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SPIRE Test Facility Requirements Specification

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Document Changes

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1.1 Draft	12-Jun-2000	First Draft
1.2 Draft	17-Oct-2000	Scope extended to include provision of general AIV facilities and cold vibration rig.
1.2 Draft 2	15-Nov-2000	Includes requirements for control and monitoring and addresses requirements for STM program.
1.2	15-Feb-2001	Incorporated comments from QMW received 06-Feb-2001. Folded in telescope simulator and source requirements from Martin Caldwell.
1.3	10-Apr-2001	Changes following comments from QMW and BMS Lambda bath operating temperature corrected to 1.7K Change to cryoharness requirements Additional requirements for chopper.

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1 Scope of the document

This document describes the main requirements for the facilities to be used for the Herschel/SPIRE AIV phase. The facilities will include clean rooms for mechanical and electrical integration, optical alignment, vibration and a dedicated cryolab for cryogenic testing. The cryogenic tests will include thermal balance, cold functional tests and calibration of the CQM, PFM and FS instruments (AD 2). The majority of this document will cover the requirements for the dedicated test facility since this has the largest amount of development activity. The test facilities will be required for the duration of the SPIRE development until the launch of Herschel.

2 Documents

2.1 Applicable documents

	Title	Author	Reference	Date
AD 1	Outline Specification of the SPIRE instrument calibration facility	B.Swinyard	SPIRE/RAL/N/0058	
AD 2	SPIRE Development Plan	K.King	SPIRE-RAL-PRJ-000035	20-06-2000
AD 3	Effects of particulate contamination on SPIRE mirror performance at 200µm.	B.Swinyard		29-09-2000
AD 4	FIRST/Planck Instrument Interface Document Part A (IIDA)	ESA	SCI-PT-IIDA-04624	01-09-2000
AD 5	FIRST/Plank Instrument Interface Document Part B (IIDB), Instrument “SPIRE”	SPIRE Project Team	SCI-PT-IIDB/SPIRE-02124	01-09-2000
AD 6	SPIRE Product Assurance Plan	G.Douglas	SPIRE-RAL-PRJ-000017	05-02-1998
AD 7	SPIRE AIV Plan	B.Swinyard	SPIRE-RAL-DOC-000410	23-02-2001
AD 8	Deleted in preference to AD4			
AD 9	SPIRE optics design spreadsheets.	M. Caldwell	SPIREconfigPhot & SPIREconfigSPEC .xls files.	
AD 10	SPIRE Cryoharness Definition	J. Delderfield	SPIRE-RAL-PRJ-000608	29-03-2001
AD 11	Temperature Stability Requirements for SPIRE	J. Bock	SPIRE-RAL-NOT-000623	09-04-2001

2.2 Reference documents

	Title	Author	Reference	Date
RD 1	SPIRE Test Facility Control System Requirements	D.L. Smith	SPIRE-RAL-PRJ-000503 Draft 1	
RD 2	SPIRE Test Facility Floor Plan	D.L. Smith	SPIRE-RAL-NOT-000515 Issue 1	08-Nov-2000
RD 3	SPIRE Work Breakdown Structure	K. King	SPIRE-RAL-PRJ-000031	12-Feb-2000
RD 4	Long wavelength (sub-mm) telescope simulator	W Duncan et al.	Infra-red Phys. Vol.34,No.1,pp.1-15	1993
RD 5	SPIRE Instrument STM Requirements	B. Swinyard	SPIRE-RAL-NOT-000613	30-Mar-2001
RD 6	SPIRE Instrument CQM Requirements	B. Swinyard	SPIRE-RAL-NOT-000389	30-Mar-2001
RD 7	The International Temperature Scale of 1990		www.Its-90.com	

2.3 Glossary

AD	Applicable Document	STM	Structural Test Model
CDR	Critical Design Review	TBC	To Be Confirmed
CQM	Cryogenic Qualification Model	TBD	To Be Defined
DDR	Detailed Design Review	TFCS	Test Facility Control System
EGSE	Electrical Ground Support Equipment	WE	Warm Electronics
FIRST	Far InfraRed Space Telescope	ITS-90	International Temperature Scale of 1990
FIR	Far InfraRed		
FPU	Focal Plane Unit		
FS	Flight Spare		
FTS	Fourier Transform Spectrometer		
MGSE	Mechanical Ground Support Equipment		
NA	Not Applicable		
PFM	ProtoFlight Model		
QMW	Queen Mary and Westfield College		
RAL	Rutherford Appleton Laboratory		
RD	Reference Document		
SPIRE	Spectral and Photometric Imaging Receiver		

3 Introduction

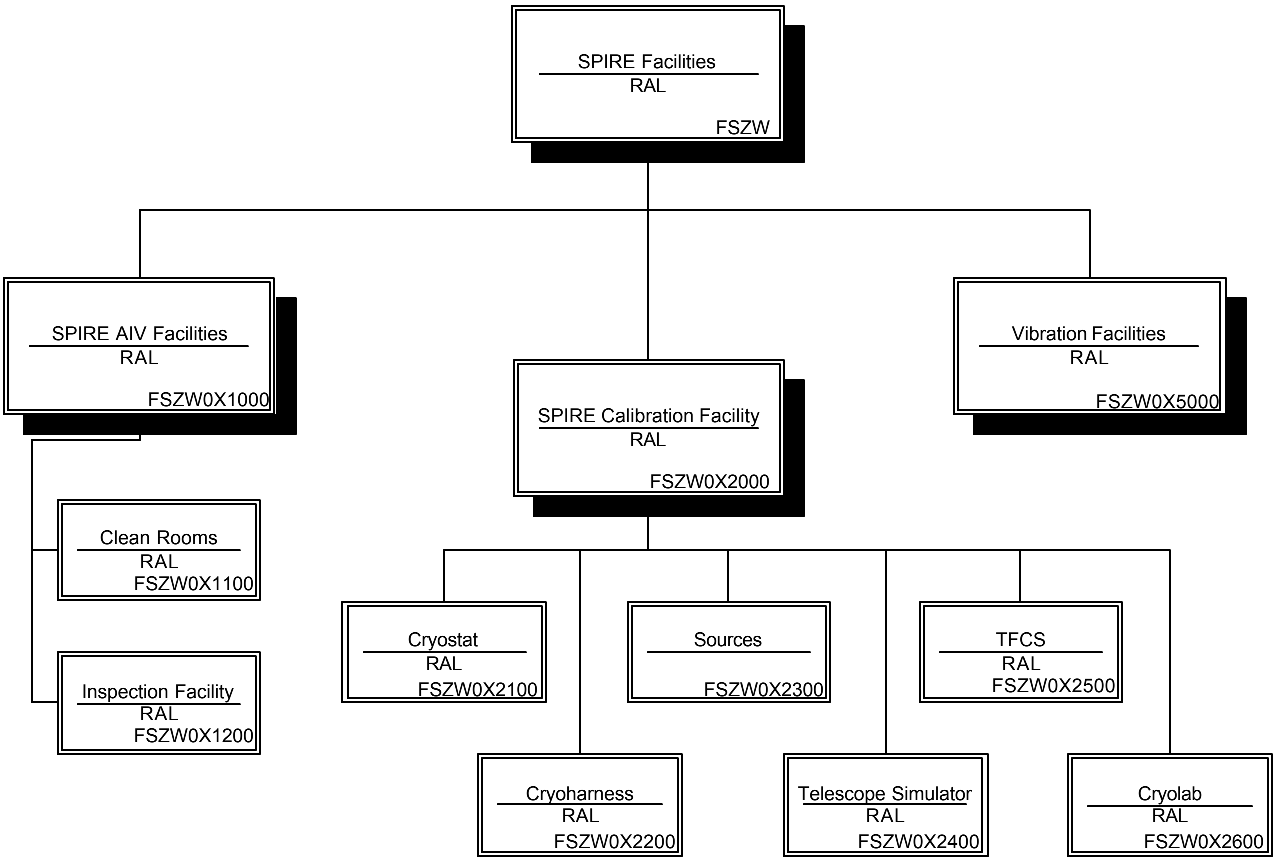

Figure 1: Breakdown of SPIRE AIV Facilities

The following facilities have been identified to perform the SPIRE AIV activities

- Dedicated cryogenic test facility, incorporating a 1.7K liquid helium cryostat, calibration equipment and control system.
- Clean rooms for mechanical and electrical integration
- Mechanical inspection facilities
- Vibration facilities for unit and instrument level tests at both ambient and cryogenic conditions.

