SPIRE Test Facility Requirements Specification

Distribution List :

RAL	Ken J. King	**X**
	Bruce M. Swinyard	**X**
	Dave L. Smith	**X**
	John Delderfield	**X**
QMW	Matt Griffin	**X**
	Alex Ellery	**X**
	Peter Hargrave	**X**

Document Changes

Issue	Date	Remarks
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.

Host system	Windows NT 4.0 SR4
Word Processor	Microsoft Word 97 SR2
File	

Table of contents

1 Scope of the document

This document describes the requirements for the FIRST/SPIRE facilities to be used for the 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.

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 Instrument STM Requirements	B.Swinyard	SPIRE-RAL-NOT-	02-11-2000

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

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		
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

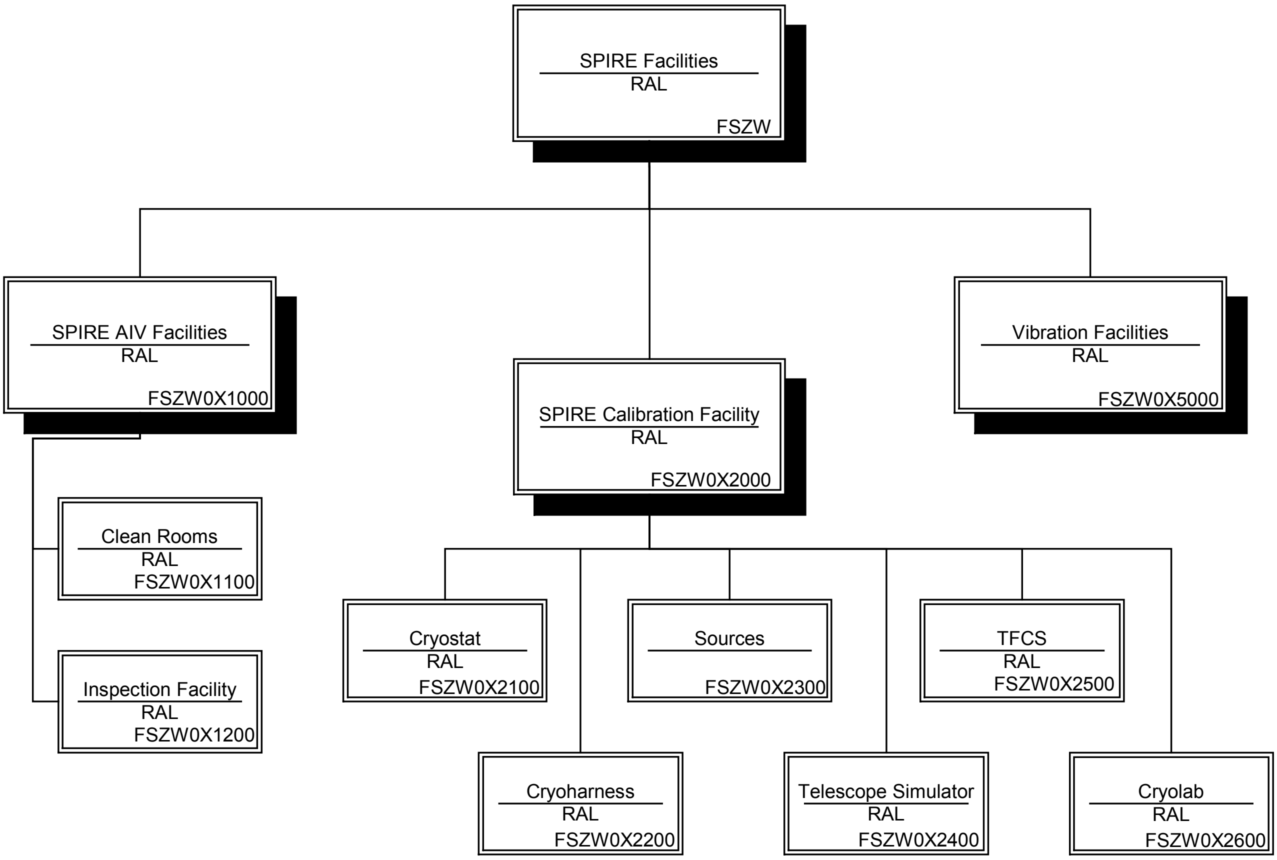

Figure 1: Breakdown of SPIRE AIV Facilities

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

- Dedicated cryogenic test facility, incorporating a 2K 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 2K. External calibration sources will be viewed via a telescope simulator situated outside the cryostat at room temperature. A cold blackbody source (4K-40K) 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, telescope simulator and cryostat temperatures will be performed via a single test facility systems computer (TFSC), connected to the main SPIRE EGSE.

