SPIRE STM Instrument Level Test Plan

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1 Scope of Document

This document describes in detail how the SPIRE STM AIV will be implemented. It describes the step-by-step sequence of activities, high-level procedures, organisation, resources and facilities required.

2 Documents

2.1 Applicable Documents

	Title	Author	Reference	Date
AD 1	SPIRE Instrument Qualification Requirements	B. Swinyard	SPIRE-RAL-PRJ-000592 Issue 1.1	29-Mar-2001
AD 2	SPIRE STM Requirements	B. Swinyard	SPIRE-RAL-NOT-000613 Issue 1.0	30-Mar-2001
AD 3	Instrument AIV Plan	B. Swinyard	SPIRE-RAL-PRJ-000410 Issue 2.1	29-Mar-2001
AD 4	Instrument Integration Plan	B. Winter	SPIRE-MSS-PRJ-000652 Issue 0.1D	Apr-2001
AD 5	Calibration Requirements Document	B. Swinyard	SPIRE-RAL-PRJ-001064 Issue 0.1D	3-Jan-2002
AD 6	SPIRE Optical Alignment Verification Plan	K. Dohlen	SPIRE-LAM-PRJ-000445 Issue 3	10-Apr-2001
AD 7	SPIRE Product Assurance Plan	D. Kelsh	SPIRE-RAL-PRJ-000017 Issue 1.0	11-Apr-2001
AD 8	Cleanliness Plan	B. Swinyard	TBD	
AD 9	SPIRE Alignment Tools Specification	K. Dohlen, A. Origne		

2.2 Reference Documents

	Title	Author	Reference	Date
RD 1	SPIRE AVM Instrument Level Test Plan	E. Sawyer		
RD 2	SPIRE CQM Instrument Level Test Plan	D.L. Smith	SPIRE-RAL-DOC-000 Issue 0.1D	19 Dec-2001
RD 3	SPIRE Test Facility Requirements Specification	D.L. Smith	SPIRE-RAL-PRJ-000463 Issue 1.3	2-April-2001
RD 4	AIV Facility Description	G.M. Toplis	ISO9:SPAP/AIV/000	01-July-2000
RD 5	Herschel Ground Segment Design Description		FIRST-FSC-DOC-0146 Issue 1 rev 1	10-Dec-2001
RD 6	SPIRE EMC Control Plan	D. Griffin	SPIRE-RAL-PRJ-852 Issue 0.1D	7-Sep-2001
RD 7	Thermal test specification	S. Heys	SPIRE-RAL-DOC-	