The breakdown of these facilities is shown in Figure 1.

The cryogenic test facility will comprise of two working areas: a clean room to house the cryostat and optical bench, and a control room to house the instrument EGSE and control equipment for the cryostat and calibration equipment, Figure 2. The working area around the cryostat will be class 1000, and other areas in the clean room will be class 10, 000 or better.

The SPIRE instrument will be mounted in a cryostat to simulate the thermal conditions provided by the FIRST cryostat, namely 7-11K, 4K and 1.7K. External calibration sources will be viewed via a telescope simulator situated outside the cryostat at room temperature. A cold blackbody source (4K-20K) mounted in the cryostat will provide an absolute calibration reference.

The telescope simulator is required to present the instrument with an F-8.68 beam to correctly represent the input from the FIRST telescope.

The control and monitoring of the calibration sources, the telescope simulator and cryostat temperatures will be performed via a single test facility systems computer (TFCS), connected to the main SPIRE EGSE.

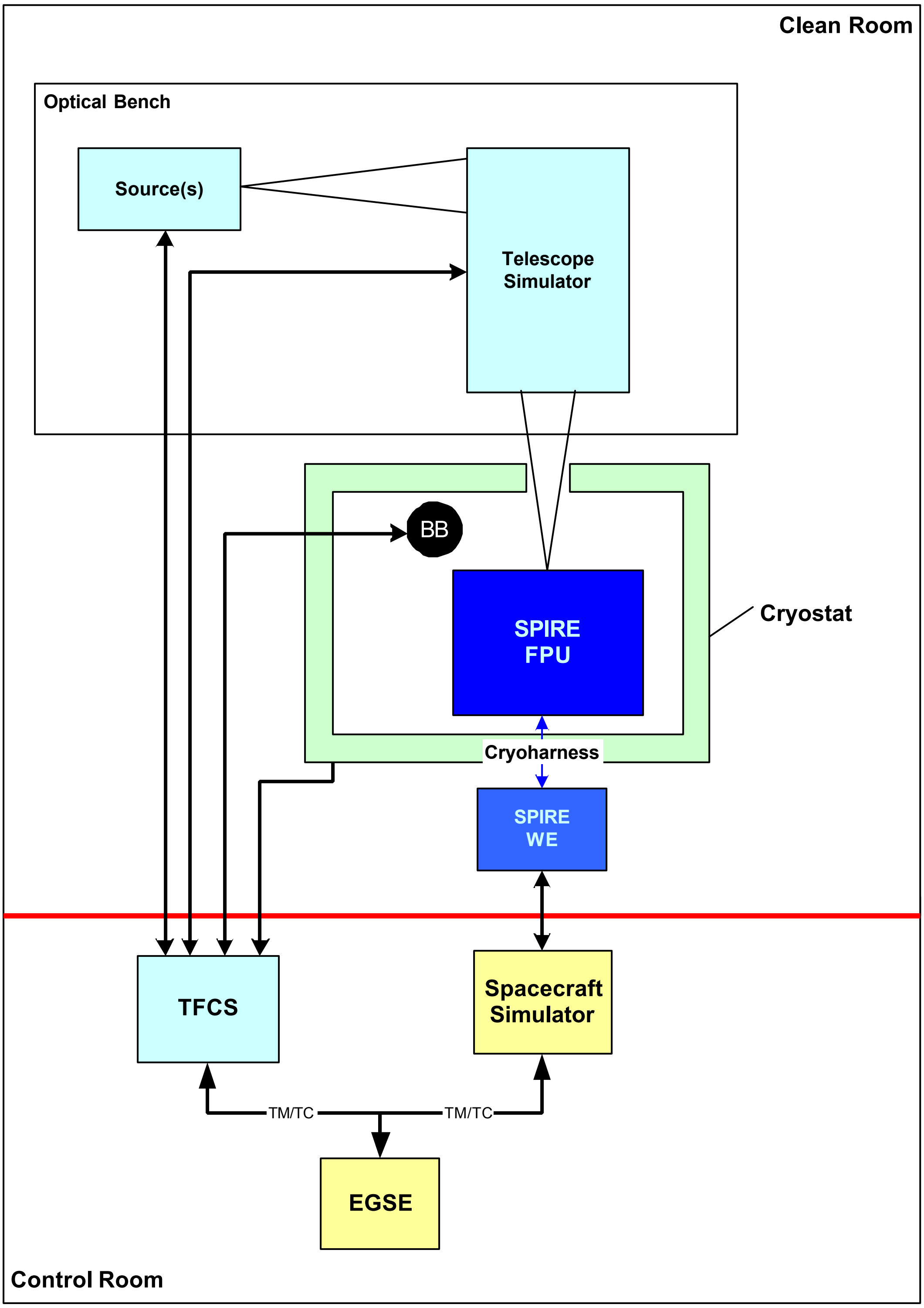

Figure 2: Schematic diagram showing the fundamental elements of the SPIRE Cryogenic Test Facility.

4 Requirements

4.1 General

R0-1	Facilities are required to enable the SPIRE AIV plan to be executed
R0-2	The AIV facilities shall be available to SPIRE until the launch of Herschel

4.2 Cryostat

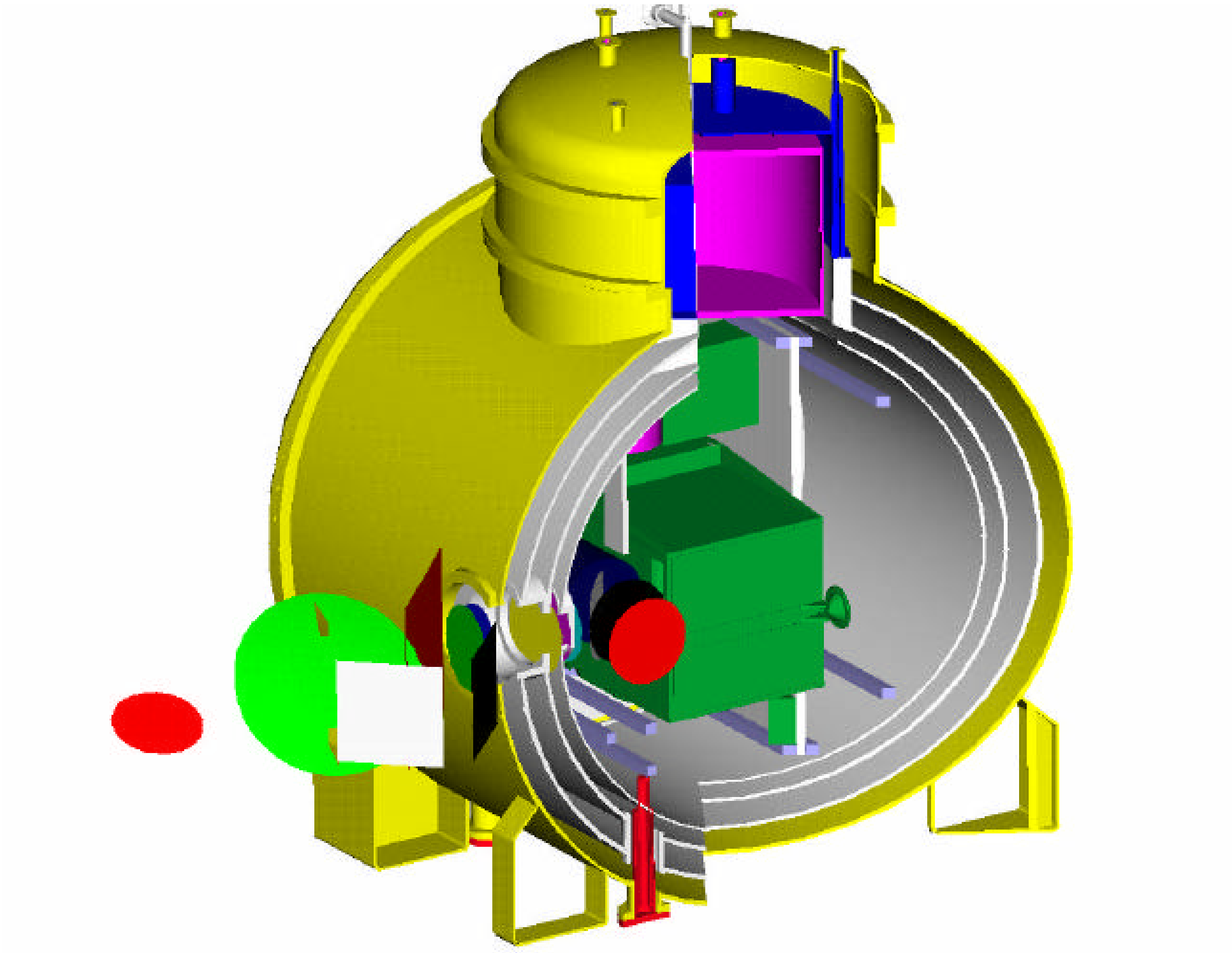

Figure 3: Design concept of SPIRE calibration cryostat, showing the instrument, cold blackbody and filters.