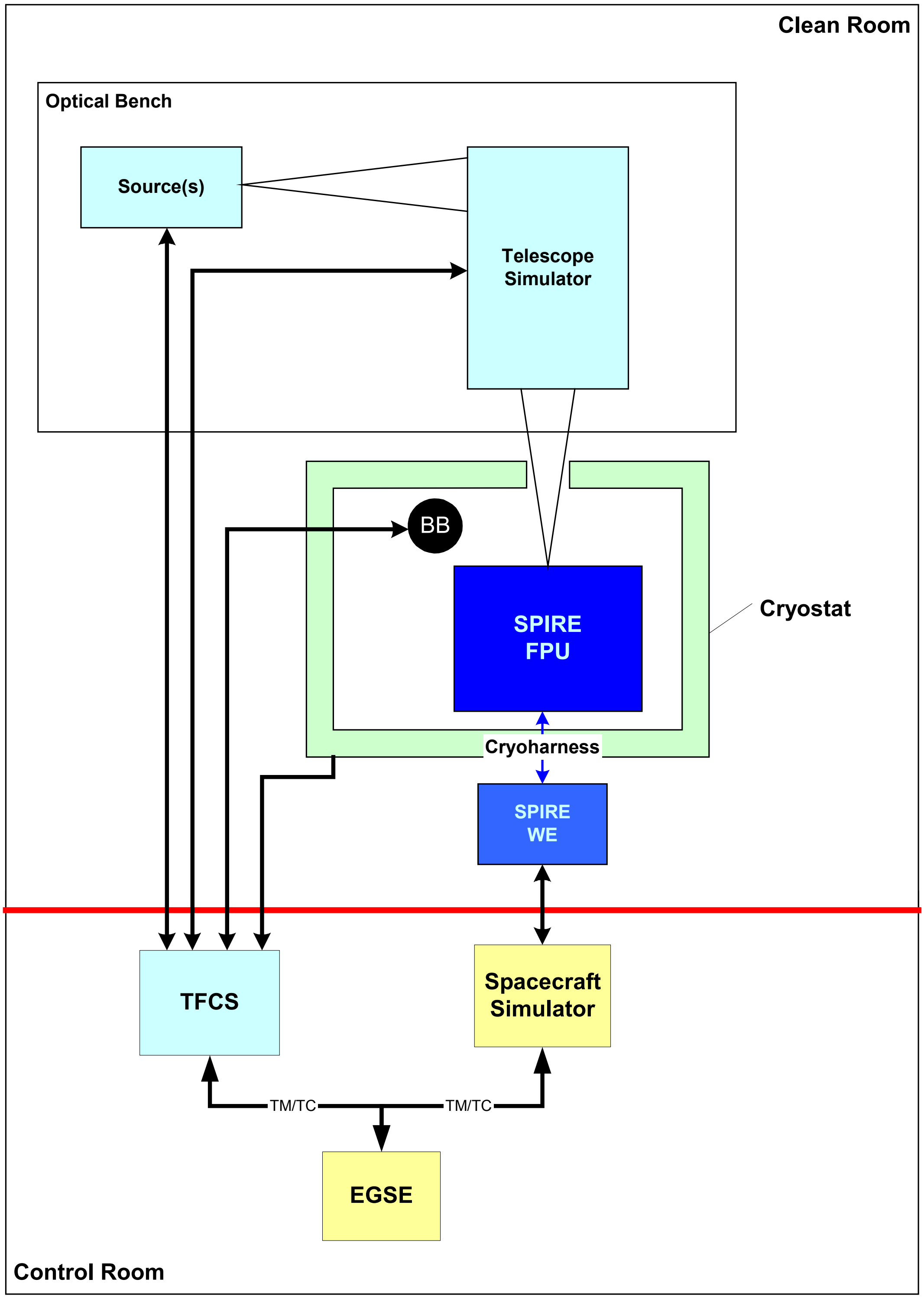

Figure 2: Schematic diagram showing the fundamental elements of the SPIRE Cryogenic Test Facility.

