL3L	Spectrometer FILter 3 (long wave)
SFIL3S	Spectrometer FILter 3 (short wave)
SFIL4L/5L	Spectrometer FILter at nose SLW
SFIL4S/5S	Spectrometer FILter at nose SSW
SM6-7	Spectrometer Mirror6-7
SM8A-12A	Spectrometer Mirror 8-12 +X chain
SM8B-12B	Spectrometer Mirror 8-12 –X chain
SMEC	Spectrometer MEChanism
SOB	Spire Optical Bench Panel
SOR	Spire Optical Reference

Hereafter each individual subsystem mounted on or inside the SPIRE structure and therefore interfacing with it is discussed in separate sections.

3.2.6 SPIRE structure

In order to prevent deformation of the structure due to thermal contraction of the interface with the spacecraft, it will be suspended kinematically on the Herschel optical bench (HOB). Furthermore in order to prevent excess deformation of the instrument due to it being cooled down, it will consist of one type of material for all structural parts. The material used to construct the instrument is aluminium 6082-T6. The only deformation present after cooling down from room temperature down to 4 Kelvin (nominally) is due to thermal contraction. Possible deformation due to thermal gradients over the structure (with all temperatures well below 6 Kelvin) will be negligible.

3.2.7 Structure suspension

The structure is mounted on a fixed point (cone shape support) and two A-frames. These items should ensure sufficient mounting stiffness, such that the overall dynamics of the instrument complies with the eigenfrequency requirements. Besides that they should provide for sufficient thermal insulation such that the total heat load running through the supports is minimised. The material used for these supports is stainless steel (321). The arrangement of the supports is such that the suspension of the structure is kinematic. The fixed-point suspension serves as a reference with respect to the HOB. It is the only part of the instrument that will not move relative to this bench due to possible differential thermal contraction.

3.2.8 SPIRE optical bench

The SPIRE optical bench (SOB) is the part of the instrument where in principle all subsystems inside the instrument will be mounted on. The optical bench should be stiff. All items mounted on this bench will be aligned within 0.1 mm for each interface point.

3.2.9 Straylight baffles

Currently the following straylight baffles are foreseen:
1. At beam entry of the instrument
2. Between PM7 and PM8, dividing the photometer in two parts. One with the common optics and one with the photometer optics, including cooler and detector box.
3. Two baffles within the spectrometer section of the instrument. Each one shielding the optics at each beam splitter

The surface finish will have an emissivity of less than 0.2. Except at the apertures, where possibly black material will be used to absorb IR-light.

3.2.10 Detector boxes

On both sides of the SOB detector boxes will be mounted to provide for a level 0 enclosure. The detectors will be mounted on the outside of these boxes with the detector nose, pointing inside the box. At the apertures possibly black material will be used to absorb IR-light.

3.2.11 Mirror supports

The mirrors will be mounted, baseline, on mirror mounts. These mirror mounts will be bolted on the optical bench. The exceptions are for mirrors mounted inside the detector boxes, some mirrors mounted on the central photometer straylight baffle and CM3, CM5 and CM7 mounted on a secondary optical bench. Mirror mounting is MSSL's responsibility.

3.2.12 Beam splitter supports

Within the spectrometer two beam splitters are mounted on separate splitter mounts. Care will be taken to ensure the (co)planarity of these splitters.

3.2.13 Mounting provisions for detectors

The detectors will be mounted on the outside of the detector boxes with the nose pointing inwards. The detector harness will exit the detectors from the back, outside the detector boxes. The 0.3 K thermal strap will exit the detectors close to the nose of the detector, inside the detector box. The thermal strap will be attached to the 0.3 K thermal busbar. The harness of the detectors will be routed via the structure outside the instrument. This routing will be RF-shielded outside the instrument.

3.2.14 Mounting provisions for dichroics and filters

Two dichroics will be mounted inside the photometer detector box. Care will be taken to ensure the planarity of the dichroics. Filters will be mounted in various locations within the instrument. The first one will be located at the beam entry of the instrument. After that for each part of the instrument (photometer and spectrometer) two filters will be located in the optical train. For the spectrometer there will be one located at the optical bench beam entry. The other two at each beam entry of the spectrometer detector box. For the photometer there will be one located at the beam passing through the central photometer straylight baffle and one at the beam entry of the photometer detector box.

3.2.15 Mounting provision for the SMEC

The SMEC will be mounted on the optical bench between the two spectrometer straylight baffles (and beam splitters). There are 4 interface bolt holes. No provision for mounting a locking device (that is a SMEC internal interface). Harness will be routed via the structure to the RF-filter boxes.

3.2.16 Mounting provision for the ^{3}He cooler

The cooler will be mounted next to the photometer detector box. It needs to be connected with two level 0 thermal straps to the cryostat dewar (outside the structure). The other thermal interface is with the 0.3 K thermal busbar. Harness will be routed via the structure to the RF-filter boxes.

3.2.17 Mounting provision for BSM

The BSM will be mounted on the optical bench within the photometer section of the instrument. The BSM will hold the CM4 mirror and the photometer calibration source. Harness will be routed via the structure to the RF-filter boxes. The BSM will provide for its own support.

3.2.18 Mounting provision for spectrometer calibration source

The spectrometer calibration source will be mounted with its own mount on the optical bench. Harness will be routed via the structure to the RF-filter boxes.

3.2.19 Mounting provisions for thermal straps

The structure will provide for mounting provisions for the thermal straps and the thermal busbars. (see also section 3.2.3)

1. Level 0 thermal strap to the evaporator interface with the cooler (including straylight baffle at the entry of the structure)
2. Level 0 thermal strap to the pump interface with the cooler (including straylight baffle at the entry of the structure)
3. Level 0 thermal strap to the photometer detector box, continuing to the spectrometer detector box (including straylight baffle at the entry of the structure)
4. Level 1 thermal strap, attached to the SOB on the outside of the instrument.
5. 300mk Strap System, routed from the cooler to the inside of the photometer detector box and the spectrometer detector box. Sizing and conceptual design will be performed together with RAL and Cardiff.

The level 2 thermal strap has no direct interface with the instrument. The link between the level 2 vent line, and the instrument, is via the HERSCHEL optical bench. The area around the mounting will be cooled using thermal links between the level 2 vent lines.

3.2.20 Mounting provisions for filters

The various filters will be mounted in the appropriate locations.

3.2.21 RF-seal (attenuation) for Common Structure

The various panels, comprising the outside of the structure will be RF-sealed. Such to attenuate incoming RF radiation sufficiently

3.2.22 I/F to JFET box

The structure will interface with the two JFET boxes on the outside of the instrument. The main concerns there are RF shielding of the detector harness outside the structure, thermal insulation from the (possibly hot) JFET box and grounding.