4.2.1 General

R1-1	The calibration cryostat must be able to accommodate the SPIRE instrument and two JFET filter boxes.
R1-2	The cryostat will also house a cold blackbody source operating between 4K and 40K for use during calibration.
R1-3	The SPIRE instrument must be mounted with the baseplate horizontal (I.E., +Y direction down) so that the instrument mechanisms do not work against gravity (AD 5).

R1-4	The distance from the Cryostat outer window to the SPIRE image plane must be no greater than 759mm to ensure correct alignment to the telescope simulator.
R1-5	All materials used for the cryostat and equipment contained in the vacuum environment must be suitable for vacuum and low temperature use. Recommended vacuum materials include: Stainless Steel Aluminium Copper Gold Glass and Quartz Teflon Polymide (Trade named Vespel) Viton Carbon Composites Crystalline Filter Materials (e.g. MgF, LiF etc) Solder Kynar Where materials not on this list are to be used (e.g. black paint, adhesives), their outgassing properties must conform to ESA and NASA outgassing rates as referenced in the SPIRE PA plan.
R1-6	The instrument must be mounted in such a way as to allow ease of access and minimum effort during integration.

4.2.2 Thermal

R1-8	The cryostat must be able to simulate the thermal environment provided by the FIRST cryostat. The main interface temperatures are 7-11K, 4K and 1.7K.
R1-9	At operating temperatures, the temperature of the SPIRE FPU should drift by no-more than 1 Khr^{-1} at 4K (AD 11)
R1-10	The cryostat should enable the SPIRE instrument and electronics to attain operating temperature within 24 hours, at a maximum rate of 20Khr^{-1}.
R1-11	The cryostat should allow a cryogen hold time of at least three days when the instrument is fully cooled. This will eliminate the need for an automatic liquid He delivery system, therefore reducing overall costs. The helium exhaust will not be recovered for future use.
R1-12	The cryostat design should allow the instrument to be heated to TBDK before allowing the He shrouds to warm up to prevent contamination of the instrument optics.
R1-13	Heat leaks must be kept to a minimum by anchoring the thermometer wires to the refrigerant tanks, and/or using low thermal conductivity wire.
R1-14	Temperatures of the thermal environment must be measured during the tests. The location and accuracy of the thermometers will be defined in the thermal test plan.
R1-15	The support structure and optical bench simulator shall not impart any forces (lateral or twisting) on the SPIRE instrument during cool-down or warm-up.

4.2.3 Vacuum

R1-16	The vacuum system must be able to pump the chamber to 10^{-6}mbar (TBD) within 24 hours before filling the cryogen tanks to ensure that the inside of the instrument is at least 10^{-4}mbar (TBC).
R1-17	The maximum pumping rate shall be 50mBar min^{-1} (TBC) to protect the instrument filters. These rates also apply for letting up to air.

R1-18	The pumping system must be mechanically isolated from the chamber to prevent vibrations being transmitted to the instrument optics.
R1-19	The pumping system must be oil free if possible to prevent contamination of the optical surfaces.
R1-20	A gate valve will be installed between the pumping system and cryostat. The valve must be closed before filling the cryogen tanks in order to prevent backflow of any lubricants into the main chamber. The gate valve must automatically close in the event of a failure of the pumping system.
R1-21	A burst valve must be installed to prevent the chamber exceeding atmospheric pressure either during controlled let-up-to-air, or a sudden loss of vacuum.
R1-22	The cleanliness of the inside of the tank must be better than class 1000. Mountings for TBD witness mirrors shall be provided in the calibration rig.
R1-23	The vacuum pressure must be measured during pumpdown. The pressure range is expected to be 1bar to 10^{-8}mbar. After high vacuum has been reached the pressure gauges will be switched off.
R1-24	A Residual Gas Analyser (range 1-200 AMU) is required to monitor partial pressures of contaminants in the chamber during commissioning. This is not required for the actual calibration tests.

4.2.4 Optical

R1-25	The support structure must ensure that the optical alignment is maintained to TBD'' when the instrument is cold.
R1-26	Optical filters will be mounted at each of the cryostat interfaces between the instrument aperture and telescope simulator. The filtering scheme should ensure that the radiative load on the instrument to simulate the load from the FIRST telescope as closely as possible.
R1-27	A flip mirror will be mounted to allow the instrument to view the full area of the cold blackbody source.
R1-28	The cryostat design should allow the optical alignment to be verified with the instrument cold (STM only see RD 5).

4.2.5 Electrical Interfaces

R1-27	Electrical feedthroughs between the air and vacuum sides of the chamber will be provided for the instrument electronics, thermometry and cold calibration target(s).
R1-28	It must be demonstrated that there is no electrical interference to the supplies of the SPIRE instrument and EGSE.

4.2.6 Control and Monitoring

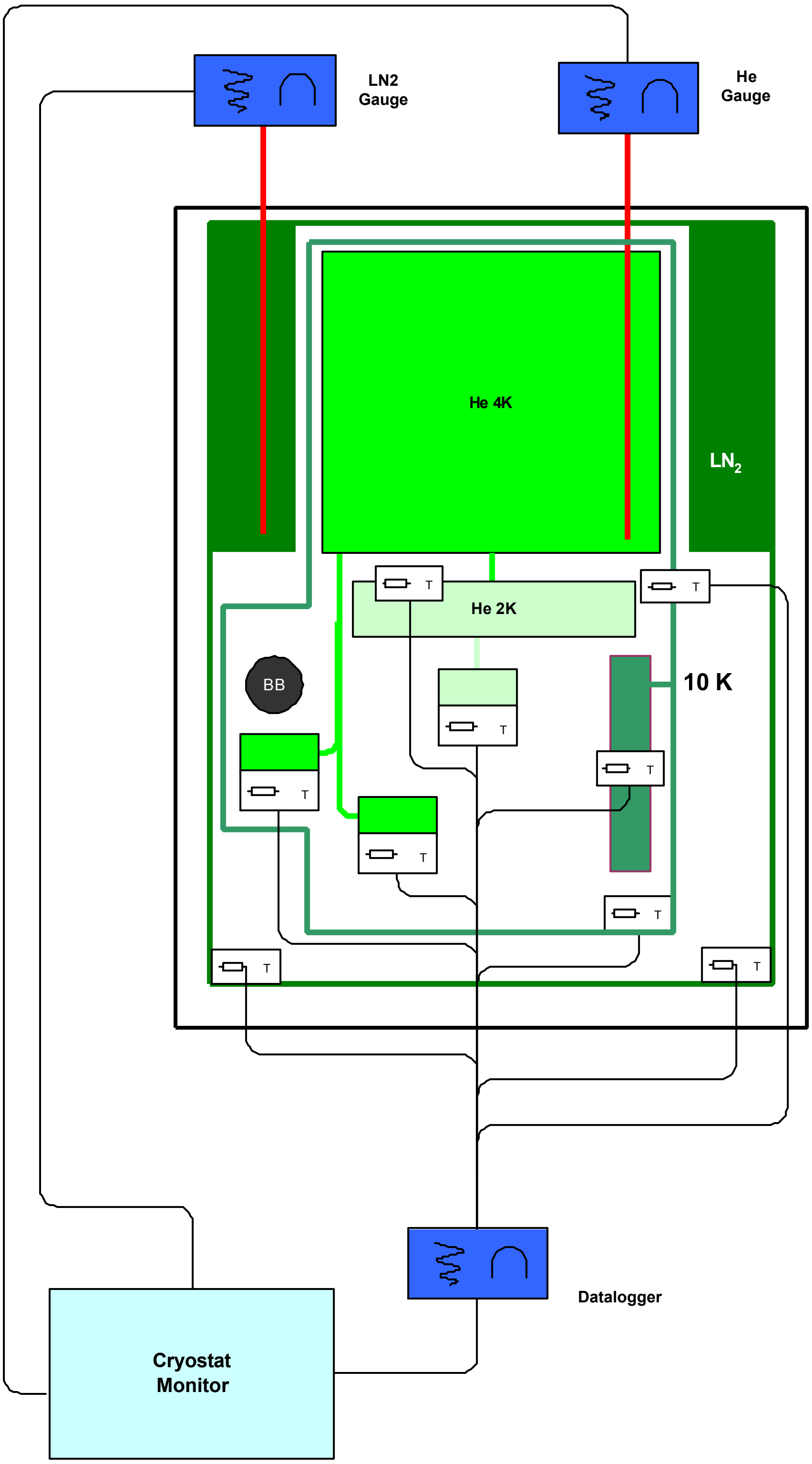

Figure 4: Schematic showing the control and monitoring system for the SPIRE calibration cryostat.