4 Requirements

4.1 Cryostat

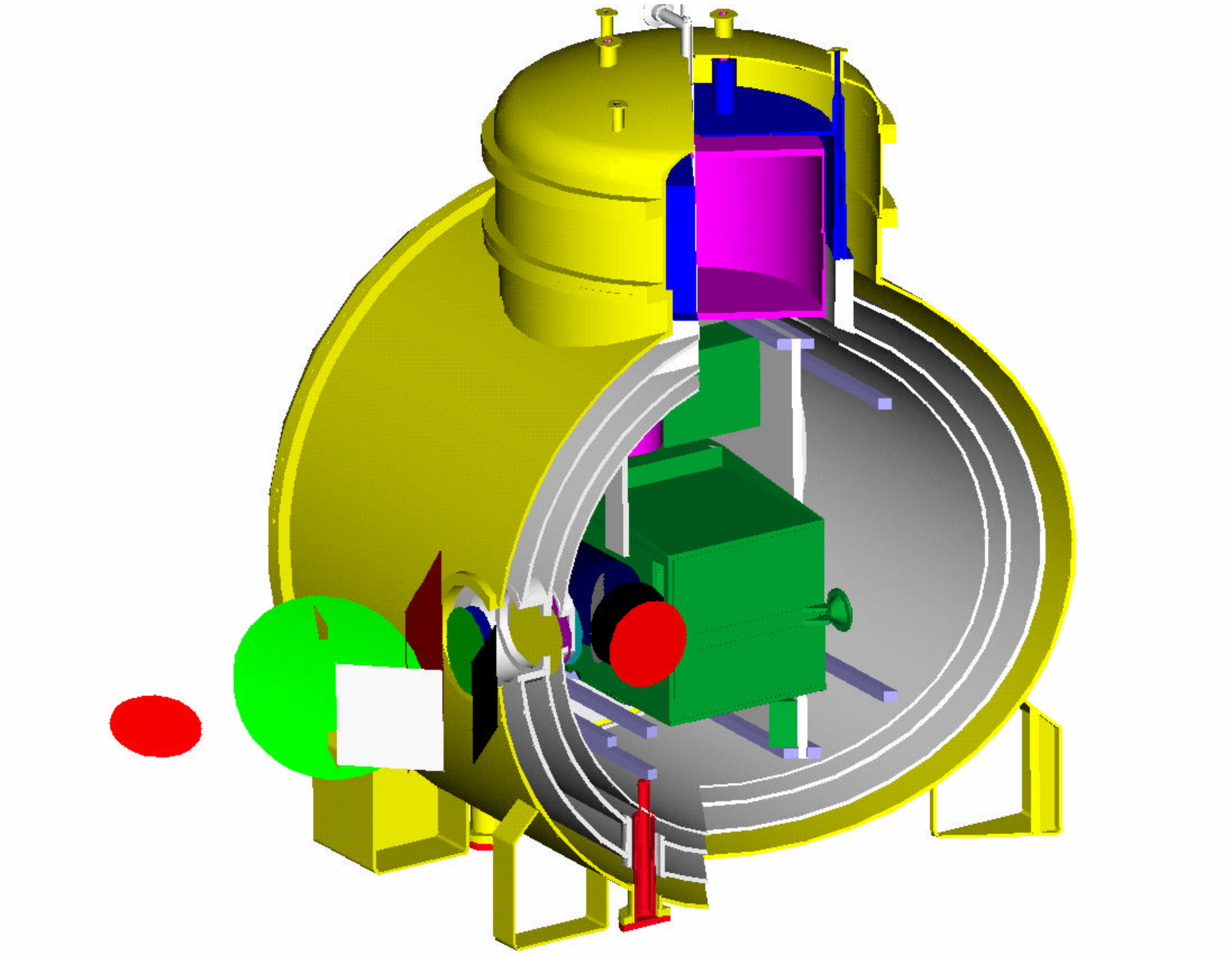

Figure 3: Design concept of SPIRE calibration cryostat, showing the instrument, cold blackbody and filters.

4.1.1 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.
R1-7	The cryostat will be painted yellow.

4.1.2 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 2K.
R1-9	At operating temperatures, the temperature of the SPIRE FPU should drift by no-more than TBD $Kmin^{-1}$
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.

4.1.3 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.

4.1.4 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. The required (TBC) transmissions for the filters are 77K $\tau = 0.0 \mid \lambda \le 100\mu m$, $\tau = 0.9 \mid \lambda > 100\mu m$ 10K $\tau = 0.0 \mid \lambda \le 125\mu m$, $\tau = 0.9 \mid \lambda > 125\mu m$ 4K $\tau = 0.0 \mid \lambda \le 167\mu m$, $\tau = 0.1 \mid \lambda > 167\mu m$
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).

4.1.5 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.

