SPIRE Test Facility Development Plan

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1 Scope of the document

This document describes the development plan of the FIRST/SPIRE Test Facility to be used for the thermal balance, cold functional tests and calibration of the CQM and PFM instruments (AD 1).

2 Documents

2.1 Applicable documents

	Title	Author	Reference	Date
AD 1	SPIRE outline AIV flow	B.Swinyard	SPIRE/RAL/N/0020	
AD 2	Outline Specification of the SPIRE instrument calibration facility	B.Swinyard	SPIRE/RAL/N/0058	
AD 3	SPIRE Development Plan	K.King		

2.2 Reference documents

	Title	Author	Reference	Date

2.3 Glossary

AD	Applicable Document	WE	Warm Electronics
CDR	Critical Design Review		
CQM	Cryogenic Qualification Model		
DDR	Detailed Design Review		
EGSE	Electrical Ground Support Equipment		
FIRST	Far InfraRed Space Telescope		
FPU	Focal Plane Unit		
FTS	Fourier Transform Spectrometer		
MGSE	Mechanical Ground Support Equipment		
PFM	ProtoFlight Model		
RAL	Rutherford Appleton Laboratory		
RD	Reference Document		
SPIRE	Spectral and Photometric Imaging REceiver		
TBC	To Be Confirmed		
TBD	To Be Defined		
TFCS	Test Facility Control System		

3 Description of the Test Facility

The 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 1. The working area around the cryostat will be class 100, 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 20K-blackbody source mounted in the cryostat will provide an absolute calibration reference.

The telescope simulator is required to present the instrument with an F/5 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.