R1-29	The temperatures of the following points in the cryostat will be measured and logged • 77K shield at TBD points • 10K shield at TBD points • 10K instrument base-plate at TBD points • 1.7K instrument interface plate • 4K instrument interface plate • 4K cold blackbody interface plate
R1-30	The liquid nitrogen level shall be monitored throughout the tests. The output from this monitor will feed back to an automatic LN2 dispenser to ensure that the level remains above TBD cm. If the level drops below TBD cm an alarm will sound.
R1-31	The 4K helium level will be monitored throughout the tests. An alarm will sound when the level falls below TBD cm. There will be no automatic dispensation of He.
R1-32	The cryostat must be automatically monitored from the TFCS (see §4.7). The cryostat monitoring software should interface to the facility control software in accordance with an agreed interface specification (see R5-17).
R1-33	No command instructions are required for the cryostat monitor.
R1-34	The monitoring software will send the cryostat temperatures, cryogen levels and status of alarm flags to the TFCS-TEI to be compiled in telemetry packets for transfer to the SPIRE EGSE.
R1-35	A software interface specification will be produced. The specification should define • The mechanism for passing data between the telescope simulator and TEI. • The content and format of telemetry to the TFCS • The timing of data transfer.
R1-36	The cryostat monitor will save all data to an archive.

4.3 Cryoharness

The cryoharness is the internal harness between the SPIRE DRCU and the JFET boxes and FPU. It will comprise of 3 sections: a warm, airside length between the DRCU and the vacuum tank wall, a TBDm length between the vacuum tank wall and the external instrument interfaces at ~10K via the 77K shroud and the 10K shroud. The harness will be based on the specifications for the flight internal harness (AD 10).

R2-1	The heat load from the harness into the level 1 interfaces must be less than 5mW.
R2-2	The total impedance of the conductors must be less than the limits specified in the SPIRE IIDB (AD 5)
R2-3	The harness routing must not obstruct the instrument’s field of view.

4.4 Cryolab

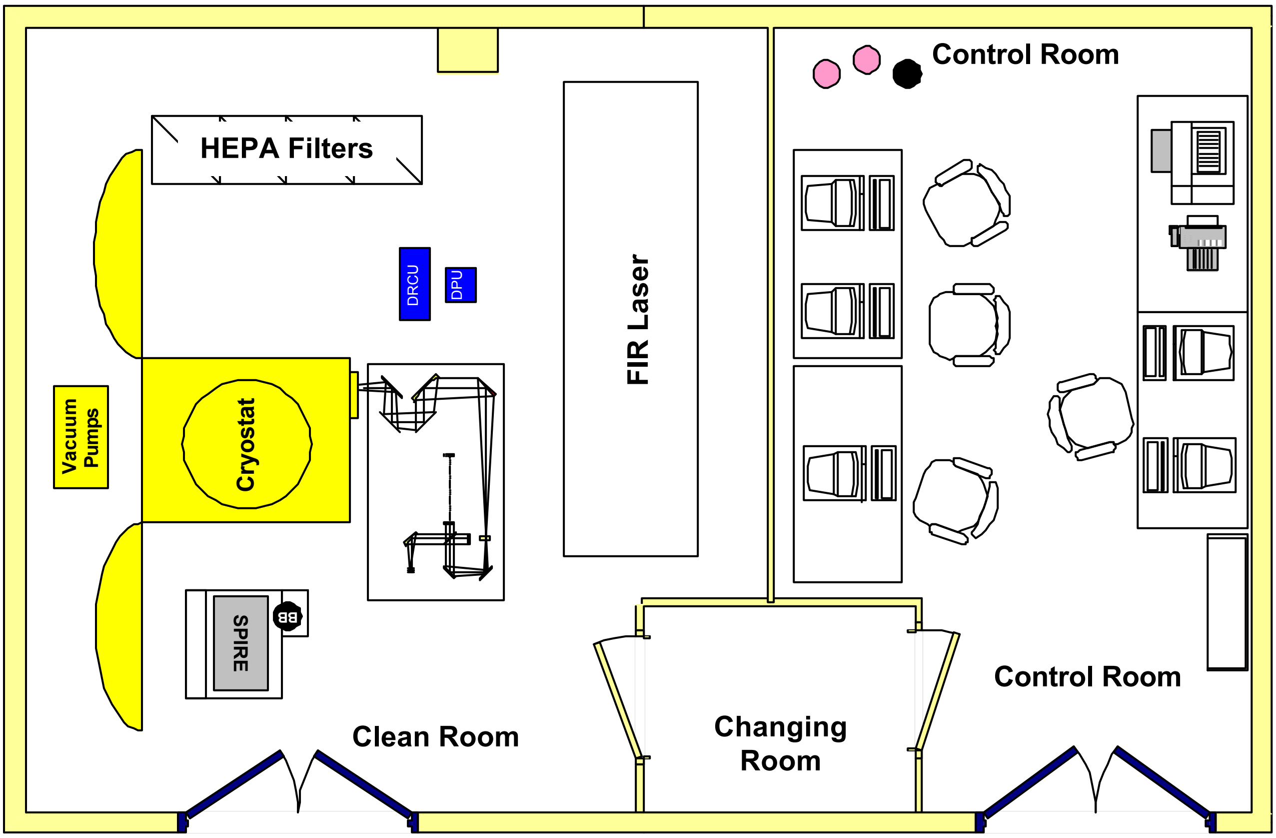

Figure 5: Proposed layout of SPIRE cryolab and control room.

The clean room will house the calibration cryostat, optical bench supporting the sources and telescope assembly and the SPIRE instrument mounted on MGSE. This area will only be used for instrument calibration and not for general AIT activities (RD 2). Hence only limited workspace will be available to prepare test equipment and the instrument for the calibration.

4.4.1 Cleanliness

R3-1	The area immediately surrounding the cryostat, where instrument optics will be exposed, will be class 1000.
R3-2	All other areas in the clean room will be class 10,000 or better.
R3-3	Cleanliness will be monitored throughout the SPIRE calibration period in accordance with AD 6.

4.4.2 Electrical

R3-4	Two clean 28V power supplies must be provided for the SPIRE instrument.
R3-5	There shall be adequate mains power points for the SPIRE EGSE, test equipment and vacuum system. The mains supply must be uninterruptible and surge protected.
R3-6	The electrical design of the facility must ensure that there are no ground loops that could pose an EMI problem.
R3-7	All electrical connections in the facility must be fully documented and readily accessible.

R3-8	ESD protective equipment (mats, wristbands) must be used during instrument integration.

4.4.3 Access

R3-9	The entrance to the clean room must be wide enough to allow the instrument and MGSE to pass through.
R3-10	Due to limited space and to maintain cleanliness, access to the clean room will be restricted to a few authorised personnel. To prevent unauthorised access, a card key system will be installed.

4.4.4 Safety

R3-11	Oxygen monitors will be installed in the clean room that should sound a clear alarm in the event of O_2 going below safe levels.
R3-12	Escape from the room in the event of an emergency must be unrestricted.
R3-13	A full risk assessment must be carried out and emergency procedures must be ready before the facility is used for cryogenic work.
R3-14	Laser warning signs and eye goggles will be provided in accordance with RAL site regulations.
R3-15	A full risk assessment must be carried out and emergency procedures must be ready before using laser equipment.