3.2.23 Application of thermal finishes

The instrument will have a low emissive finish on the inside and outside of the instrument. This to provide for a cold background inside the instrument and for thermal radiation shielding on the outside of the instrument.

3.2.24 Application of black material

At the various apertures within the instrument where the IR-beam will pass through possibly black material will be applied to absorb excess/stray IR-light.

3.2.25 Mounting provision for RF-filter box

All harness inside the instrument (except for the detector harness) will be routed via the structure to the RF-filter boxes, These are located within the spectrometer section of the instrument. The RF-filter boxes will interface with the cryo-harness inside the cryotstat. This harness comprises the harness from the cooler, the various mechanisms, calibrators and the thermistors.

3.2.26 Thermometers

There is a requirement to have thermometers to monitor the temperature of the various structure parts. Such as the common structure, SPIRE optical bench and the detector boxes. In principle the harness of the sub-systems mounted inside the structure will be used a much as possible to route the harness of the thermometers. The actual number of thermometers that have to be mounted and routed by MSSL is TBD.

3.3 Mission profile

All parts will be baked out before integration (TBC).

The SPIRE CQM structure will be subjected to several tests. These tests consist of an STM test, which is a structural test verifying the dynamic properties of the structure (stiffness, strength, mass), and the CQM test programme (requirements outlined in RD9). After that a PFM model will be built, tested and mounted on the spacecraft. On the spacecraft it will go through the spacecraft proto-flight programme. The CQM will be refurbished (TBC) to serve as flight spare.

In the table hereafter (3.3-1) the allowable times a certain handling/test is performed or the allowable amount of time

Model:	STM	CQM	PFM	FS
Integration	2	2	5	1
Cold cycles (down to 2-4 K)	5 (TBC)	15 (TBC)	5 (TBC)	5 (TBC)
Mounting and dismounting detector boxes	15 (TBC)	15 (TBC)	5 (TBC)	5 (TBC)
Mounting and dismounting mirror mounts	15 (TBC)	5 (TBC)	3 (TBC)	3 (TBC)
Mounting and dismounting instrument suspension	15 (TBC)	15 (TBC)	5 (TBC)	5 (TBC)
General use[1]	1 Yr	2 Yr	2 Yr	1 Yr
Storage	1 Yr	2 Yr	2 Yr	2 Yr
In orbit	-	-	4.25 Yr	4.25 Yr

Table: 3.3-1: Overview life of the structure (split in the different models)

[1] General use encompasses 1 qualification test or two proto-flight test programmes. If the structure is needed for more tests, fatigue critical components need to be replaced.

After successfully, withstanding the qualification tests, the PFM will be constructed. The PFM will be subjected to the same tests as the CQM (except STM testing). After successfully withstanding the proto-qualification tests the PFM will be integrated in the spacecraft. Integrated in the spacecraft it will be subjected to the spacecraft proto-qualification programme. If these tests prove successful the spacecraft will be launched. More details can be found in AD28. The CQM model will be refurbished to act as a flight spare. The FS will be interchangeable with the PFM unit.

If the FS goes through a proto-qualification programme or a qualification programme it needs to be refurbished

3.4 Product tree

Hereafter the parts as listed in the product tree (AD15) are listed.

ID	Product Item	Descriptor	STM	AVM	CQM	PFM	FS	RESP
1.1	Structure	STRC	x		X	x	x	**MSSL**
1.1.1	Cover	COV	x		X	x	x	MSSL
1.1.2	Common Structure (incl. Interface wit JFET and RF filter box and HERSCHEL optical bench)	C4K	x		X	x	x	MSSL
1.1.3	Photometer detector box	PDBX	x		X	x	x	MSSL
1.1.4	Spectrometer detector box	SDBX	x		X	x	x	MSSL
1.1	Mounting provisions for thermal straps		x		X	x	x	MSSL
1.1	Mounting provision for thermal interface with level 0		x		X	x	x	MSSL
1.1	Mounting provision for thermal interface with level 1		x		X	x	x	MSSL
1.1	Mounting provisions for thermal straps from cooler to detectors		x		X	x	x	Cardiff/ MSSL
1.1	Alignment reference mirror	SOR	x		X	x	x	MSSL
1.1.10	Structure thermistors	T_PDBX_1 T_PDBX_2 T_SDBX_1 T_SDBX_1 T_C4K_1 T_C4K_2	x		X	x	x	MSSL
1.2	Photometer mirror mounts		x		X	x	x	MSSL
1.2	Spectrometer mirror mounts		x		X	x	x	MSSL
1.2.1	Filters, Dichroics and beam splitters mountings		x		X	x	x	MSSL
1.2.2	Baffles	BAFF	x		X	x	x	MSSL
1.3.3	Cooler I/F	COOL	x		X	x	x	MSSL
1.4.1	Detector I/F		x		X	x	x	MSSL
1.4.2	Detector I/F		x		X	x	X	MSSL
1.5.2	SMEC I/F		x		X	x	X	MSSL
1.6.2	Spectrometer calibration I/F		x		X	x	X	MSSL
1.7	RF I/F		x		X	x	X	JPL/MSS L
1.1.12	Mechanical ground support equipment	MGSE	x		X	x	X	MSSL
	Mathematical model structure	FEM						MSSL

A more detailed list of deliverables is part of the development plan (AD28 Section 3.2.1)

4 Specification

4.1 Functional

4.1.1 Performance specification

The focal plane unit structure will hold all cold sub-systems in the focal unit. This includes all thermometers necessary to monitor the instrument during cool down and operation.

Hereafter the performance of the subsystem is specified and compared with the required performances and general requirements as set out in AD03.

The mass requirements are listed in the budget allocations (AD04). The mass of the current baseline design meets the strict requirements as set out in section 3.4.3 of AD03.

IRD-SUBS-R03: The mass of the structure, including 20% contingency instrument is 32.6 kg

Included in this mass are the straylight baffles, mirror mounts, filter splitter and dichroic clamps/mounts. The straylight baffles are not strictly a part of the structure, nor are the various subsystem supports. However they will be deliverables and are therefore added to this mass budget. The budget does not include the fasteners required to mount the various subsystems in/on the common structure or one of the detector boxes. See for a more detailed mass allocation section 4.1.2, with the technical (implementation) requirements.

The subsystem structure is further specified hereafter. The specifications are compared with the requirements.

The alignment of the structure with respect to the HOB depends on the machining tolerance of the HOB. At present the machining tolerance is expected to be within +/- 0.05 mm for each interface bolt.