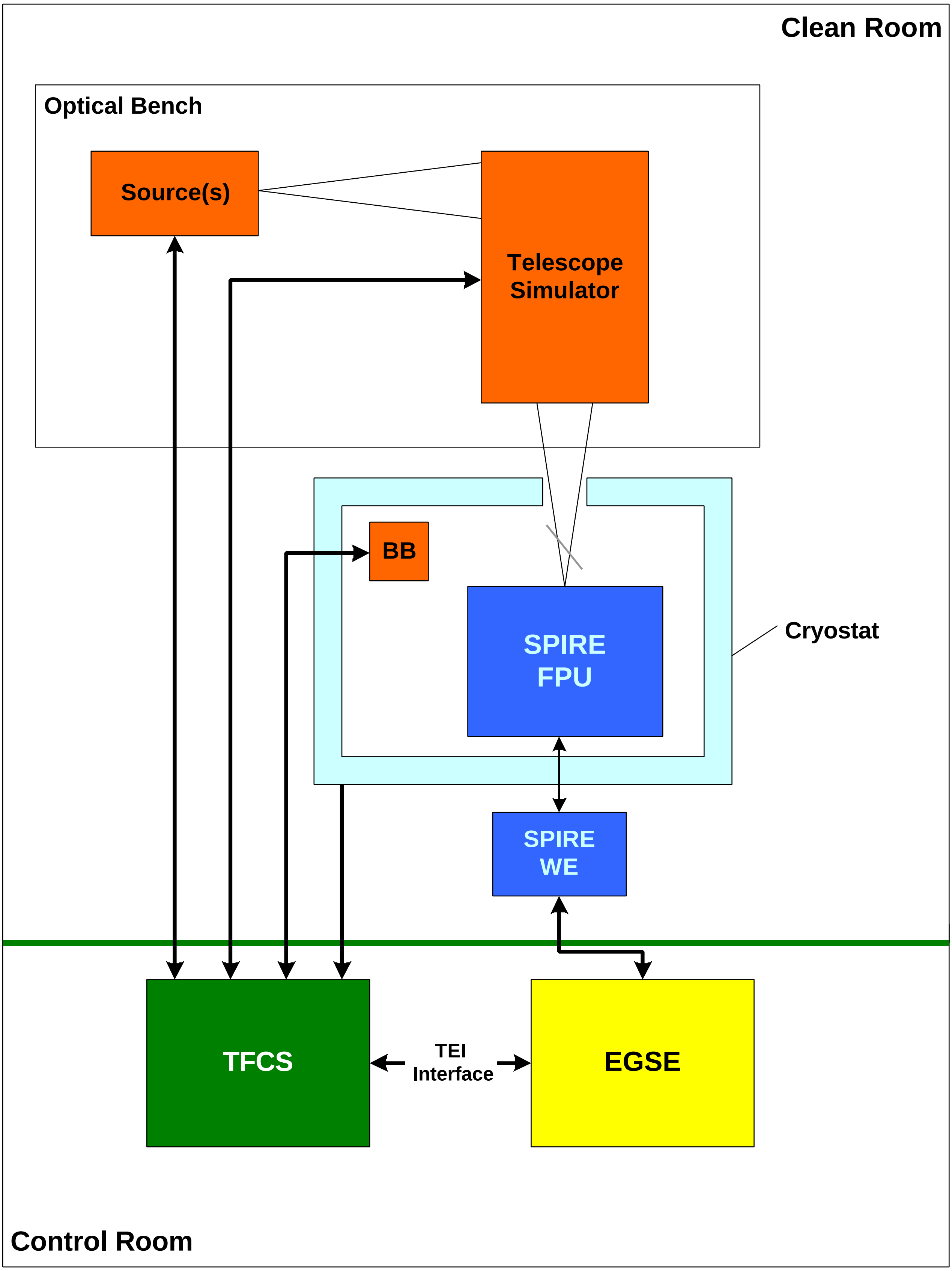


Figure 1: Fundamental elements of the SPIRE Test Facility

4 Constraints

4.1 Calendar constraints

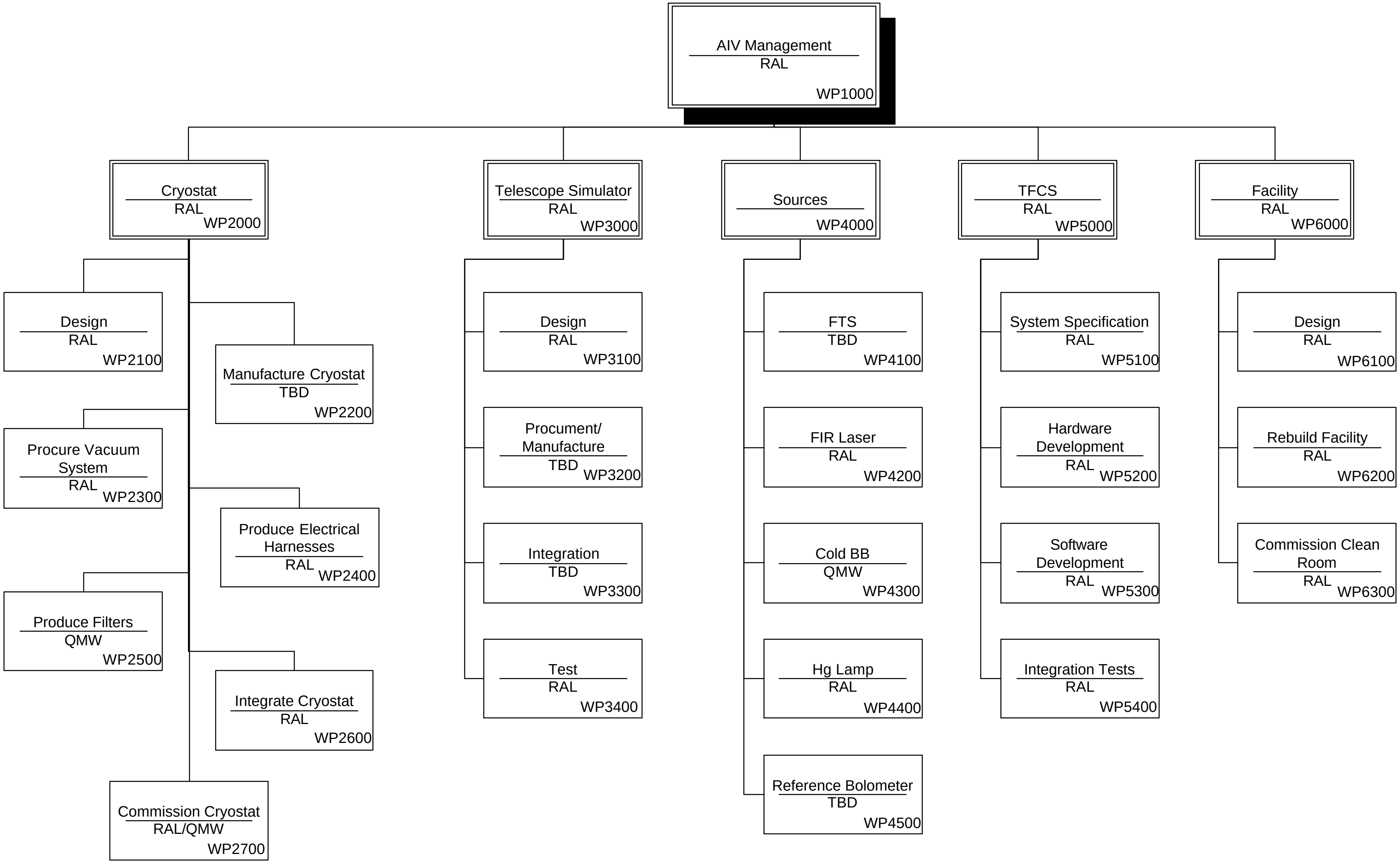
SPIRE PDR	26/27 Jun 2000
SPIRE STM Arrives	Mar 2002
SPIRE EGSE	30 Jun 2002
SPIRE CQM Arrives	1 Aug 2002
SPIRE CQM Delivery to ESA	Apr 2003
SPIRE PFM delivery to ESA	July 2004
SPIRE FS delivery to ESA	July 2005
FIRST launch	2007