3 STM AIV Requirements

3.1 STM Definition
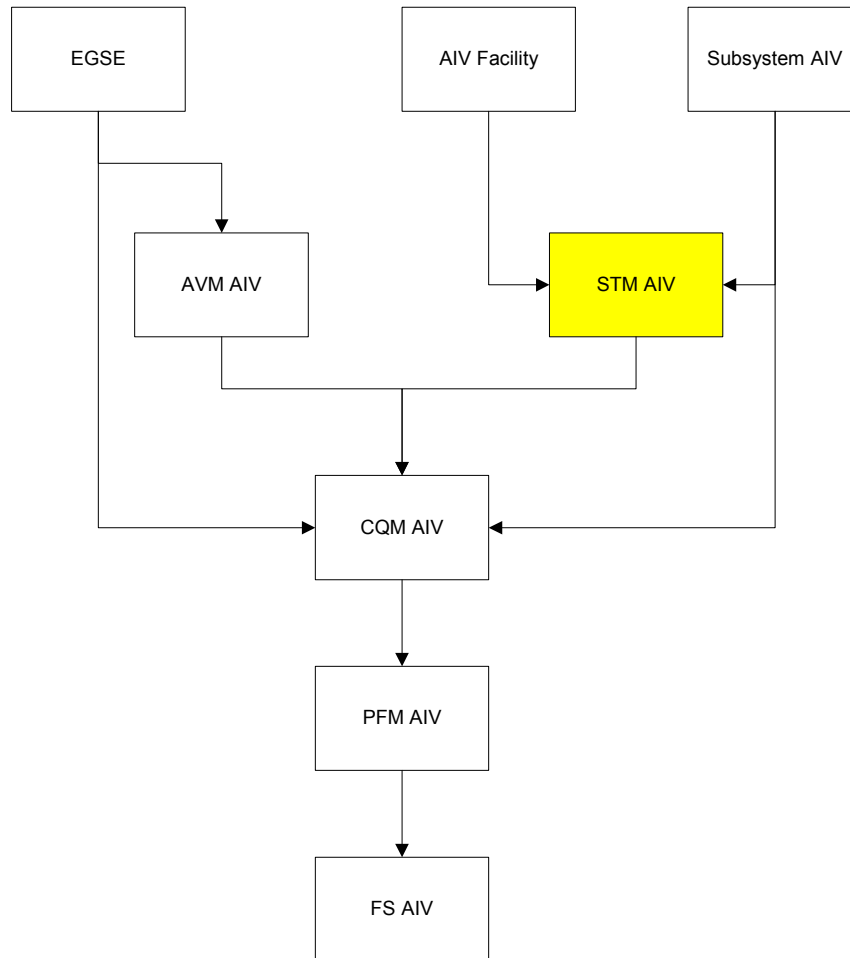
Figure 1: Flow chart showing the logical association of the SPIRE STM model within the SPIRE development programme.

The SPIRE instrument model philosophy is described in AD 1 and AD 3. The SPIRE STM model is mechanically and thermally representative of the flight model but has no functioning subsystems, other than heaters to simulate the thermal loads within the FPU. The main purpose of the STM model is to qualify the mechanical and thermal design of the FPU structure. The detailed requirements for the STM instrument model are described in AD 2.

3.2 STM Qualification Requirements

3.2.1 Mechanical

A qualification level vibration test will be performed on the STM instrument at room temperature to verify the mechanical design of the FPU structure. The input levels will be defined by MSSL and will be based on those specified in the IIDA. To confirm that the instrument has survived the qualification levels, optical alignment and thermal performance tests will be performed before and after the vibration test. The proposed sequence will be:

> Configure Instrument
> Electrical Checkout
> Optical Alignment Check
> Vibration test for each axis
> > Low-level survey
> > Sine test
> > Random test
> > Low-level survey
> Optical Alignment Check

If the STM instrument passes the warm qualification tests, a cryogenic vibration of the FPU and JFET modules to be carried out. The levels for these tests will be defined by MSSL.

3.2.2 Thermal

The STM instrument will be tested in a test cryostat that will simulate as close as possible the thermal environment of the Herschel cryostat. A test campaign will be run in which the thermal model of the FPU structure will be verified. The STM will be fitted a fully functioning CQM cooler after the warm vibration has been completed, and will have at least one thermally representative detector model. The STM thermal tests will provide the first opportunity to test the operation and thermal performance of the cooler within SPIRE. Details of the test conditions will be defined in the SPIRE thermal test specification (RD 7)

3.2.3 Optical

The STM instrument will have near flight standard optical components to allow the optical geometric model to be verified. The optics will be integrated and aligned in accordance with the optical alignment plan (AD 6). The alignment will be verified both at ambient and cryogenic conditions.

Because of program constraints, the STM structure will be reused as the CQM structure. The mirrors will remain installed and the alignment will be maintained during reconfiguration. Hence, for optical alignment purposes, the STM can be treated as the CQM.

3.2.4 Electrical

The STM will be fitted with the cryogenic test harness that will be used for CQM and PFM models. The performance of the harness will be measured during STM tests.

4   AIV Flowchart

The AIV phase is broken down into a series of 'activities' and 'test campaigns'.

'Activities' include integration of the FPU, preparation for a test campaign, single test or task within a campaign and other tasks.