4.4.5 Other

R3-16	The clean room should be light tight to allow use as a dark room.
R3-17	The temperature within the clean room must be maintained at TBD°C± °C.
R3-18	The humidity within the clean room must be maintained at TBD

4.5 Control Room

R4-1	There must be adequate space for the SPIRE EGSE, TFCS, vacuum equipment and at least 4-5 people.
R4-2	Access to the control room will be restricted by a card key system provided by the RAL AIV facility.
R4-3	The entrance to the clean room will have changing facilities.
R4-4	There will be sufficient mains power supplies for the EGSE and support equipment. The mains supply must be uninterruptible and surge protected.
R4-5	The control room will have a telephone.
R4-6	Connection points will be provided to allow connection to the internet, and fax machines.
R4-7	The control room must be air-conditioned.

4.6 Telescope Simulator

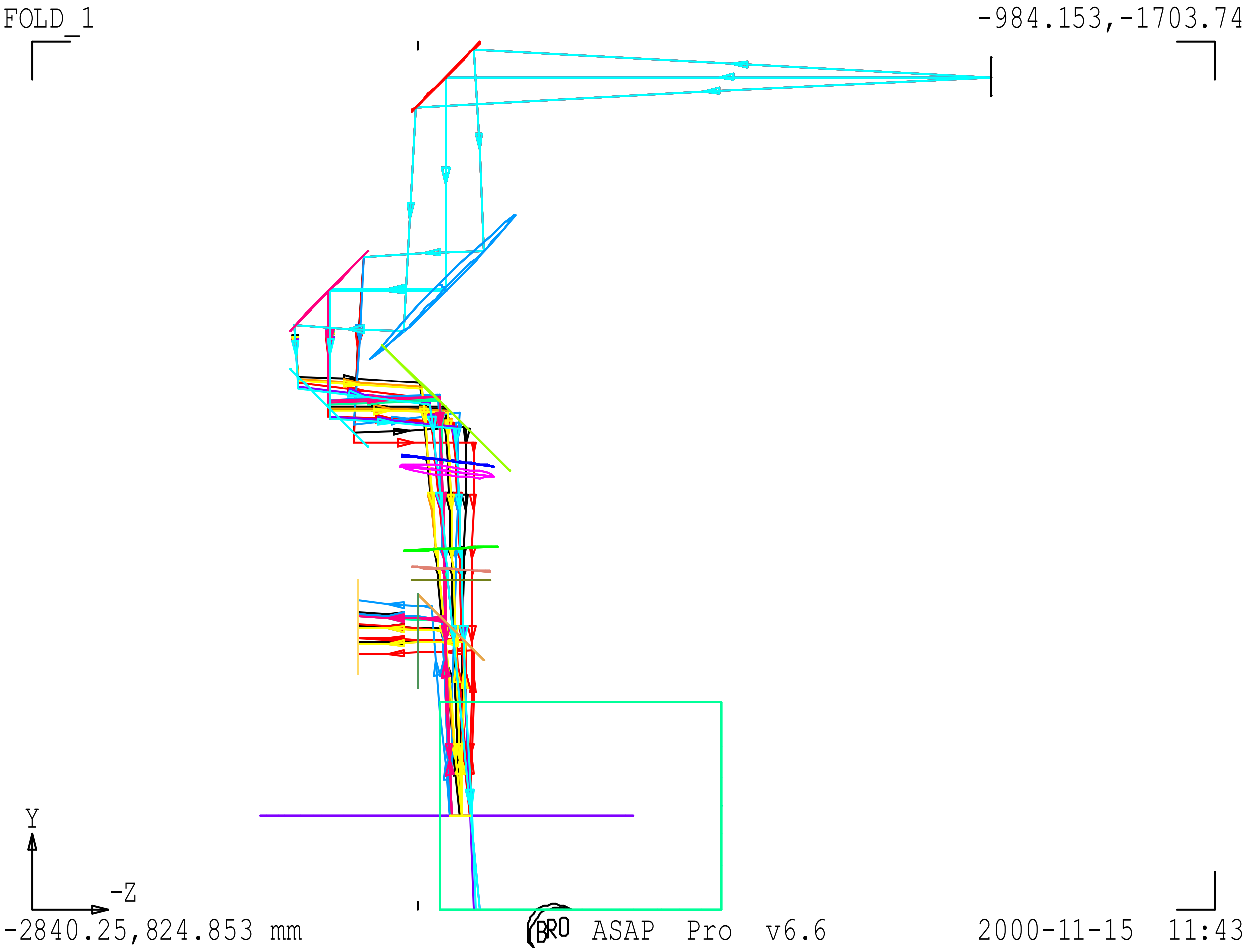

Figure 6: Optical design concept of the Telescope Simulator. To be updated.

The SPIRE telescope simulator is of the type for sub-mm wavelengths, whose principle & design is as per RD 4. It is to be used as general-purpose equipment during the system-level instrument tests & calibration in the cryostat facility at RAL. The optical functions that the simulator performs are described in the following sections. Each is considered as one type of requirement among the several non-optical ones in the list.

The main function of the TS is to present the instrument with a test beam of spatial/angular shape close to that of the point-source beam which is provided by the FIRST telescope in flight. Details of this telescope beam are in AD 4. Although such a point-source beam has full spatial coherence, the test beam may instead be partially coherent, where the source is incoherent & has size which is significant (or oversized) with respect to the SPIRE point source transmittance (PST).

The telescope simulator should as far as possible be self-verifying. This concerns how we ensure that the simulator beam functions as per its design to replicate the telescope beam. Verification is needed in terms of:

- Beam form (amplitude & wavefront shape).
- Field angle (beam direction steering relative to instrument).
- Focus (beam axial position relative to instrument).

A possible scheme for optical verification is similar to LWS, but with a restriction that full-aperture imaging may not be possible in the visible if the surface roughness of the large aspheric mirror cannot be made << 1μm. The LWS scheme is to add a trace laser beam to the simulator input, and to include a pellicle beam splitter in the output. This will reflect the trace into an alignment telescope, and into a pinhole+Golay cell FIR detector. The alignment telescope is to visually locate the simulator angle reference, & the FIR detector to locate the focus reference (if the main mirror can be made of optical quality, it may be possible to make both references with the alignment telescope, as in LWS). A compensator plate to is needed in the verification path to correctly allow for the optical paths of the cryostat window & filters. The verification of field angle & focus may be made by moving the telescope/detector on a calibrated positioner, or by locating the focussed beam on a spherical reference surface + mask to represent SPIRE 'FP', and making metrology on this.

Where the pellicle does not transmit the required source, the verification/monitoring cannot be continuous, but will be made periodically. This will be done on setting up each source & periodically during calibration runs. For automation the pellicle may be shuttered.

R5-1	**Optical beam** The Telescope Simulator will present the SPIRE FPU with a test beam of spatial & angular form close to that of the point-source beam which is provided by the Herschel telescope in flight. Details of the telescope design are in TBD. In detail, this beam is nominally spatially coherent, and is a uniform amplitude spherical wave at the telescope pupil. In the simulator, in addition to obtaining the correct beam form, the beam size in terms of F-number (F~8.68) and orientation in terms of exit pupil distance must both be representative of the Herschel telescope. To achieve this beam all optics subsequent to the pupil mask have to be oversized with respect to the geometric beam to so that their clipping of the FIR beam is < 1% intensity at the longest wavelength. The sources are required to be compatible with such output. Although the Herschel point-source beam has full spatial coherence, the test beam may instead be partially coherent, where the source is incoherent & has size which is significant (or oversized) with respect to the SPIRE point source transmittance (PST).
R5-2	**Field-of-view.** The beam must to steered and focus-adjusted over the range required to measure the spatial response of all SPIRE detectors. This must be achievable in a single cryogenic run, i.e. without having to re-configure the instrument, for both the PHOT & FTS. The angle & focus ranges required are those of the SPIRE instrument design geometry, AD 10 (the FOV extreme positions lie on the feedhorn aperture edge of the outermost detector of each array).
R5-3	**Spectral range.** The system must satisfy the beam-shape requirement and have sufficient throughput over a wavelength range of **200 to 700 microns.**
R5-4	**Sources.** The main beam requirement of the simulator is for point source beams, i.e. sources which approximate to full spatial coherence in having etendue ~ λ^2. They should also have far-field divergence sufficiently large that they over-illuminate the simulator pupil mask, thereby making a beam pattern that approximates to a uniform illumination ('top-hat' shape). The use of extended sources may be considered in order to allow more than one detector to be illuminated, but only for measurements which don't involve spatial resolution. The main requirement of the simulator optics is to provide a point source beam, and it is not required to pass an extended source without vignetting. Any extended-source measurements would therefore require the vignetting behaviour of the simulator to be measured.
R5-5	**Instrument line-of-sight.** This test does not require the Herschel-representative infra-red beam, but is included here because it must be done with the instrument cold, and so with this facility. The test involves a check that the alignment of SPIRE with respect to its reference cube (located on outside of the instrument box) remains within budget between room & operational temperatures. (ref.: optical alignment plan, LOOM.KD.SPIRE.2000.001-1). The test can be made on the structural model and so in a separate & earlier cryogenic run to the main calibration task. The test is in LOS only; i.e. does not need to include focus.