4.2 Long Lead Items

The following items have been identified as having a lead-time that could have a significant impact on the overall schedule.

Cryostat Design and Manufacture	~1 Year
Cryostat Electrical Harnesses	TBD
Electrical Feedthroughs	TBD
Telescope Simulator	~1 Year
FIR FTS	~1 Year

Figure 2: Work Breakdown Structure for SPIRE TEST Facility



5 Work Description

The work breakdown structure in Figure 2 shows the principal activities and organisation for the development of the SPIRE AIV facility. A description of the activities is described in this section.

5.1 AIV Facility Management

Task Name	**AIV Facility Management**
Responsibility	RAL
Objective	RAL will have overall responsibility for managing the design and development of the test facility, ensuring that the completed cryostat is available for the arrival of the SPIRE CQM in March 2002. RAL will then be responsible for the day-to-day running of the facility and management of the test and calibration activities.
Description	1. Manage the design and development of the SPIRE AIV facility 2. Manage the day-to-day running of the test facility. 3. Manage test and calibration activities. 4. Co-ordinate activities between sub-groups. 5. Preparation and monitoring of schedules; ensuring that these are realistic and are properly distributed and agreed with the participating team members. 6. Preparation of financial data for RAL management. 7. Preparation and submission of progress reports. 8. Attend meetings as required. 9. Set up regular progress meetings, and ensure that minutes are circulated.

5.2 Cryostat

The calibration cryostat will accommodate the SPIRE instrument with its associated electronics units (JFET/ Filterbox) and 20K-blackbody calibration source. The cryostat will simulate the thermal environment provided by FIRST and cool the instrument to its operating temperatures of 7-11K, 4K and 2K.

It had been hoped to re-use the cryostat used for the ISO LWS calibration. However, the SPIRE instrument is significantly larger than ISO LWS was and therefore the existing cryostat is not suitable, and therefore a new cryostat design is being proposed.

The key elements of the cryostat are:

- Vacuum chamber – this will be a stainless steel vessel approximately 1.2m in diameter that can be pumped to a pressure of $<10^{-6}$mbar (with instrument and support equipment) prior to filling the cryogen tanks.