A 'test campaign' covers a complete test period from the test readiness review to the completion of the test activities.

Each test campaign will start with a test readiness review, at which all test procedures must be ready and the EGSE configuration will be 'frozen'.   A formal post-test review will be held at the end of the test campaign after which the instrument can proceed with the next activity.

The test campaign will be broken down into 'activities' and 'tests', see Figure 2. Activities include pump-down, cool-down, warm-up, and let-up. Each 'Test' within the campaign will comprise a series of 'test cases'. For example, a functional test will include test cases to checkout individual mechanisms, i.e. the cooler, BSM, SCAL etc. The test campaign will be controlled by a master procedure that references the specific test procedures, e.g. functional test procedure. The test procedure will identify the necessary EGSE test sequences and pass-fail criteria.
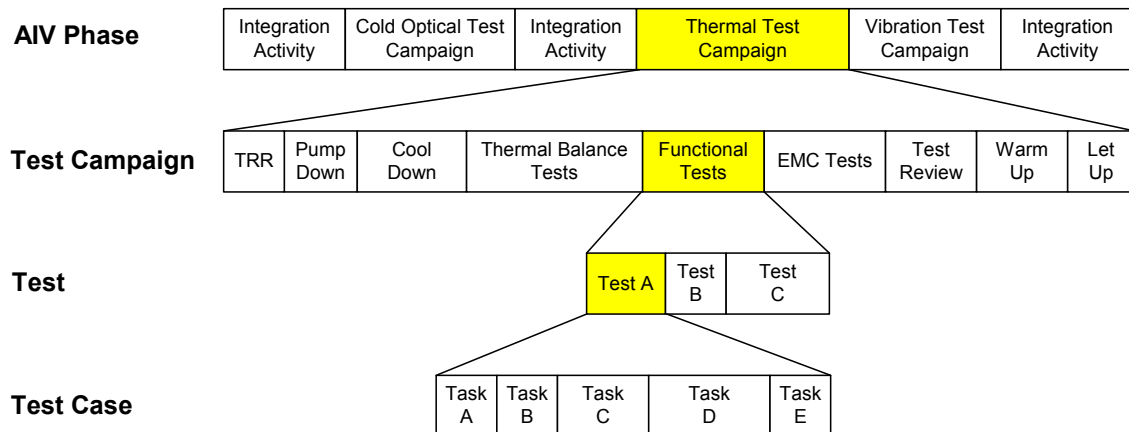
Figure 2: Definition of AIV Phase, Test Campaign, Tests and Test Case. (Note: the example given does not represent the actual SPIRE AIV)

The flowchart shown in Figure 4 and Figure 5 is based on the SPIRE AIV Plan (AD 3) and shows each test campaign with the facilities and test equipment required to perform the activities.