R5-6	The Telescope Simulator excluding the source will occupy an area no larger than 1500 mm x 2500mm (TBC). A restriction on the overall dimensions is necessary due to the limited space available in the facility clean room.
R5-7	The simulator is required to have sufficient working distance to access the SPIRE input focal surface (FP) as situated inside the tank. To accommodate the instrument & thermal shields/ flip mirror + filter housings etc. the tank will have approx. 750mm radius. The distance from the Cryostat outer window to the SPIRE image plane must be likewise sufficient.
R5-8	The optical axis height is defined by the cryostat design.
R5-9	The reflective response of the required filters & uncoated quartz vacuum window set up multiple paths within the output beam. For a nominal design with parallel filters these would add to the direct transmission path as out-of-focus ghost beams. These paths are to be eliminated by tilting the filters & wedging the window such that these reflections all fall on the instrument at positions outside of the entrance aperture. Where this cannot be done or where residual secondary paths arise due to other items close to the beam paths, the ghosts may be acceptable if their power level can be shown to be < 1 % of the main beam.
R5-10	It shall be possible to verify the alignment and focus of the simulated beam.
R5-11	The position of the moving mirrors will be remotely controlled and monitored by the TFCS.
R5-12	The scanning system must synthesise the curved FIRST focal surface, again by means of co-ordinated control of elements in accordance with specified control laws.
R5-13	The pupil must be sized so that the central obscuration is > 20 times longest wavelength. For use at oblique incidence it must have size & shape such that its effect on the clipped beam is to impose a pupil pattern equivalent to that of Herschel.
R5-14	Spatial uniformity of optics – to satisfy R5-1
R5-15	Spectral uniformity of optics – TBD
R5-16	Stability of beam < 0.05 pixel size of shortest wavelength.
R5-17	The simulator will include a visible source (e.g. laser trace beam) which is compatible with the instrument alignment tools for the purpose of setting up & verifying the system alignment prior to cryogenic tests.
R5-18	The telescope simulator should have the ability to scan a point source beyond the instrument's field of view in both axes.
R5-19	The telescope simulator must be automatically controlled from the TFCS (see §4.7). The telescope simulator control software should interface to the facility control software in accordance with an agreed interface specification (see R5-17).
R5-20	The telescope simulator control software must be able to receive instructions/commands from an external application. The instructions should include as a minimum: ● Move to a position (x,y)
R5-21	The telescope simulator control software will send the mirror positions to the TFCS-TEI to be compiled in telemetry packets for transfer to the SPIRE EGSE.
R5-22	A software interface specification will be produced. The specification should define The mechanism for passing data between the telescope simulator and TEI. The format of instructions from the TFCS The format of telemetry to the TFCS The timing of data transfer.
R5-23	The telescope control software shall be synchronised to the SPIRE EGSE.

R5-24	The control software shall allow continuous scanning of the telescope simulator.

4.7 Sources

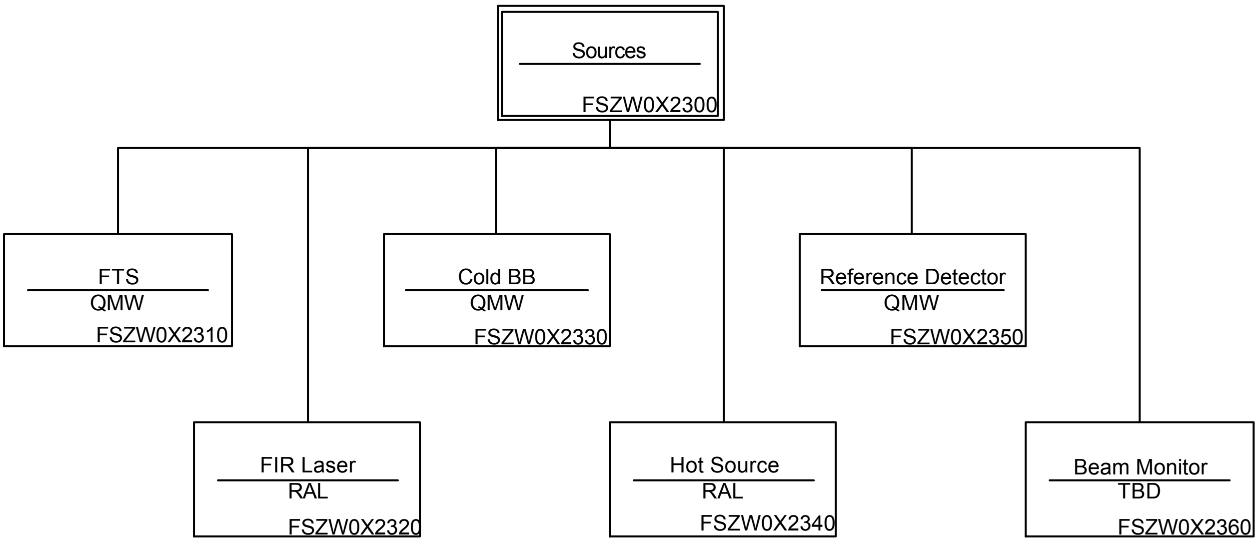

Figure 7: WBS of Calibration Sources and Test Equipment

The following sources and associated test equipment will be required for the SPIRE calibration tests

- Far Infrared – Fourier Transform Spectrometer
- Far Infrared Laser
- Cold Blackbody
- Hot Source
- Reference Detector for cryostat
- Beam Monitor
- Chopper

The main beam requirement of the telescope simulator is for point source beams, i.e. sources which approximate to full spatial coherence in having etendue ~ λ^2. They should also have far-field divergence sufficiently large that they over-illuminate the simulator pupil mask, thereby making a beam pattern that approximates to a uniform illumination (‘top-hat’ shape).

The use of extended sources may be considered in order to allow more than one detector to be illuminated, but only for measurements which don’t involve spatial resolution. The main requirement of the simulator optics is to provide a point source beam, and it is not required to pass an extended source without vignetting. Any extended-source measurements would therefore require the vignetting behaviour of the simulator to be measured.

4.7.1 FIR FTS

R6-1	The FTS shall have a resolving power of >1000 at 200μm.
R6-3	The output beam from the FTS must match the input to the telescope simulator.
R6-4	The modulation efficiency shall be >TBD.

R6-5	The source output shall be stable to TBD% over the scanning period.
R6-6	The FTS must be automatically controlled from the TFCS (see §4.7). The FTS control software should interface to the facility control software in accordance with an agreed interface specification (see R6-10).
R6-7	The FTS control software must be able to receive instructions/commands from an external application. The instructions should include as a minimum: Start Scan Abort Scan Locate ZPD
R6-8	The FTS control software will record the positions of the moving mirror as a function of time. The positions will be sent to the TFCS-TEI to be compiled in telemetry packets for transfer to the SPIRE EGSE.
R6-9	The FTS will autonomously find the zero path difference.
R6-10	A software interface specification will be produced. The specification should define The mechanism for passing data between the FTS and TEI. The format of instructions from the TFCS The format of telemetry to the TFCS The timing of data transfer.
R6-11	The FTS control software shall be synchronised to the SPIRE EGSE.

4.7.2 FIR Laser

An Edinburgh instruments CO_2-pumped FIR laser at RAL as used on ISO-LWS will be used. A range of discrete wavelengths (FIR gas emission lines) is to be provided covering the required spectral range from 200-700µm. The initial laser beam may be taken as collimated (to close to the diffraction limit), with diameter 13mm. The power available is in the order of 10's of mW, but depends greatly on the line used.

R7-1	Deleted
R7-2	The stability required is to meet SNR requirement of R5-4. The laser has a power monitor & readings from this are used to correct the measurement for effects of instability.
R7-3	The laser itself is not single-moded, but approximates to the fully spatially coherent (i.e. point-like) source required. A single longitudinal mode of the laser cavity will be selected using a Fabry-Perot filter. A single transverse mode of the laser (normally the lowest order mode which is a Gaussian beam) will be selected by a spatial filter.
R7.4	A beam expander will be required to match the output of the laser to the input of the telescope simulator. In order to produce a near-uniform top hat profile from the Gaussian beam of R7-3, it will be necessary to over-expand it with respect to the simulator pupil mask.
R7-5	The laser is linearly polarised, with orientation horizontal or vertical depending on the particular line used. This polarisation must be made switchable to provide both options at each wavelength; this can be done using rotatable wire grids or rooftop retro-reflector.