- Cryogen tanks – there will be three separate tanks containing LN_2, He at 4K and He at 2K. The hold time of the tanks will be at least three days when the instrument is cold to allow work to continue uninterrupted over the weekends. The tanks will be pre-cooled with LN_2 to reduce the overall cooldown time. There are no plans to regenerate the He.

- Thermal shrouds – the design of the cryostat should ensure that the instrument is completely surrounded by a 4K shroud therefore minimising stray light and unwanted thermal loads.

- Fluid links to instrument thermal interfaces – these will provide higher cooling power than conventional copper straps.

- Support structure – the SPIRE instrument and associated equipment will be mounted to a support structure outside of the vacuum chamber. The complete assembly will be moved into the cryostat and locked into position. The design will ensure that the structure and instrument are thermally isolated from the tank walls. The support structure will also be cooled via fluid loops.

- Electrical Interfaces – It is expected that there will be of the order of 1400 individual wires from the SPIRE instrument to the vacuum chamber wall. In addition there will be a significant number of wires for the cryostat thermometers and heaters. These will have a significant effect on the thermal performance of the cryostat. The electrical harnesses will be manufactured to order and will probably have a long lead-time. It will therefore be necessary to produce an accurate definition of the electrical interfaces as soon as possible to avoid potential impacts on the development schedule

- Optical Interfaces – The total heat flux incident on the SPIRE FPU during calibration should be of the same magnitude as presented by the 80K FIRST telescope. During calibration the SPIRE instrument views a scene a source at 1000K with a 300K background. Obviously, with no optical filtering the heat flux would be too great and have significant effects on the performance of the cryostat. Thus to bring the measured signal to representative levels, and to reduce the heat loading on the cryostat thermal shields, optical filters are required at each of the cryostat temperature boundaries, namely 300K, 77K and 4K. The 77K filter should block the thermal IR signal below 100µm, although this was not agreed formally at the time of writing. Neutral density filters at the 4K interface will reduce the signal further, although it may be possible to mount these at the 77K interface. Again, QMW and RAL were still defining the requirements for these filters at the time of writing. Calculations are required to determine the signal measured by SPIRE and the total heat load in the filters at each interface.

Task Name	**Cryostat Design**
Responsibility	RAL
Objective	Design SPIRE test cryostat.
Description	1. Produce design concept of the test cryostat for review at the SPIRE PDR, ensuring

	that the interface requirements are met. 2. Produce heat budget calculations to estimate the hold times of the cryogen tanks. 3. Modify the design after review of the design concept and assessments of the cryogen hold times. This process will probably take several iterations until accurate definitions of the filter fluxes, instrument and bb heat loads and electrical interfaces have been produced. 4. Produce detailed drawings. 5. Produce detailed specifications for tender exercise. 6. Produce test specifications 7. Issue ITT for manufacture

Task Name	**Manufacture Cryostat**
Responsibility	TBD
Objective	Manufacture the test Cryostat
Description	1. Manufacture cryostat. 2. Produce relevant documentation. 3. Provide progress reports. 4. Hold delivery readiness review 5. Deliver to RAL for installation

Task Name	**Procure Vacuum System**
Responsibility	RAL
Objective	Produce pumping system for test cryostat
Description	1. Specify pumping system requirements 2. Procure vacuum system elements 3. Integrate pumping system 4. Test pumping system 5. Produce documentation

Task Name	**Manufacture Electrical Harness**
Responsibility	RAL
Objective	Produce electrical harnesses and vacuum interfaces for SPIRE cryostat

Description	1. Specify wiring schedule for harnesses 2. Design harness 3. Manufacture and test harness 4. Produce documentation

Task Name	**Manufacture Cryostat Filters**
Responsibility	QMW
Objective	Manufacture the 300K, 77K and 4K filters for the cryostat.
Description	1. Design filters in accordance with cryostat drawings. 2. Manufacture filters 3. Measure optical transmission of the filters from 1µm to 1000µm 4. Deliver to RAL 5. Mount on cryostat. 6. Produce documentation