Start/End Condition

Activity

Test Campaign

Subsystem

EGSE/OGSE/MGSE

Facility- e.g. Clean Room, Cryostat

Document

Major Review

Transport

Link to Next Page
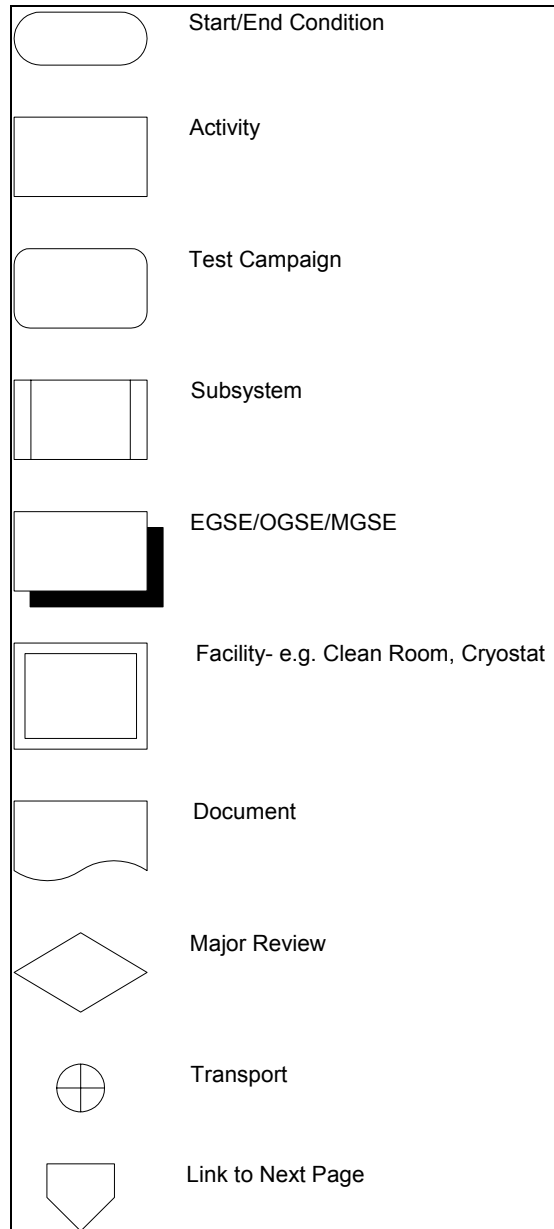