4.1.6 Control and Monitoring

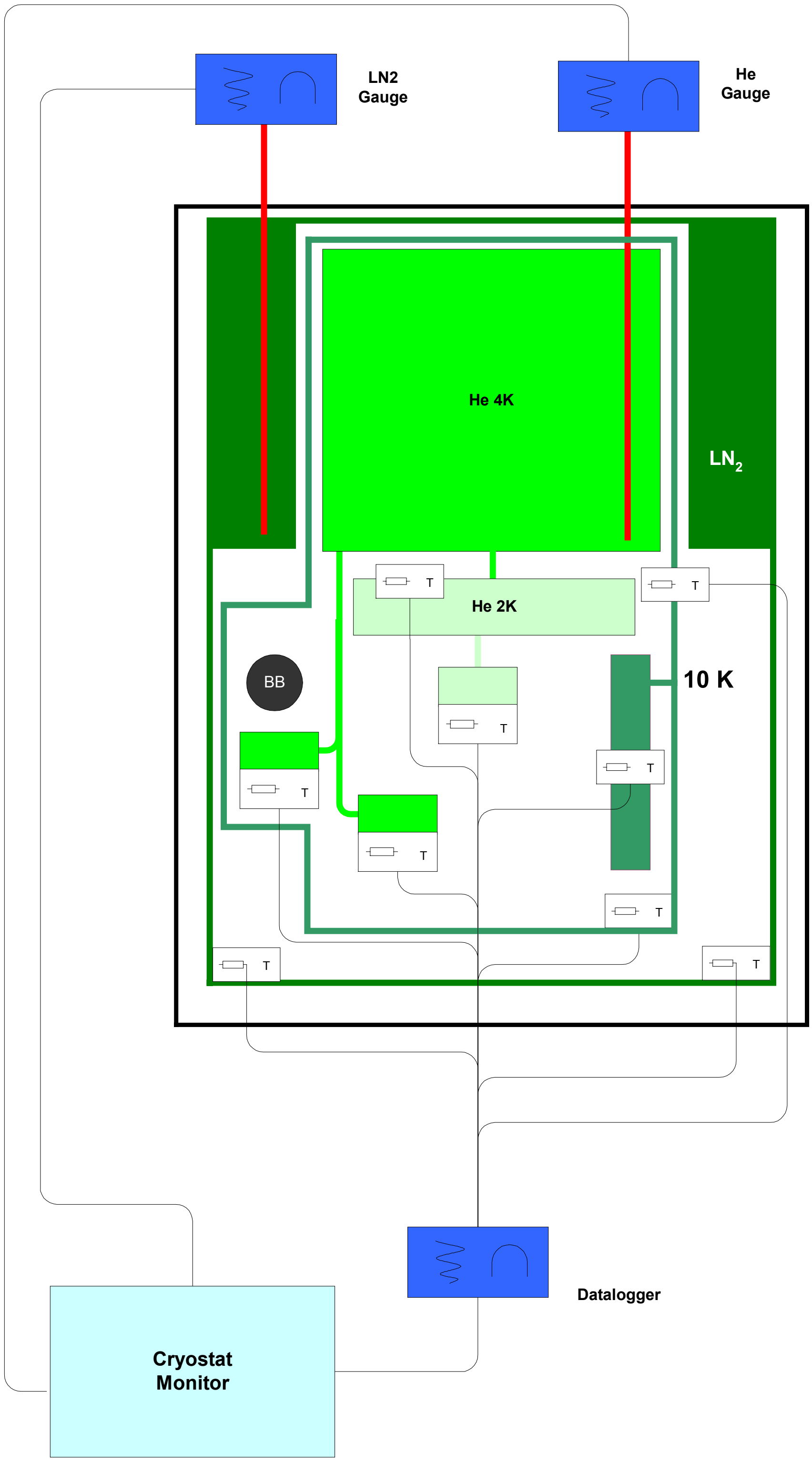

Figure 4: Schematic showing the control and monitoring system for the SPIRE calibration cryostat.

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 • 2K 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.

4.2 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 3m length between the vacuum tank wall and the 77K shield and a 2m (TBC) length between the 77K shield and the external instrument interfaces at ~10K. The 10K-77K harness will be constructed using AWG 38 stainless steel screened-twisted-pairs. The conductors will be attached to 37way MDM connectors by means of pigtails and crimps. The 77K – 300K section will consist of screened-twisted AWG 38 brass pairs. The airside section will use screened twisted copper pairs.

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.