Task Name	**Integrate Cryostat**
Responsibility	RAL
Objective	Install and integrate the cryostat and pumping system
Description	1. Move cryostat into clean room 2. Connect vacuum system 3. Install filters 4. Install cold blackbody 5. Install reference bolometer 6. Install electrical harness 7. Mount electrical feedthroughs 8. Connect instrumentation

Task Name	**Commission Cryostat**
Responsibility	RAL

Objective	Prepare the cryostat to be ready for the arrival of the SPIRE CQM
Description	1. Leak test cryostat at room temperature 2. Bake cryostat (~50ºC) 3. Cool down to operating temperatures 4. Perform Radiometric tests 5. Perform EMC tests 6. Produce commissioning report 7. Review test results

5.3 Telescope Simulator

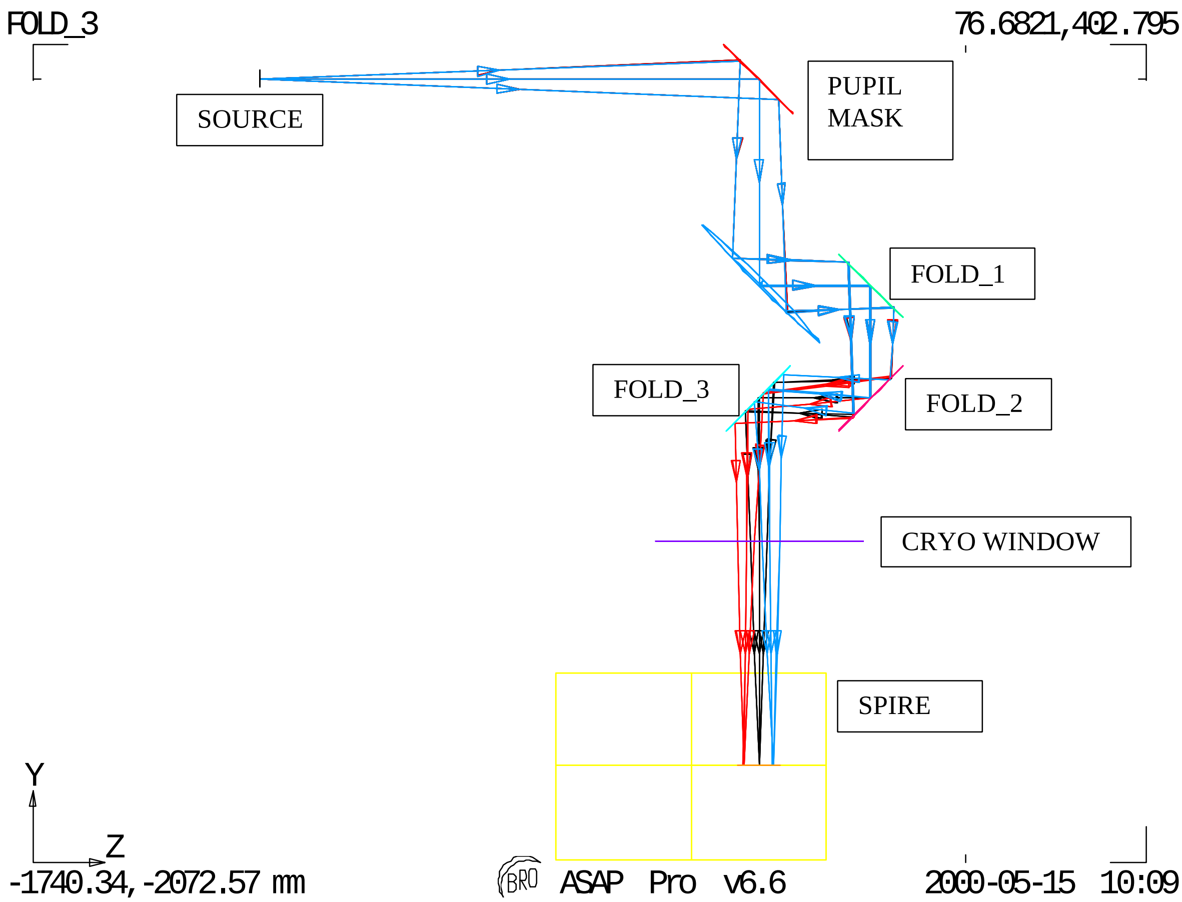


Figure 3: Optical Design of Telescope Simulator

Task Name	**Design Telescope Simulator**
Responsibility	RAL

Objective	Produce the optical design of the Telescope Simulator used for the SPIRE tests.
Description	1. Produce an initial design concept for the telescope simulator 2. Update after design review 3. Produce detailed system design 4. Produce detailed specifications for the telescope simulator – including interfaces 5. Define test specifications

Task Name	**Manufacture Telescope Simulator**
Responsibility	RAL
Objective	Manufacture and test the Telescope Simulator
Description	1. Produce manufacturing plan 2. Produce alignment and test plan 3. Produce tolerance and control budget 4. Hold Manufacturing Readiness Review 5. Manufacture telescope simulator 6. Produce progress reports 7. Define installation procedure 8. Hold delivery readiness review 9. Deliver telescope simulator.

Task Name	**Install and Test**
Responsibility	RAL
Objective	Install the Telescope simulator at RAL and perform functional tests.
Description	1. Telescope arrives at RAL 2. Install in clean room 3. Execute trial procedures in accordance with test specification 4. Review test results

5.4 Sources

5.4.1 FTS

Task Name	**FTS**
Responsibility	TBD
Objective	Design and manufacture a FIR FTS for the SPIRE calibration tests.
Description	1. Produce an optical design for the FTS 2. After review of the optical design, produce detailed design. 3. Procure components of the FTS 4. Develop software based on LabVIEW to control FTS and ensure that it can be synchronised to the SPIRE data. The software interfaces should conform to the interface requirements of the TFCS. 5. Integrate and test the FTS 6. Produce supporting documentation for FTS (e.g. manual, hardware and software interface specifications) 7. Hold delivery readiness review 8. Transport to RAL 9. Install and test FTS at RAL. 10. Install and test control software on TFCS.

5.4.2 FIR Laser

The FIR laser used for the ISO LWS calibration will be used. This is an Edinburgh Instruments PR5 gas FIR laser with lines from 30µm to 1000µm and power up to 100mW. Some modifications will be required to improve the output stability and a Fabry-Perot interferometer will be used to improve the spectral quality.

Task Name	**FIR Laser**
Responsibility	RAL
Objective	Reconfigure the FIR laser for SPIRE calibration tests.
Description	1. TBD

5.4.3 Cold BB

A 4K-20K-blackbody source provided by QMW will be used as an absolute radiance standard. This will be mounted within the 4K enclosure of the cryostat and viewed via a relay mirror.

Task Name	**Cold BB**

Responsibility	QMW
Objective	Design and manufacture a 20K-blackbody target for the SPIRE test cryostat.
Description	1. Produce design for 20K-blackbody 2. Manufacture the blackbody 3. Develop software based on LabVIEW to control 20K-BB. The software interfaces should conform to the interface requirements of the TFCS. 4. Produce supporting documentation for BB(e.g. manual, hardware and software interface specifications) 5. Transport to RAL 6. Install and test blackbody at RAL. 7. Install and test control software on TFCS.

5.4.4 Hg Lamp

Task Name	**Hg Lamp**
Responsibility	RAL
Objective	Obtain Hg Arc lamp for SPIRE calibration
Description	1. TBD

5.4.5 Reference Bolometer

Task Name	**Reference Bolometer**
Responsibility	QMW
Objective	Provide reference bolometer for test cryostat commissioning tests
Description	1. Provide reference bolometer 2. Produce supporting documentation for bolometer(e.g. manual, calibration information, hardware and software interface specifications) 3. Transport to RAL 4. Install the bolometer in the test cryostat at RAL.