ID	Description	Value	Source
IRD-STRC-R01	Alignment to the instrument w.r.t. HERSCEL optical axis	The common structure shall allow the alignment of the instrument and the telescope axis to within +/- 2.6 mm lateral, +/- 3.5 arcmin rotational about any axis.	AD03/table 3.5.-1 ECR – 027 (HR-SP-RAL-ECR-027)

The structure consists of aluminium panels, milled down to a nominal thickness of 1.5 mm. At the connection between the panels an RF-attenuating seal is provided. See figure 3.1-4.

ID	Description	Value	Source
IRD-STRC-R02	Attenuation of RF by Common Structure	All joints of the external covers shall form EMC tight joints via the use of a stepped interface and a bolt spacing of no more than 30 mm. This is deemed sufficient for EMC tightness and no o-ring type seal is required.	AD03/table 3.5.-1 ECR – 027 (HR-SP-RAL-ECR-028)

The photometer and spectrometer will be mounted on the SOB.

ID	Description	Value	Source
IRD-STRC-R03	Items required support from the Common Structure	Photometer and common subsystems, Spectrometer	AD03/table 3.5.-1

The structure will be aligned as specified in RD5.

ID	Description	Value	Source
IRD-STRC-R04	Optics and associated sub-system alignment	Specified in RD5 of AD03	AD03/table 3.5.-1

The structure will have a surface finish with an $\varepsilon < 0.2$

ID	Description	Value	Source
IRD-STRC-R05	Surface finish of the Common Structure cover	The inside and the outside of the box shall have a finish with a low emissivity. At least less than $\varepsilon = 0.2$. Parts may be blackened as part of stray light control.	AD03/table 3.5.-1

The total effective pumping capacity has to be analysed.

ID	Description	Value	Source
IRD-STRC-R06	Pumping port	The total effective pumping conductance of the common structure shall be ≥7.8 l/s	AD03/table 3.5.-1

The structure will be equipped with the specified number of thermometers

ID	Description	Value	Source
IRD-STRC-R07	Thermometry	The structure subsystem shall provide thermistors and associcated wiring to allow temperature monitoring of critical parts	AD03/table 3.5.-1

The surface finish on the outside of the instrument will have an emissivity with an ε < 0.2

ID	Description	Value	Source
IRD-STRC-R08	Attenuation of radiation from cryostat	Requirement $<2x10^{-5}$	AD03/table 3.5.-1

The structure, supported on its mounts, will have an eigenfrequency > 120 Hz

ID	Description	Value	Source
IRD-STRC-R09	First natural frequency	The structures eigenfrequency shall be above 100 Hz (req.) and preferably above 120 Hz (goal)	AD03/table 3.5-2

The instrument will be mounted on the HOB with electrically insulating washers.

ID	Description	Value	Source
IRD-STRC-R10	Instr. mechanical interface	The I/F will be directly to the HERSCHEL optical bench. The instrument will be in direct thermal contact	AD03/table 3.5-2

All parts of the structure will be electrically connected, one to the other, with a resistance less than than 0.1 W.

ID	Description	Value	Source
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 W (TBC)	AD03/table 3.5-2

The instrument will be mounted on the HOB with electrically insulating washers.

ID	Description	Value	Source
IRD-STRC-R13	Electrical isolation from HERSCHEL	All parts of the SPIRE structure shall be electrically isolated from the HERSCHEL cryostat. Resistance to be greater than TBD W	AD03/table 3.5-2

The conductance from level 2 to level 1, via the supports of the instrument, will be less than 6 mW with boundary temperatures of 9.0 K and 4.0 K respectively.

ID	Description	Value	Source
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.	AD03/table 3.5-2

Straylight baffling for the level 0 detector boxes.

ID	Description	Value	Source
IRD-STRC-R19	300-mK bus bar stray light baffle effectiveness.	The aperture in the detector boxes for the 300-mK busbar feed through shall incorporate a stray light baffle. This baffle is to provide at least four reflections for the shortest optical path between the Level 1 environment outside the detector box and the Level 0 environment inside the detector box.	E-mail from Doug Griffin dd 21/06/2001

The photometer detector box shall support the level 0 optics, dichroics, filter, detectors, straylight baffles and thermal strap supports for the detectors

ID	Description	Value	Source
IRD-STRP-R01	Items supporting	The photometer detector box shall support the level 0 optics, dichroics, filter, detectors, and thermal strap for detectors	AD03/table 3.5-3

The structure will be aligned as specified in RD5.

ID	Description	Value	Source
IRD-STRP-R02	Optics and filter alignment	See RD5 of AD03	AD03/table 3.5-3

The structure will be aligned as specified in RD5.

ID	Description	Value	Source
IRD-STRP-R03	Array module alignment	See RD5 of AD03	AD03/table 3.5-3

The structure will have a surface finish with an ε < 0.2

ID	Description	Value	Source
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 shall have a low reflective finish on all non-optical surfaces..	AD03/table 3.5-4

The effective pumping capacity has yet to be analysed.

ID	Description	Value	Source
IRD-STRP-R05	Pumping port	The total effective pumping conductance of the detector box shall be ≥ 5.6 l/s	AD03/table 3.5-4

The structure will have a surface finish with an ε < 0.2

ID	Description	Value	Source
IRD-STRP-R06	Attenuation from common structure	Requirement: $5x10^{-7}$ with a goal of $5x10^{-8}$	AD03/table 3.5-4

The first eigenfrequency of the photometer detector box on its mounts will be greater than 150 Hz

ID	Description	Value	Source
IRD-STRP-R07	First natural frequency	The first eigenfrequency of the photometer detector box on its mounts shall be greater than 200 Hz, with a goal of 300 Hz	AD03/table 3.5-4

The thermal conductance from the structure to the photometer detector box will be less than 0.75 mW via the supports, with a boundary condition of 4.0 K and 2.0 K respectively.

ID	Description	Value	Source
IRD-STRP-R09	Thermal isolation	Request one budget for both detector boxes. The conductance from the common structure to the detector boxes shall be ≤ 2.0 mW with boundary 2-4 K. (TBC)	AD03/table 3.5-4

The spectrometer detector box shall support the level 0 optics, filter, detectors, straylight baffles and thermal strap supports for the detectors.

ID	Description	Value	Source
IRD-STRS-R01	Items supporting	The photometer detector box shall support the level 0 optics, filter, detectors, and thermal strap for detectors	AD03/table 3.5-4

The structure will be aligned as specified in RD5.

ID	Description	Value	Source
IRD-STRS-R02	Optics and filter alignment	See RD5 of AD03	AD03/table 3.5-4

The structure will be aligned as specified in RD5 of AD03.