Figure 3: Legend for STM AIV Flow Chart. Key Inspection Points are indicated by (**K**), Mandatory Inspection Points are indicated by (**M**).
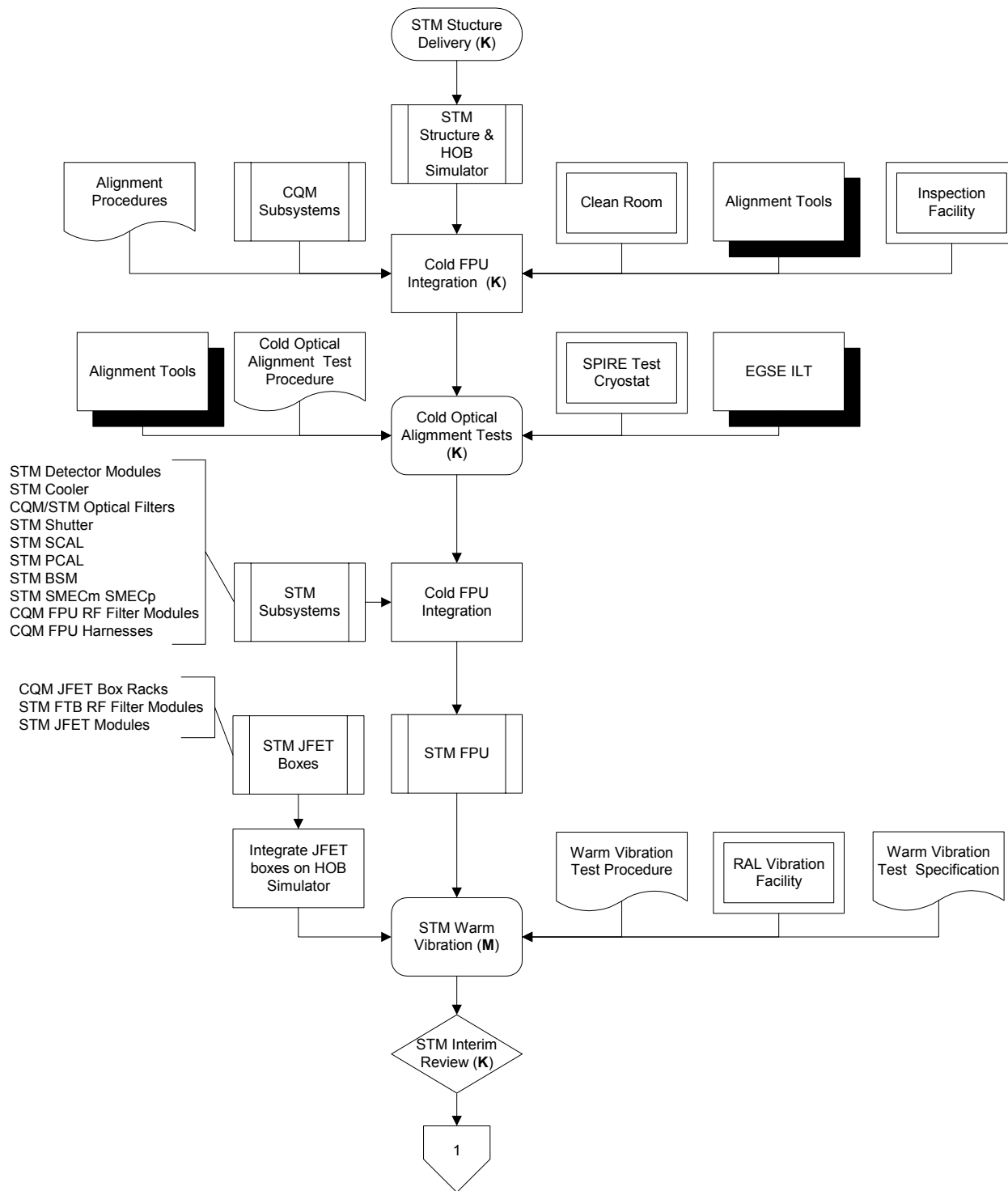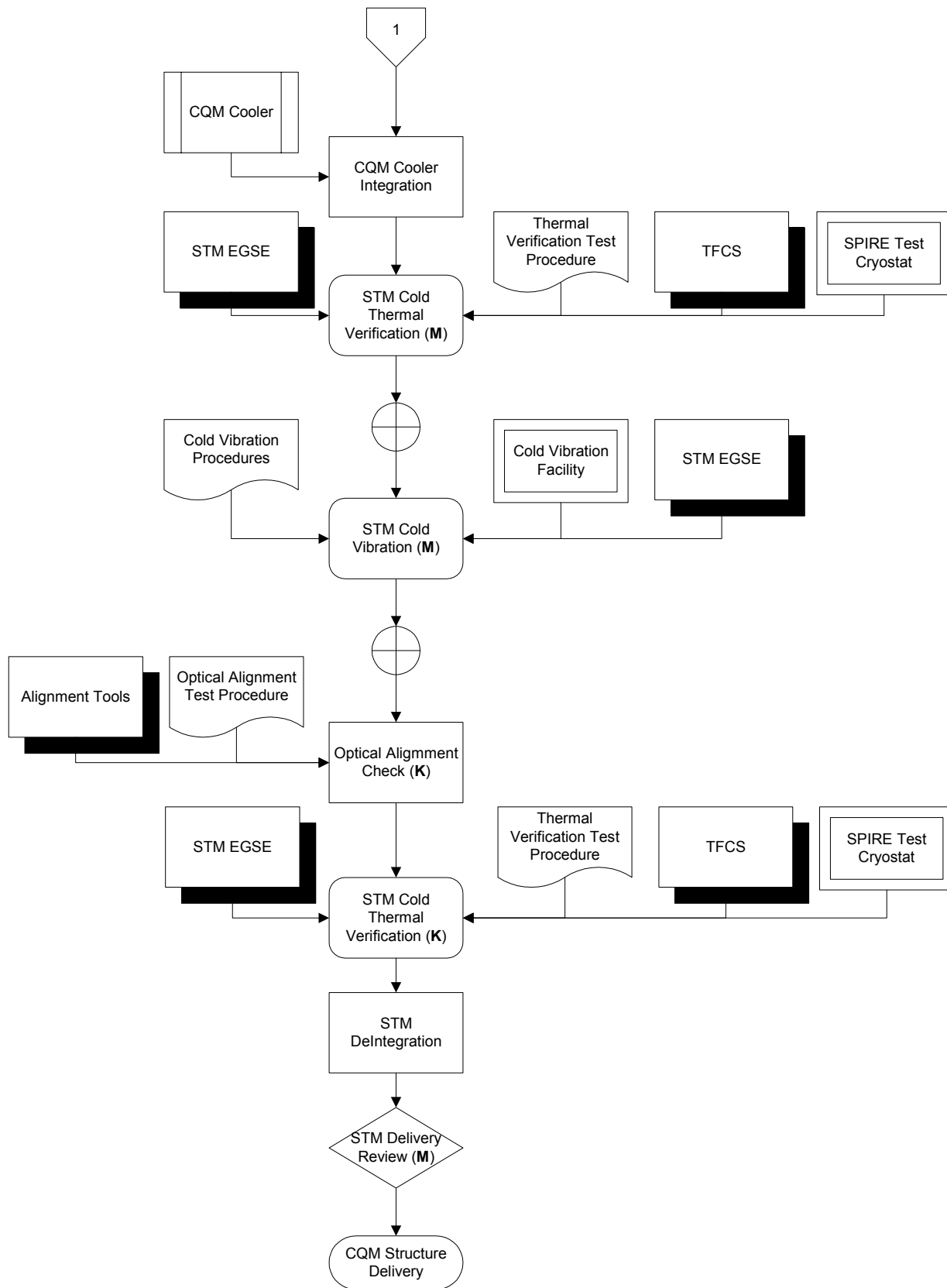
Figure 4: STM AIV Flowchart (1 of 2)