4.3 Cryolab

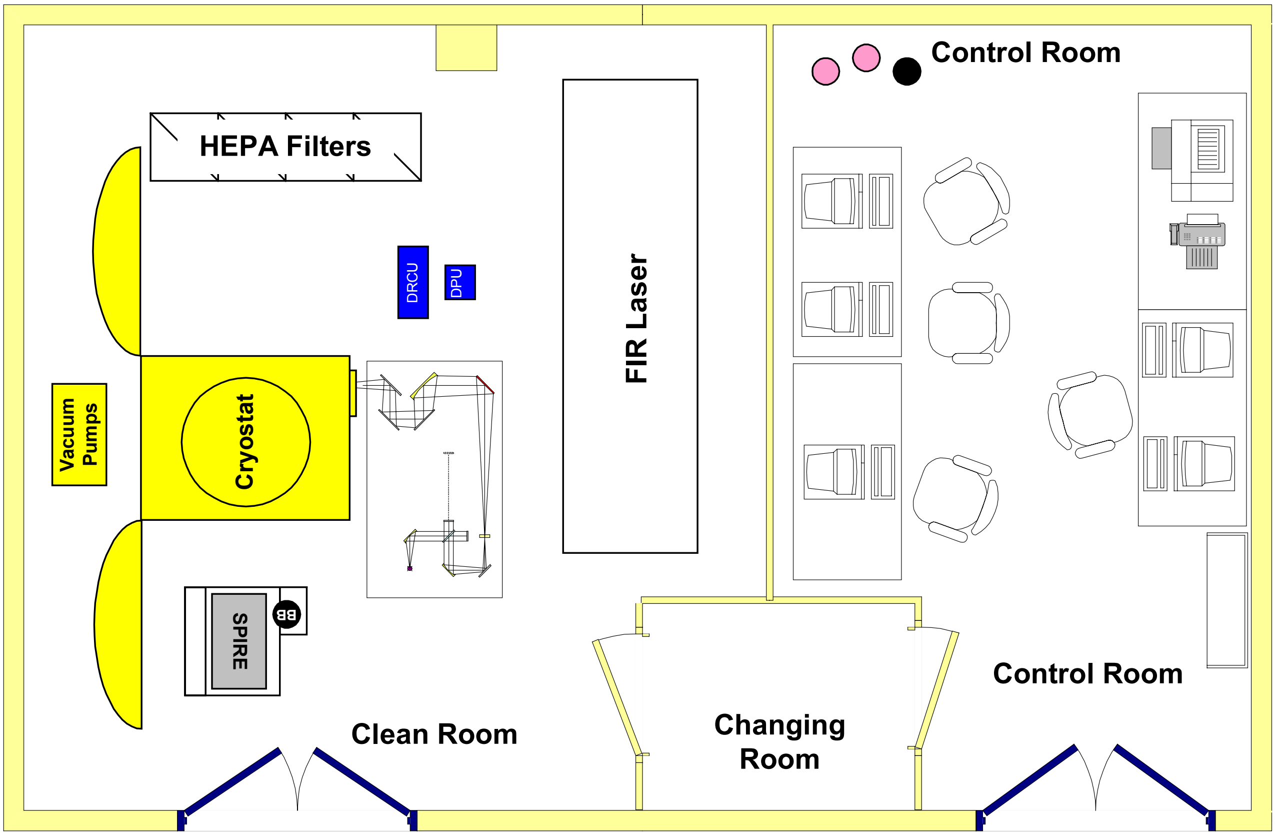

Figure 5: Layout of SPIRE cryolab and control room.

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.

4.3.1 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.

4.3.2 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.

4.3.3 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.

4.3.4 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.

4.3.5 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 TBDºC± ºC.
R3-18	The humidity within the clean room must be maintained at TBD

4.4 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.