ID	Description	Value	Source
IRD-STRS-R03	Array module alignment	See RD5 of AD03	AD03/table 3.5-4

The structure will have a surface finish with an ε < 0.2

ID	Description	Value	Source
IRD-STRS-R04	Surface finish	The outside of the box shall have a finish with a low emissivity. At least ε = 0.2. The inside shall have a low reflective finish on all non-optical surfaces..	AD03/table 3.5-4

The effective pumping conductance of the structure has yet to be analysed

ID	Description	Value	Source
IRD-STRS-R05	Pumping port	The total effective pumping conductance of the detector box shall be ≥ 5.6 l/s	AD03/table 3.5-4

The structure will have a surface finish with an ε < 0.2

ID	Description	Value	Source
IRD-STRS-R06	Attenuation from common structure	Requirement: $5x10^{-7}$ with a goal of $5x10^{-8}$	AD03/table 3.5-4

The first eigenfrequency of the spectrometer detector box on its mounts will be greater than 150 Hz

ID	Description	Value	Source
IRD-STRS-R07	First natural frequency	The first eigenfrequency of the spectrometer detector box on its mounts shall be greater than 200 Hz, with a goal of 300 Hz	AD03/table 3.5-4

The thermal conductance from the structure to the photometer detector box will be less than 0.75 mW via the supports, with a boundary condition of 4.0 K and 2.0 K respectively.

ID	Description	Value	Source
IRD-STRS-R09	Thermal isolation	Request one budget for both detector boxes. The conductance from the common structure to the detector boxes shall be ≤ 2.0 mW with boundary 2-4 K. (TBC)	AD03/table 3.5-4

The 300mk Strap system has a mass of TBD g and a first mode of vibration of TBD hz.

Requirement ID	Description	Value	Reference	Notes
STRAP-Req. –04	Accommodation	The 300-mK Strap system is to be supported entirely from the Level-0 Photometer and Spectrometer Detector Boxes.	SPIRE-RAL-PRJ-001323	
STRAP-Req. –05	Mass	285g	AD 3 - §2.12.6 SPIRE-RAL-PRJ-001323	This includes the mass of the Photometer and Spectrometer Straps and Stray Light Baffles
STRAP-Req. –06	First mode of vibration	>300Hz, goal > 400Hz	SPIRE-RAL-PRJ-001323	
STRAP-Req. –07	Qualification level random vibration loads.	$0.5g^2$/Hz between 100Hz and 400Hz. 6dB/octave roll-off below and above this.	SPIRE-RAL-PRJ-001323	This specification applies to all three axes
STRAP-Req.–08	Qualification level Sine vibration loads	40g between 5Hz and 110Hz	SPIRE-RAL-PRJ-001323	This specification applies to all three axes

4.1.2 Technical requirements

The following co-ordinate system as reference to the cryostat shall be taken into account (AD02). See also DR1 and appendix A.

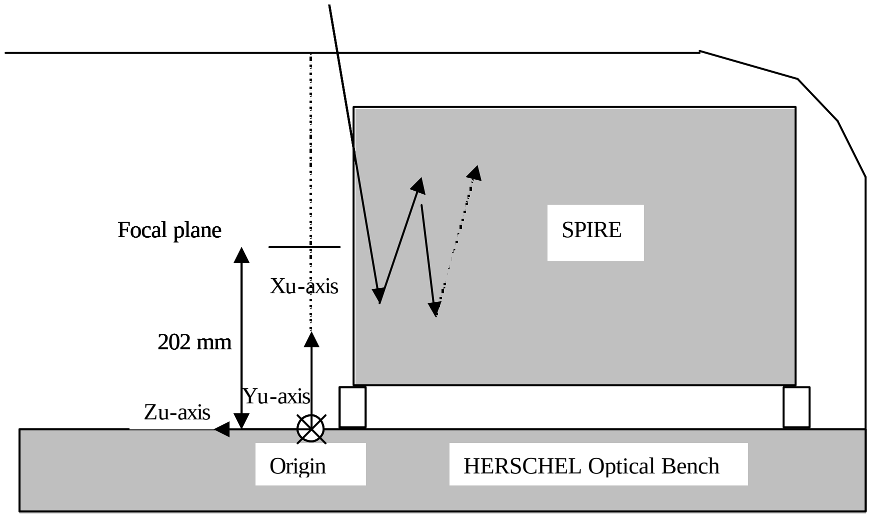


Figure 4.1.2-1 Cryostat reference co-ordinate system.

The following local co-ordinate system shall be taken into account for the SOB mounted subsystems. See also DR1 and appendix A. The origin lies on the optical bench datum point. This is visible and reachable both before, during and after integration. It will however not be visible from outside the spacecraft cryostat. As optical reference an optical alignment cube will be used, mounted on top of the optical bench, outside the common structure, closest to the spacecraft optical axis and visible from outside the cryostat. The advantage of the datum point on the optical bench is that all co-ordinates inside the instrument are positive. Both the co-ordinate systems, are co-aligned with the S/C co-ordinate system, only the origins differ.

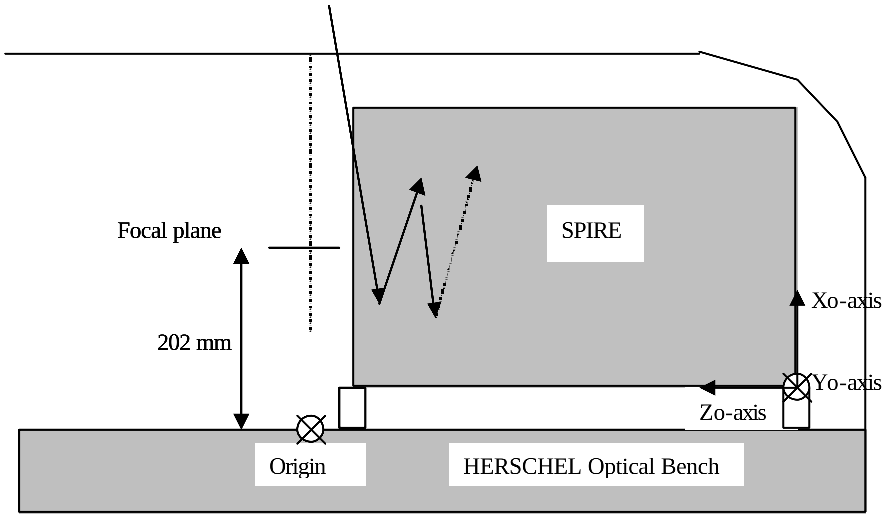


Figure 4.1.2-2 Spire optical bench reference co-ordinate system.