5.5 Test Facility Control System (TFCS)

The TFCS will monitor and log the temperatures within the cryostat and control the calibration sources. At the time of writing the TFCS is expected to control the FTS, Telescope Simulator and 20K-blackbody.

To allow independent development of the test equipment, it is proposed that LabVIEW be used as the basis of the system. This should reduce the overall development time since LabVIEW is widely used and many drivers are available. Standard interfaces between the TFCS and sources should be used where possible.

Propriety electronics units should be used to perform the low-level control and feedback of stepper motors for the optical systems (e.g. Unidex, McLennan) and temperature control of the control blackbody (e.g. Eurotherm).

The TFCS will be connected to the SPIRE EGSE via a TCP/IP interface and be able to receive commands and transmit telemetry packets.

Task Name	**TFCS Specification**
Responsibility	RAL
Objective	Specify the requirements for the TFCS
Description	1. Define the technical and user requirements for the TFCS, highlighting the functions to be performed and the interfaces between the subsystems and instrument EGSE. 2. Produce draft specification for review 3. Update specification following review 4. Issue requirements specification.

Task Name	**TFCS Hardware Development**
Responsibility	RAL
Objective	Produce computer system, interfaces and cables
Description	1. Procure Computer Platform 2. Procure additional interfaces for hardware drives (e.g. stepper motors, thermal control) 3. Specify and manufacture electrical harnesses. 4. Integrate system

Task Name	**TFCS Software Development**
Responsibility	RAL
Objective	Develop Software

Description	1. Produce architectural design 2. Produce detailed software design 3. Write the code 4. Test the software

Task Name	**Integrate and Test**
Responsibility	RAL
Objective	Integrate and test the TFCS
Description	1. Produce Integration and Test Plan 2. Install QMW and TBD supplied elements onto TFCS 3. Connect computer to the test equipment. 4. Perform functional tests on the individual subsystems; verify control of stepper motors, synchronisation, accuracy of sensors, reliability, repeatability and EMC. 5. Test TM/TC interface to SPIRE EGSE 6. Perform simulated calibration sequence.

5.6 Facility Infrastructure

Task Name	**Facility Design**
Responsibility	RAL
Objective	Design the SPIRE test facility clean room and control room.
Description	1. Design layout of clean room and control room.

Task Name	**Rebuild Facility**
Responsibility	RAL
Objective	Reconfigure the ISO LWS AIV area to accommodate the SPIRE calibration cryostat.
Description	1. Remove ISO LWS cryostat 2. Move FIR laser and optical bench to clean storage 3. Clear out existing area 4. Remove partition wall and door 5. Rebuild partition wall and door 6. Replace clean room flooring (if necessary) 7. Replace clean room filters 8. Install services 9. Install connections to LN2 supply

Task Name	**Commission Clean Room**
Responsibility	RAL
Objective	Prepare clean room in readiness for SPIRE cryostat installation.
Description	1. Clean the room. 2. Switch on HEPA filters. 3. Measure the air flow 4. Measure cleanliness and obtain certificate. 5. Replace optical bench and laser source.

6 Development calendar

6.1 Cryostat

Design Concept	Apr -Jun 2000
Detailed Design	Jul -Nov 2000
Manufacture	Dec 2000 - Sep 2001
Integration	Sep – Dec 2001
Commissioning	Dec 2001 – Feb 2002

6.2 Telescope Simulator

Design Concept	Apr -Jun 2000
Detailed Design	Jul -Sep 2000
Manufacture & Test	Sep 2000 – May 2001
Installation at RAL	Jun-Jul 2001

6.3 Sources

Hg Lamp	Jun 2001
FTS	Dec 2001
20K-Blackbody	Nov 2001
FIR Laser	Jun 2001
Reference Bolometer	Nov 2001

6.4 Calibration Facility

Design	Jul – Sep 2000
Rebuild Facility	Sep 2000 – Feb 2001
Commission Clean Room	Mar 2001 – Apr 2001

6.5 Test Facility Control System

Specifications	Oct-Nov 2000
Development	Dec 2000 – Jul 2001
Integration	Aug 2001- Feb 2002