4.5 Telescope Simulator

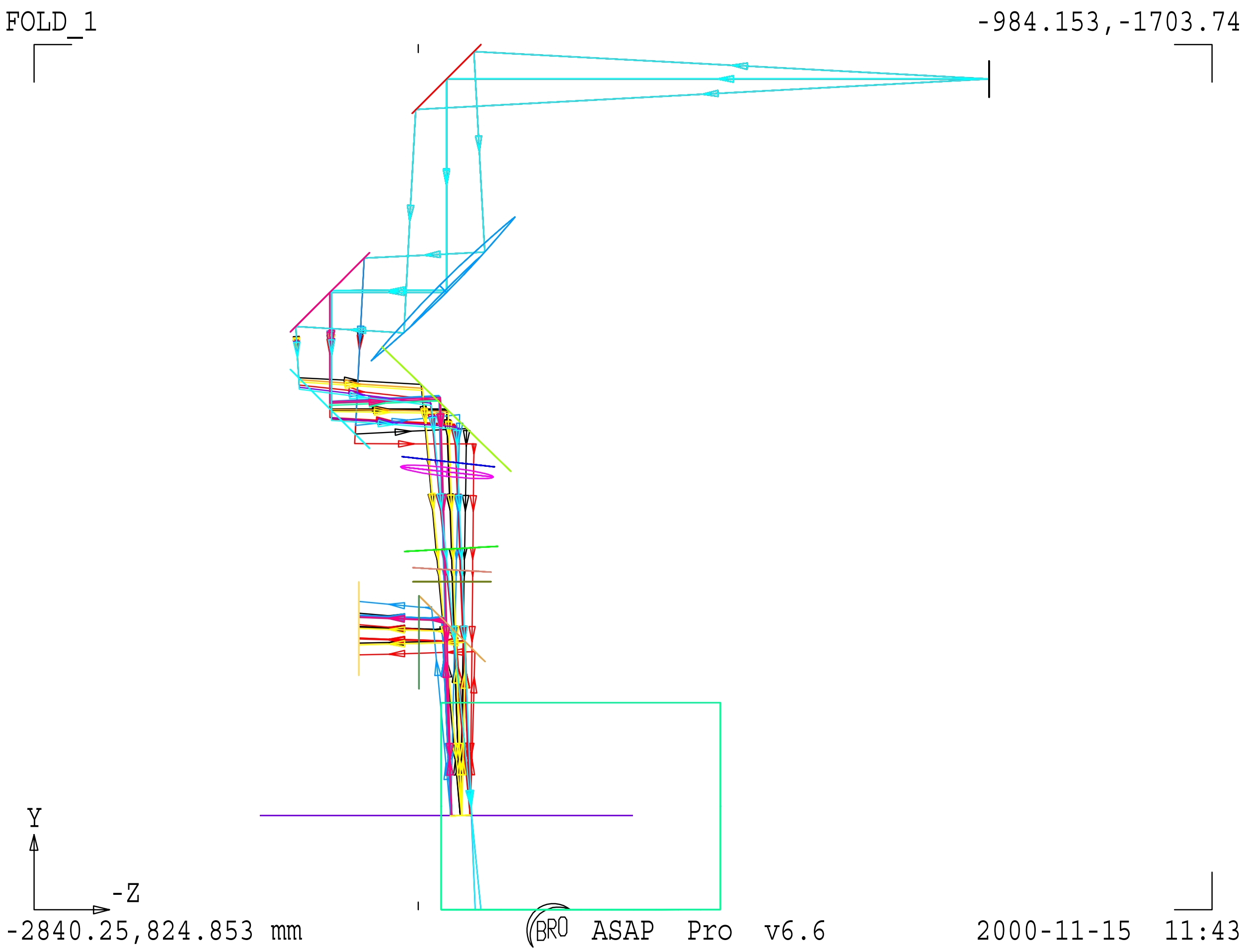

Figure 6: Optical design of the Telescope Simulator

R5-1	The Telescope Simulator will present the SPIRE FPU with a beam having the required telescope F-number (F~8.68), pupil distance, and FOV sufficient to cover the FOV of either instrument. This is to allow each instrument (not necessarily both) to be characterised in a single cryogenic run. In this context the simulator FOV is not instantaneous but refers to the range of beam positions that can be generated by scanning of the optics outside the cryostat (but not any within the cryostat). The scanning system is required to generate this FOV pattern (in 2-d) by co-ordinated motion control as per the specified control laws.
R5-2	The SPIRE beam envelope must not be vignetted. The coherent beam in above requirement should have the same 'fully-filled' point-source beam pattern of FIRST. I.e. that for a uniform amplitude spherical wave as clipped by the pupil only. To achieve this all optics have to be oversized with respect to the geometric beam to give clipping of actual beam to < 1% at the longest wavelength. The sources are required to be compatible with such output.
R5-3	The Telescope Simulator excluding the source will occupy an area no larger than 550mm x 1200mm. A restriction on the overall dimensions is necessary due to the limited space available in the facility clean room.
R5-4	The simulator working distance i.e. from final optic to focal surface, shall allow sufficient path length for the vacuum window, 3 filters, flip mirror & instrument box to be incorporated in the design.

R5-5	The distance from the Cryostat outer window to the SPIRE image plane must be likewise sufficient.
R5-6	The position of the moving mirrors will be remotely controlled and monitored by the TFCS.
R5-7	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.
R5-8	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 FIRST. It must have edges with 100 to 0 % cut-off resolution of << 1 times the shortest wavelength.
R5-9	Spatial uniformity of optics – TBD
R5-10	Spectral uniformity of optics – TBD
R5-11	Stability of beam << pixel size of shortest wavelength.
R5-12	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.
R5-13	The telescope simulator should have the ability to scan a point source beyond the instrument's field of view in both axes.
R5-14	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).
R5-15	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)
R5-16	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.
R5-17	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.
R5-18	The telescope control software shall be synchronised to the SPIRE EGSE.