For the current baseline design the following mass distribution holds:

SPIRE – structure				
Contingency taken into account: 20%				
	Nett	Contg.	Total	
Photometer cover	7.64	1.158	8.798	[kg]
Spectrometer cover	6.88	1.032	7.912	[kg]
Optical bench	8.00	2.35	10.35	[kg]
Mounting common structure	0.54	0.081	0.621	[kg]
Phot. det. box	1.84	0.287	2.127	[kg]
Spect. det. box	1.35	0.222	1.552	[kg]
Mounts, Clamps Phot.	1.31	0.194	1.506	[kg]
Mounts, Clamps Spect.	0.86	0.129	0.989	[kg]
Straylight Baffles	2.42	0.484	2.904	[kg]
Thermal Straps,	0.282	0.060	0.342	[kg]
Cooler Straps	0.235	0.047	0.282	[kg]
Cooler I/F	0.10	0.020	0.120	[kg]
Strap Baffles	0.50	0.10	0.60	[kg]
total	31.957	6.146	38.103	[kg]
Excluding:	Harness wiring			
	RF-filter boxes			
	JFET I/F structure			
	Spect. Cal.			
	Shutter			

Table 4.1.2-1: Mass distribution SPIRE structure and related

Implementation requirements still to be defined:

Thermal flow characteristic through A-frame and fixed point suspension. (AD02, section 5.9.1.2, total 6 mW – See AD33)
Thermal flow characteristic through detector box suspension. (AD02, section 5.9.1.2, total 1.5 mW - See AD34)

4.2 Operational

4.2.1 Operational Safety

N.A.

4.2.2 Lifetime

Expected integrated lifetime is 9 years, including on orbit life, TBC

4.2.3 Operating modes

N.A.

4.2.4 Telemetry

NA

4.2.5 Telecommands

NA

4.3 Interface requirements

The interface with the HERSCHEL optical bench is given by ja1-5264-300, pictured in appendix A.

Hereafter all subsystem interfaces and the applicable ICD's are listed. The ICD's contain the interface drawings

ICD	Part name	ICD	Other party
1.1 - 1.2	Mirrors/Optics	AD2	LAM
1.1 - 1.5.2	FTS mechanism	AD3	LAM
1.1 - 1.2.2	Straylight attenuation	TBI	RAL
1.1 - 1.2.1	Filters, splitters & dichroics	AD4	CARDIFF
1.1 - 1.4.1/2	Detectors	TBI	JPL
1.1 - 1.5.1	BSM	TBI	ATC
1.1 - 1.6.1	Calibration source Photometer	TBI	CARDIFF
1.1 - 1.6.2	Calibration source Spectrometer	TBI	CARDIFF
1.1 - 1.3	He^3 Cooler	AD5	CEA-Grenoble
1.1 - ?	Thermal hardware	TBI	?

Table 4.3-1: ICD list

The requirements for the subsystems are listed in the mechanical ICD, AD29.

Quasi-Static

The qualification levels are given by AD01.

Quasi Static levels	Case 1	Case 2	Case 3
x-direction	20g	-	-
y-direction	-	10 g	-
z-direction	-	-	10 g

Table 4.3-1: Qualification levels for quasi static vibration

Sine

The qualification levels are derived from the coupled analysis with the instrument structure with the input at base of the instrument following the requirements stated in AD01. These levels include the required qualification margin (factor 1.5). They do not include any further margin with respect to design loads. These will have to be added by the subsystems.

Sine vibration levels	Frequency range	Input at base (QUAL)
X-direction	5-18 Hz 18-100 Hz	22 mm (peak-peak) 20 g
Y-direction	5-18 Hz 18-100 Hz	22 mm (peak-peak) 10 g
Z-direction	5-18 Hz 18-100 Hz	22 mm (peak-peak) 10 g

Table 4.3-2: Qualification levels for sine vibration (sweep rate 2.0 oct/min)

Notching, such as not to exceed quasi-static I/F loads, is allowed for modes with significant modal mass (I.E. >50% structural mass).

Random

The qualification levels are given by AD01.

Random vibration levels	Frequency range	Input at base (QUAL.)
X-direction	5 – 100 Hz 100-300 Hz 300 – 2000 Hz	+6 dB 0.05 g^2/Hz -3 dB
Y-direction	5 – 100 Hz 100-300 Hz 300 – 2000 Hz	+6 dB 0.05 g^2/Hz -3 dB
Z-direction	5 – 100 Hz 100-300 Hz 300 – 2000 Hz	+6 dB 0.05 g^2/Hz -3 dB

Table 4.3-3: Qualification levels for random vibration (5.27 g_{rms})

4.4 Design and manufacture requirements

4.4.1 Design requirements

The key baseline design requirements and implementation are the following

1 -Stiffness

In order to provide for the required stiffness the baseline design of the structure consists of a monocoque structure with a central stiff optical bench panel. In principle all sub-systems are mounted on the optical bench panel. In order to comply with the sine vibration input specification the design goal set for the structure is to reach an first natural frequency of 120 Hz or higher. Because of the uncertainty taken into account for the frequency prediction of 10% the baseline design should have its predicted first natural frequency of at least 133 Hz. Furthermore the various sub-systems need to be decoupled (dynamically) as much as possible. The eigenfrequency of the SOB should be at least 40 % higher than the first overall natural frequency (160 Hz). The minimal eigenfrequency of all subsystems and detector boxes should again be at least 40% higher (200 Hz). Ideally the eigenfrequency of a subsystem mounted on another should be a factor 1.41 higher in order to avoid any amplification due to modal coupling.

2 - Thermal

The structure will be thermally isolated from the HERSCHEL optical bench as much as possible. Assuming a 6.0 K interface temperature and a 4.0 K structure temperature the maximum heat flow through the mounting of the structure should be less than 2 mW. Refer to the instrument requirements, AD03.

3 - Electrical

The structure will be electrical isolated from the HERSCHEL optical bench. This to allow for controlled grounding of the structure and its various subsystems. The thermal straps routed along various locations within the structure will be electrically isolated from the structure. Refer to the instrument requirements, AD03.

4.4.2 Design rules

No specific design rules as yet.

4.4.3 Manufacture requirements

The general machining tolerance will be 0.05mm.

4.5 Logistic requirements

AD01, 5.15.1.1: For all deliverable units, a transport container shall be provided.