4.7.3 Cold Blackbody

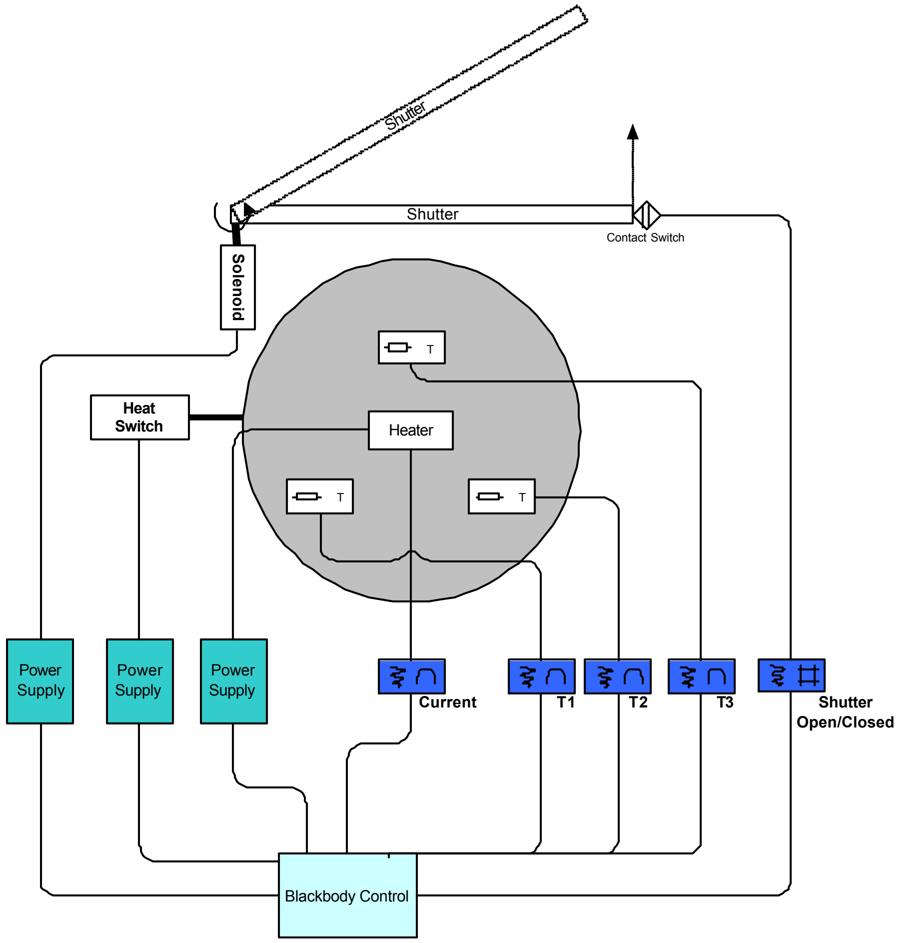

Figure 8: Schematic of cold-blackbody source control and monitoring.

This BB is a source directly to the instrument & does not pass through the simulator optics. It is required to provide a calibration signal to the instrument in a 'direct' radiometric path, i.e. not via the cryostat filters & window. It provides this to all detectors of the arrays simultaneously, to aid flat-field characterisations.
It has variable temperature to allow dynamic range, gain & linearity measurements.
The baseline design (QMW) is a 'Plate' geometry viewed via a flip-mirror, lying directly along-side SPIRE and mounted on the 4K envelope. The flip-mirror/plate design is required to give manageable stray-light in both deployed & stowed positions.

R8-1	The cold blackbody source must be able to operate at any temperature between 4K and 40K.
R8-2	The temperature of the cold blackbody must be stable to ±TBDK over a TBD minute period during calibration
R8-3	The temperatures of the cold blackbody source must be measured by three separate temperature sensors calibrated to an accuracy of TBDK traceable to ITS-90 (RD 7).
R8-4	The radiance errors of the blackbody must be less than an equivalent temperature of TBDK.
R8-5	The cold blackbody will be mounted in the calibration cryostat. The target will be cooled to 4K by a thermal strap from the cryostat. The target must be thermally isolated from the cryostat when operating at temperatures > 4K.
R8-6	The instrument will view by the cold blackbody source via a flip mirror. This mirror must be moved out of the instrument's field of view when the blackbody source is not in use.

R8-7	The blackbody should completely fill the SPIRE field of view.
R8-8	The cold blackbody must be automatically controlled and monitored from the TFCS (see §4.7). The control software should interface to the facility control software in accordance with an agreed interface specification (see R8-11).
R8-9	The cold blackbody control software must be able to receive instructions/commands from an external application. The instructions should include as a minimum: Set heater power Open/Close Shutter Open/Close Heat Switch
R8-10	The cold-blackbody control software will record the position of the shutter/mirror, the blackbody temperature(s), the heater power and the position of heat switch. The data will be sent to the TFCS-TEI to be compiled in telemetry packets for transfer to the SPIRE EGSE.
R8-11	A software interface specification will be produced. The specification should define The mechanism for passing data between the cold blackbody control and TEI. The format and content of instructions from the TFCS The format and content of telemetry to the TFCS The timing of data transfer.
R8-12	The cold-blackbody control software shall be synchronised to the SPIRE EGSE.

4.7.4 Reference Detector

A calibrated reference detector to be fitted in the cryostat is required to measure the FIR transmission through the cryostat filters, and to measure the straylight in the closed cryostat.

R9-1	The reference detector is located in the cryostat & is to have a wide field of view. It may therefore be a 'bare' detector, i.e. without feedhorn. Its location & view is TBD in the design but the aim is for it to view possible stray radiance affecting the instrument. It is to be mounted on the 4K structure (TBC).
R9-2	The detector is to be capable of detecting radiance from a 20K source, and so should have sensitivity to ~200um wavelength.

4.7.5 Hot Source

A hot black body is to be available as the 'point source' referred to in the beam requirements. It is therefore used with its aperture placed in an image plane, to feed a beam of relative aperture likely to be similar to the FIRST telescope, i.e. F=8.68. In this case the coherence patch diameter, approx. $2F\lambda$, is ~ 3.5 to 12mm over the wavelength range above. The BB aperture will typically be varied from 1 to 12mm, to control the degree of spatial coherence /signal level in the measurement.

The BB is likely to be an 800K proprietary BB of the type used in the FTS prototyping at QMW (e.g. Electro-Optics version).

R10-1	The output of the hot-source shall be strong enough to produce a TBDnW signal
R10-2	The optical geometry of the source output must be matched to the input of the FTS or telescope simulator.
R10-3	The source output must not drift by more than TBD over TBDs.

4.7.6 Chopper and Beam Monitor

A 1-25Hz chopper will be required to modulate the input signal.

An airside detector is needed to monitor the input beam from the telescope simulator

R11-1	The input signal from the telescope simulator will be chopped using a variable 1-25Hz chopper.
R11-2	The output of the telescope simulator will be picked off before the cryostat window using a broadband beamsplitter. This may be switchable into the path.
R11-3	The detector used to measure the beam output must be stable to TBD.
R11-4	The beam monitor output must be automatically monitored and logged by the TFCS (see §4.7). The data will be sent to the TFCS-TEI to be compiled in telemetry packets for transfer to the SPIRE EGSE. The software application should interface to the facility control software in accordance with an agreed interface specification (see R11-5).
R11-5	A software interface specification will be produced. The specification should define The mechanism for passing data between the beam monitor and TEI. The format and content of telemetry to the TFCS The timing of data transfer.
R11-6	The chopper frequency will be logged by the TFCS