4.6 Sources

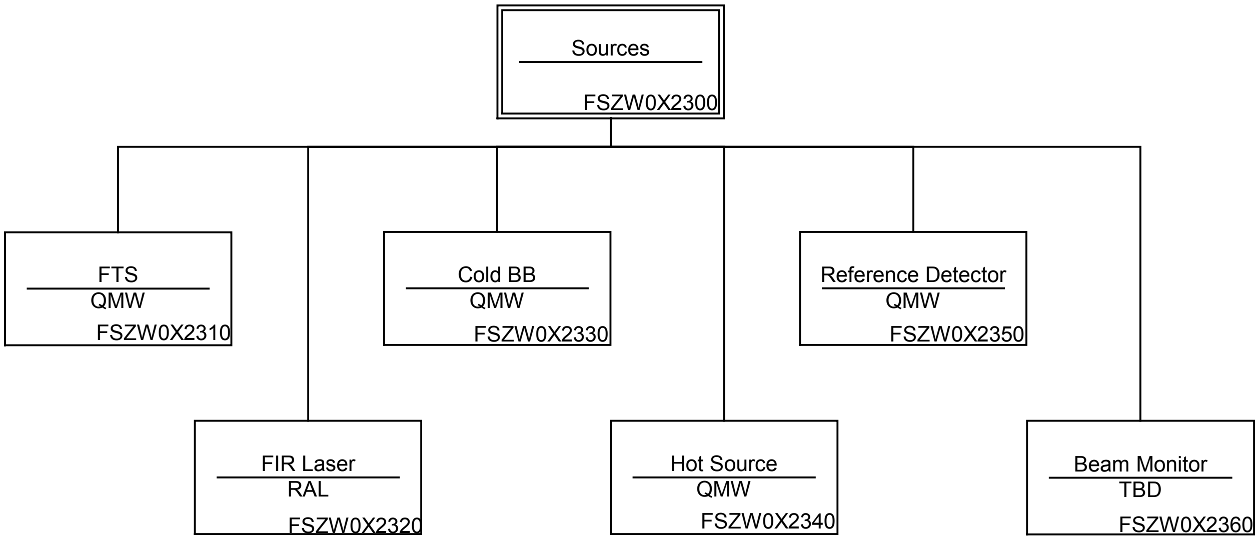

Figure 7: WBS of Calibration Sources and Test Equipment

The following sources 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

4.6.1 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.

4.6.2 FIR Laser

An Edinburgh Instruments FIR laser will be used to provide lines between 200μm to 1000μm.

R7-1	Available lines?
R7-2	Stability?
R7-3	A Fabry-Perot interferometer will be used to select single lines.
R7.4	A beam expander will be required to match the output of the laser to the input of the telescope simulator.
R7-5	A spatial filter will be employed to ensure that the output of the laser is spatially uniform.

4.6.3 Cold Blackbody

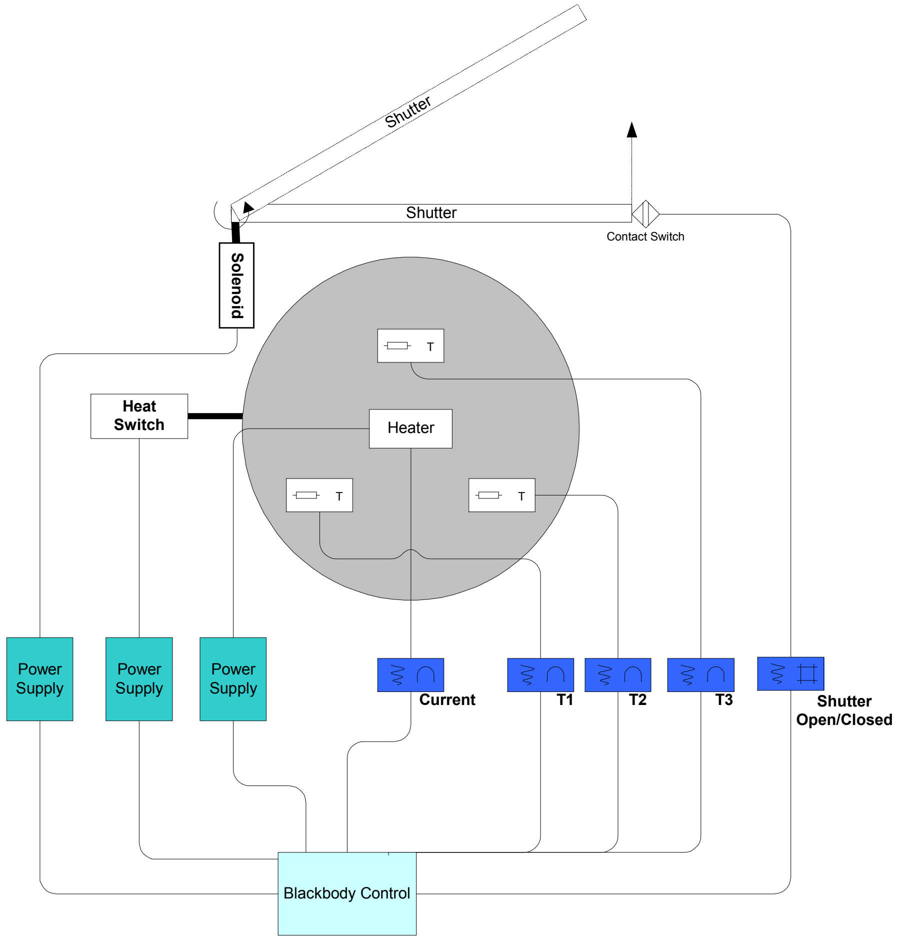

Figure 8: Schematic of cold-blackbody source control and monitoring.