1. Each model will have its transportation container and handling frame. Only one set of integration tools is required. (If applicable) Since the FS will be a refurbished CQM model, only two sets of transportation containers and handling frames are required. One for the CQM/FS and one for the PFM.
2. The subsystem will be transported from MSSL to RAL, and from RAL to ESTEC as an instrument.
3. The container shall be vacuum tight, be purged and slightly overpressured with dry nitrogen gas (TBC) Refer to AD01.
4. The instrument will be mounted using shock absorber supports.
5. Shock recorders shall be mounted at TBD location (TBC).
6. IID-B shall list size and mass of the container as well as the overall mass including the instrument package.

4.6 Environment requirements

These requirements describe the environment the structure needs to be able to sustain during its life. Life includes all ground operations and tests, launch and all on orbit operations. For the structure it is assumed that the warm vibration test, followed by the CQM qualification programme envelopes the worst case environment for the structure. Therefore the structure

4.6.1 Natural environment

This is the description of the natural environment around the subsystem during its life.

#	Parameter	Value	IRD	Note
EN1	Vacuum	Less than 10-4 Pa		In operation
EN2	Operating temperature	during system qualif and on orbit = 4K, 2K		
EN3	Storage and handling temperature Humidity Cleanliness	-20 to +30 °C Less than 45% TBD		Overall, on ground In clean room In clean room
EN4	Radiations	Less than 3.5 kRAD		On orbit

4.6.2 Operating environment

N.A.

4.7 Verification requirements

AD03 lists in section 2.6 the verification requirement for the instrument. They are repeated hereafter and the compliance is indicated.

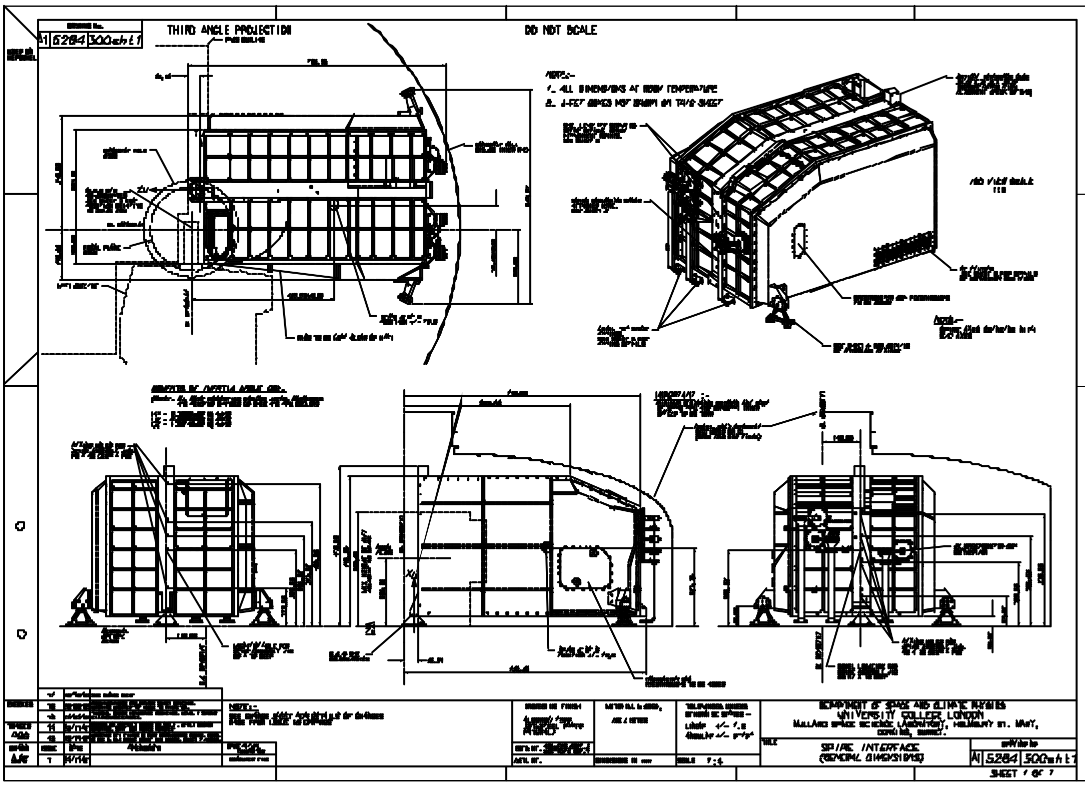
ID	Description	Response	Compliant
IRD-VER-01	STM verification: stiffness and strength of the structure	STM sine vibartion test (warm)	yes
IRD-VER-R02	AVM verification	Not applicable	-
IRD-VER-R03	CQM verification 1 correct operation (all operating modes) at cryogenic temperatures 3 thermal dissipation 6 Straylight	 1 Cryogenic test 3 Cryogenic test 6 Cryogenic test	 1 yes 3 yes 6 yes
IRD-VER-R04	PFM and FS same as for CQM verification (structure)	Cryogenic test	yes

Prior to the STM and CQM test, mathematical models will be used to verify the strength and stiffness of the proposed structure. The mechanical tests will be simulated for as far as the software allows doing that. The principle loads will be derived from these analyses and forwarded to all subsystems, if required, via the ICD.

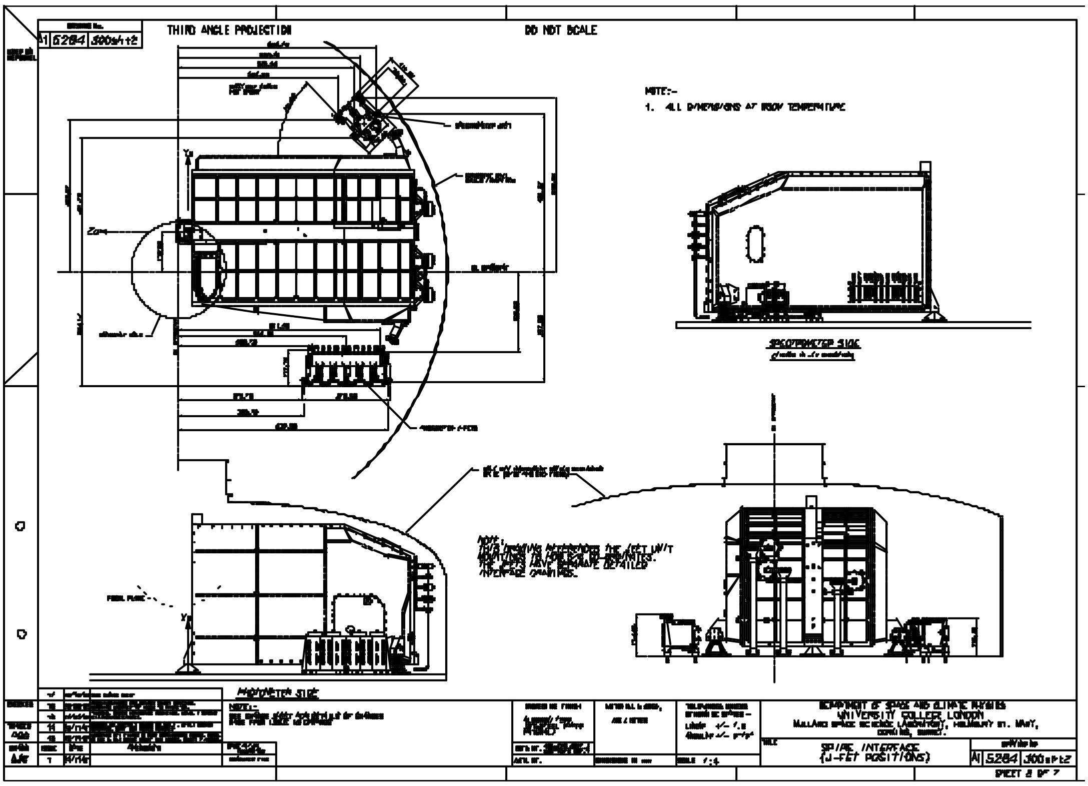
At present the draft mechanical environment requirements as issued by ESA (AD10) are listed hereafter. These apply for the structure subsystems as a whole. Not for the subsystems individual.