4.8 Test Facility Control and Monitoring

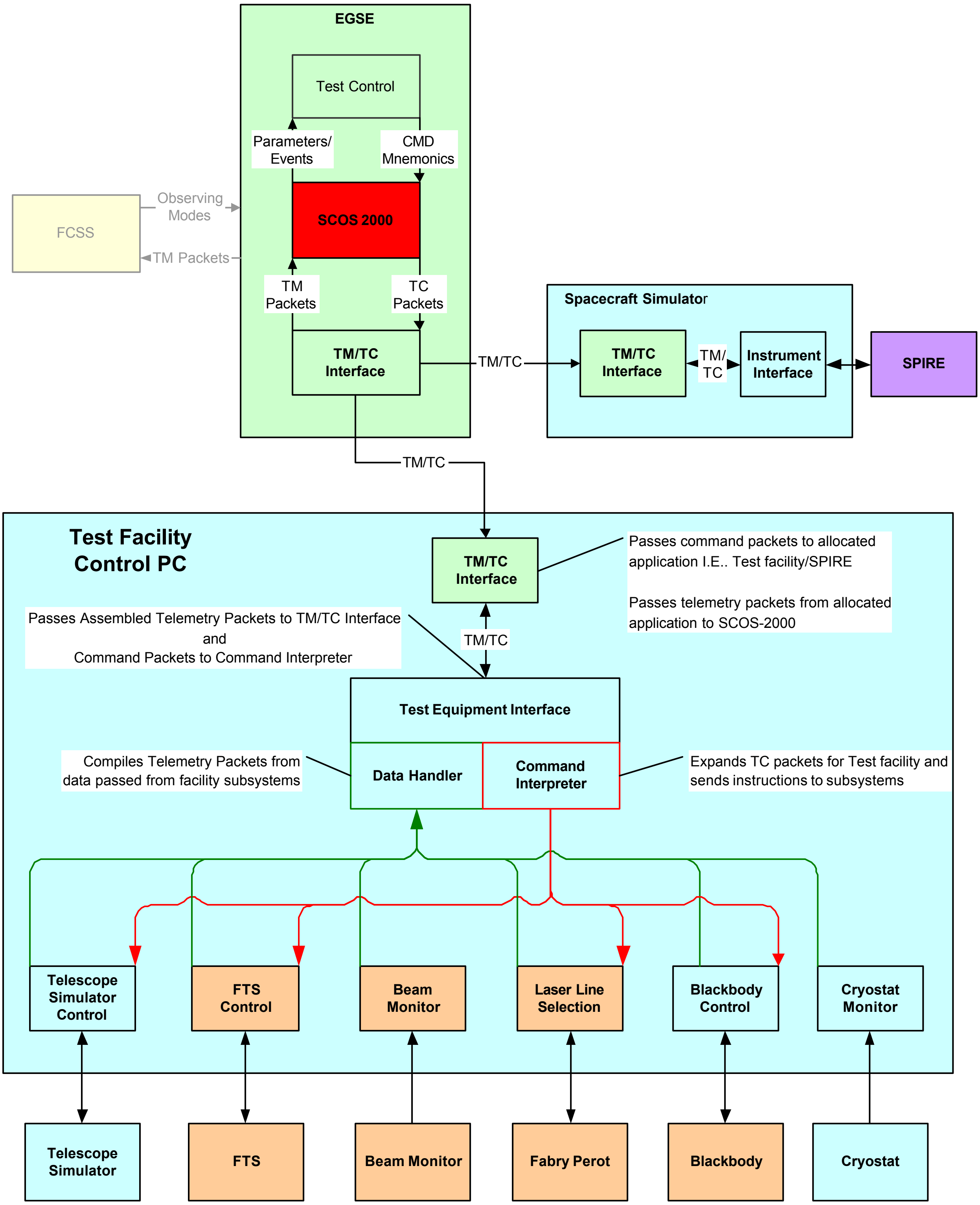

Figure 9: Schematic showing the main elements of the Test Facility Control System (TFCS) and the interfaces to the instrument EGSE and test equipment.

Fully automatic control of the whole calibration system is not necessary since the duration of the calibration tests is only a few weeks. Development of a fully automated system would be disproportionately expensive on cost, effort, and high risk. However remote control and monitoring should be provided, where appropriate, for temperature monitoring, liquid nitrogen and helium levels, and control of the calibration equipment. A Test Facility Control System (TFCS) will be required to control and monitor the following sub-systems:

- Cryostat
- Telescope Simulator
- Cold Blackbody
- Fabry Perot (for laser line selection)
- Beam Monitor
- FTS
- Chopped Frequency

These subsystems will comprise of a number of mechanisms, temperature sensors, data-loggers, solenoids, heaters etc. that will require control and monitoring throughout the SPIRE AIV tests. Each subsystem must be able to receive instructions and/or transmit data to a Test-Equipment-Interface (TEI) that decodes tele-commands (TC) received from the EGSE, and compiles telemetry (TM) packets to be transferred to the main EGSE running SCOS-2000 as shown in Figure 9. Data packets will be passed between the instrument EGSE and the TFCS via a single TM/TC interface as shown. This document defines the high level requirements for the TFCS.

R12-1	The TFCS will be used to provide central control for the test equipment, log temperatures and other test data (e.g. source levels).
R12-2	The TFCS will monitor the temperatures and fluid levels of the calibration cryostat.
R12-3	The TFCS will control and monitor the telescope simulator.
R12-4	The TFCS will control and monitor the cold blackbody source.
R12-5	The TFCS will control and monitor the FTS
R12-6	The TFCS will monitor the signal from the beam pickoff monitor.
R12-7	The TFCS will provide control of a Fabry Perot for laser line selection.
R12-8	There will be a TCP/IP network to allow transfer of data between the TFCS and the SPIRE EGSE.
R12-9	The TFCS will be assigned its own application ID.
R12-10	The TFCS will be able to receive command packets from the SPIRE EGSE
R12-11	The TFCS will transmit telemetry packets to the SPIRE EGSE
R12-12	The TFCS clock will be synchronised to the SPIRE EGSE to allow accurate matching of data.
R12-13	The TFCS will be able to run in a stand-alone mode.
R12-14	The TFCS will log all cryostat and cold blackbody temperatures.
R12-15	The TFCS will record the chopper frequency

4.9 Assembly Clean Rooms

Clean rooms will be provided for assembly and integration of the SPIRE instruments.

4.9.1 Cleanliness

R13-1	The area where instrument optics will be exposed, will be class 100 in accordance with AD 3.
R13-2	All other areas in the clean room will be class 10,000 or better.
R13-3	Cleanliness will be monitored throughout the SPIRE integration period in accordance with AD 6.
R13-4	When transporting SPIRE between clean areas, the instrument and MGSE will be sealed in an airtight bag.

4.9.2 Electrical

R13-5	Two clean 28V power supplies must be provided for the SPIRE instrument.
R13-6	There shall be adequate uninterruptable mains power points for the SPIRE EGSE, test equipment and vacuum system.
R13-7	The electrical design of the facility must ensure that there are no ground loops that could pose an EMI problem.
R13-8	All electrical connections in the facility must be fully documented and readily accessible.

4.9.3 Space

R13-9	The entrance to the clean room must be wide enough to allow the instrument and MGSE to pass through.
R13-10	There must be adequate space to perform the integration activities and store tools, test equipment and flight hardware.
R13-11	To maintain cleanliness, access to the clean room will be restricted to a few authorised personnel. To prevent unauthorised access, a card key system will be installed.

4.9.4 Other

R13-12	Clean room facilities shall be available for the whole SPIRE AIV period until the launch of Herschel.

4.10 Vibration Facilities

Vibration facilities are required for unit level and instrument level tests at ambient and cryogenic conditions.

4.10.1 Performance Requirements

R14-1	The vibration facility will allow testing to be performed at temperatures between 4K and 300K
R14-2	The maximum force rating required is TBD kN
R14-3	The maximum accelerations required for qualification testing are 15g at 70Hz 9g at 100Hz 4.4g at 2000Hz (AD 4)
R14-4	The maximum velocity required is TBD ms^{-1}
R14-5	The frequency range required is 5 – 100Hz
R14-9	There shall be TBD accelerometer channels

4.10.2 Cleanliness

R14-6	The area where instrument optics will be exposed, will be class 100 in accordance with AD 3.
R14-7	All other areas in the clean room will be class 10,000 or better.
R14-8	Cleanliness will be monitored throughout the SPIRE test period in accordance with AD 6.

4.11 Inspection Facility

4.11.1 Performance Requirements

R15-1	The mechanical inspection facility must be capable of measuring the positions of the mirror interfaces in 3 axes to a precision of < 10µm.

4.11.2 Cleanliness

R15-2	The area where instrument optics will be exposed, will be class TBD in accordance with AD 3
R15-3	All other areas in the clean room will be class 10,000 or better.
R15-4	Cleanliness will be monitored throughout the SPIRE test period in accordance with AD 6.