A cold blackbody source mounted in the test cryostat will be used for an absolute radiometric source.

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.
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 FTS control software shall be synchronised to the SPIRE EGSE.

4.6.4 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	

4.6.5 Hot Source

A hot source (black-body) is required as an input to the FTS and the telescope simulator.

R10-1	The output of the hot-source shall be strong enough to produce a ?nW 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.

4.6.6 Beam Monitor

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.
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.

4.7 Test Facility Control and Monitoring

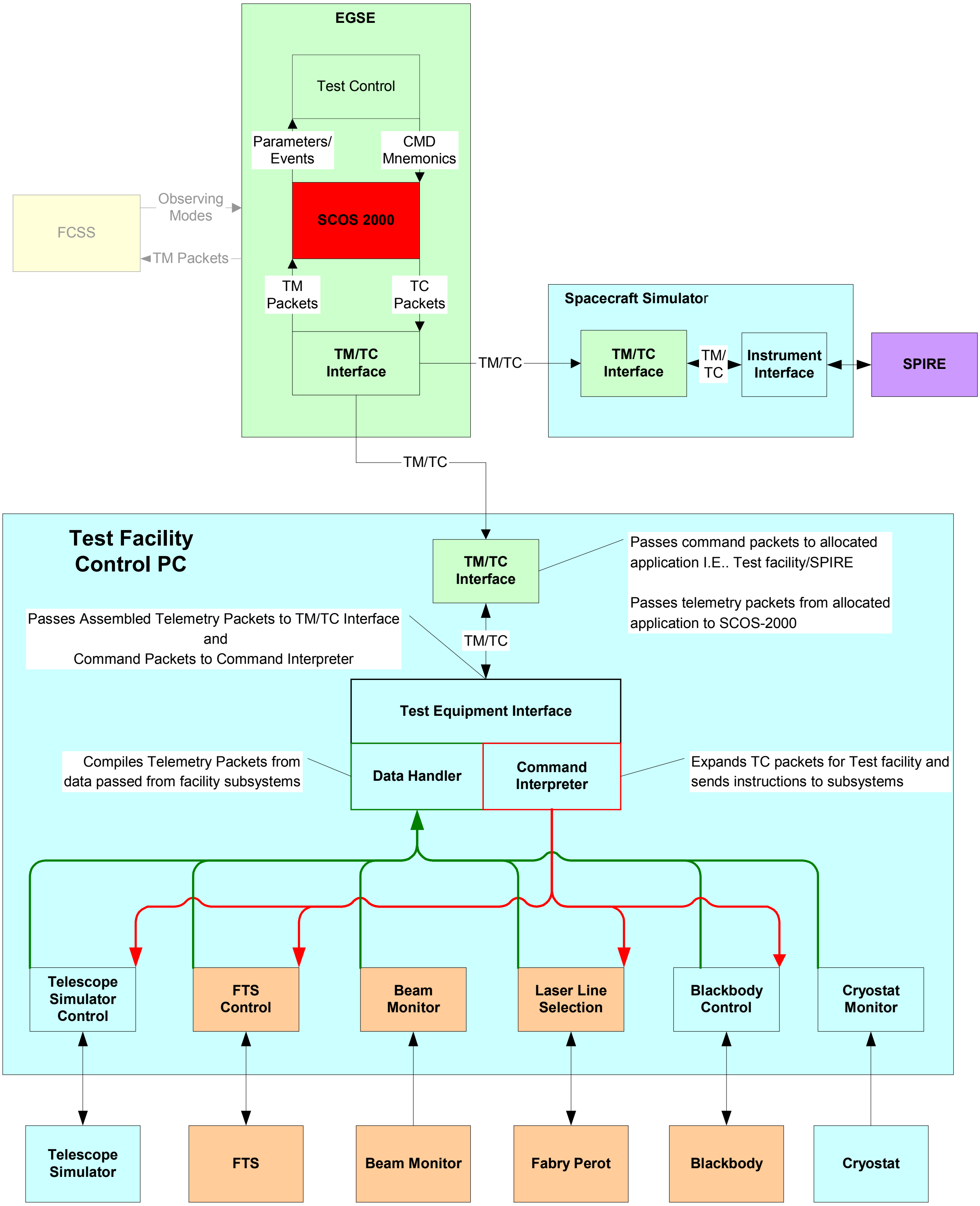

Figure 9: Schematic diagram showing the main elements of the Test Facility Control System (TFCS) and the interfaces to the instrument EGSE and test equipment.

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

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.

4.8 Assembly Clean Rooms

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

4.8.1 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.

4.8.2 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.

4.8.3 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 Vibration Facilities

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

4.9.1 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

4.9.2 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.

4.10 Inspection Facility

4.10.1 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.

4.10.2 Cleanliness

R15-2	The area where instrument optics will be exposed, will be class 100 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.