Appendix A

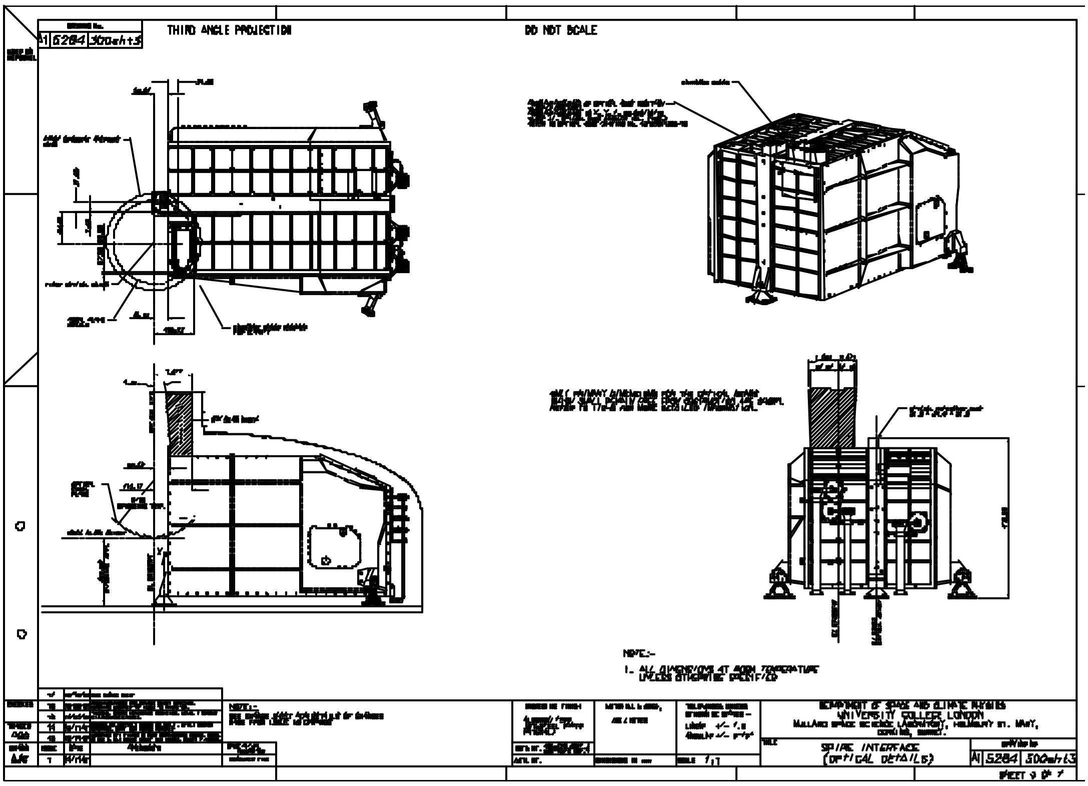
Interface Drawing Sheet 1 SPIRE-Herschel



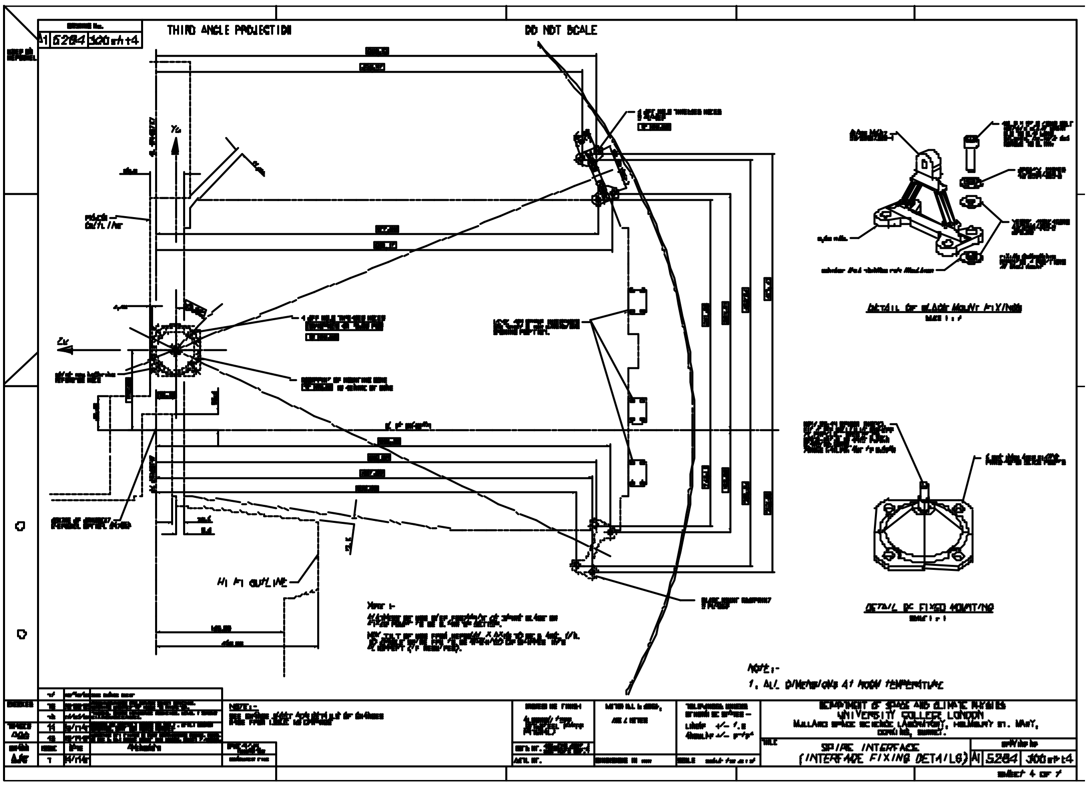
Interface Drawing Sheet 2 SPIRE-Herschel



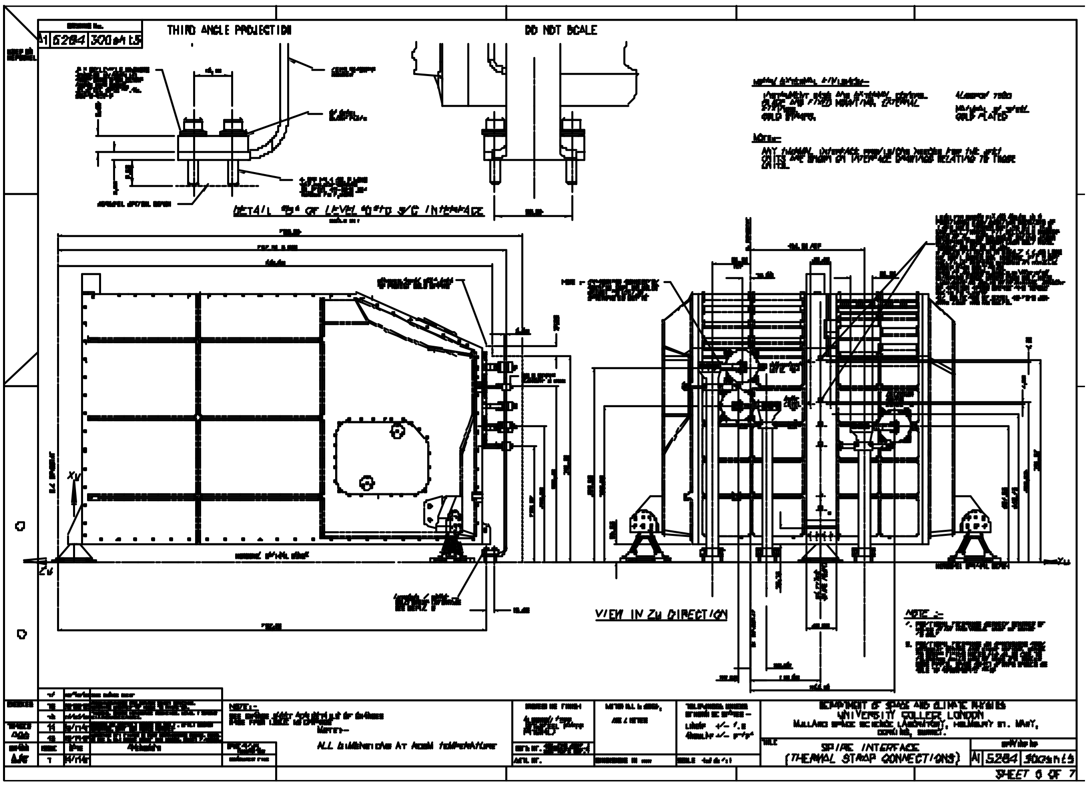
Interface Drawing Sheet 3 SPIRE-Herschel



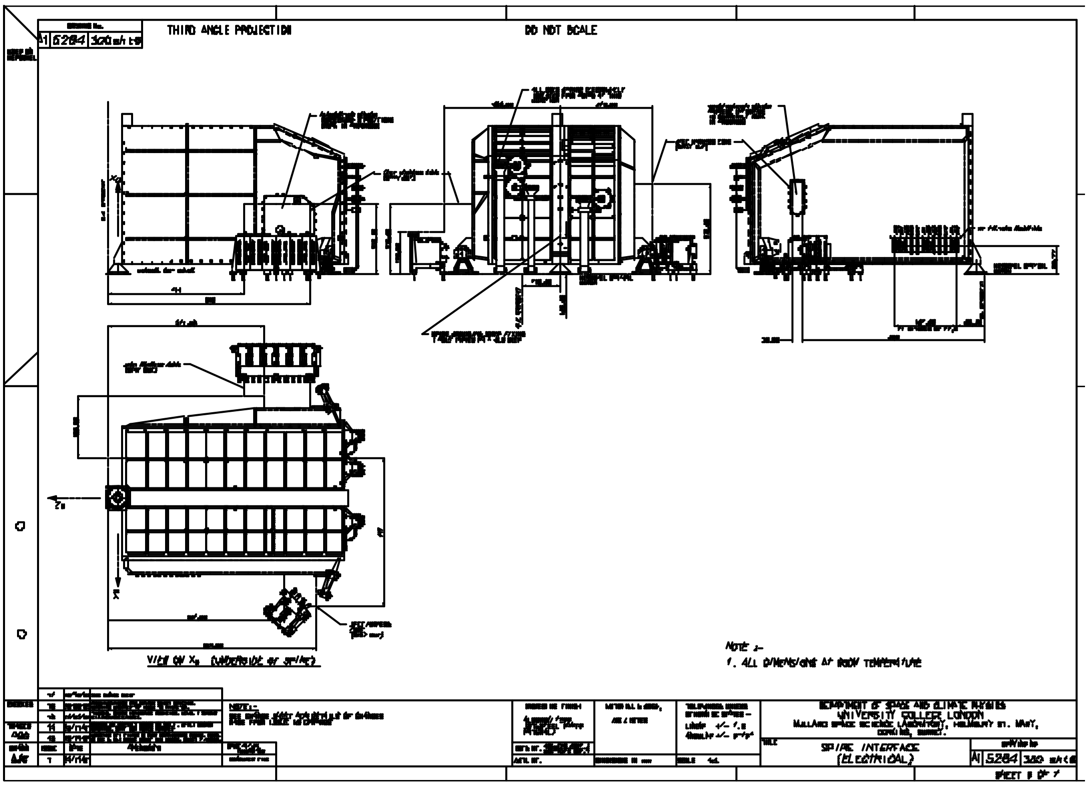
Interface Drawing Sheet 4 SPIRE-Herschel



Interface Drawing Sheet 5 SPIRE-Herschel



Interface Drawing Sheet 6 SPIRE-Herschel



Interface Drawing Sheet 7 SPIRE-Herschel