Figure 5: STM AIV Flowchart (2 of 2)

5 Task List

The following table defines the step-by-step sequence of activities for the SPIRE STM AIV. The table will form the basis of the STM AIV master procedure.

Step	Activity	Identifier	Brief Description	Instrument Requirement
STM-1	**Optics Integration**	**STM_ILT_ALIGN**		
STM-1-1	Incoming inspection	ILT_INSP	Visual inspection of the SPIRE structure and optics mounts mounted on HOB simulator.	VRD-10
STM-1-2	3D Metrology	STM_ILT_ALIGN	Structure transferred to 3D inspection facility and the positions of the optical mounts measured	VRD-06, VRD-07, VRD-10
STM-1-3	Photometer/Common optics integration	STM_ILT_ALIGN	Install and align CQM photometer/common optics mirrors.	VRD-05, VRD-06, VRD-07, VRD-10
STM-1-4	Spectrometer optics integration and alignment.	STM_ILT_ALIGN	Install and align CQM spectrometer mirrors	VRD-06, VRD-07, VRD-10
STM-1-5	Pupil quality verification	STM_ILT_ALIGN	Observe image of C-tool at Herschel M2 distance.	VRD-06, VRD-07, VRD-09, VRD-10
STM-1-6	Image quality verification	STM_ILT_ALIGN	Observe the image of D-tool sources in SPIRE object plane.	VRD-06, VRD-07, VRD-09, VRD-10
STM-2	**STM Cold Optical Alignment**	**STM_ILT_ALIGN**		
STM-2-1	Integrate SPIRE onto support frame	STM_ILT_INTG	Bolt down covers, secure structure to HOB simulator. Lift instrument onto MGSE and build up support frame.	
STM-2-2	Transfer SPIRE to Cryolab	STM_ILT_INTG	Bag up the FPU and HOB simulator and transfer to cryolab.	
STM-2-3	Integrate SPIRE into cryostat	CRY_INTG	Move instrument into cryostat, connect thermal straps, harness. Close up radiation shields, making light tight.	
STM-2-4	Test Readiness Review			
STM-2-5	Perform optical alignment	STM_ILT_ALIGN	Measure SOR wrt. HOR and D tool.	VRD-06, VRD-07, VRD-09, VRD-10
STM-2-6	Pump Down	CRY_PUMP		
STM-2-7	Cool to operating temperatures	CRY_COOL		
STM-2-8	Perform optical alignment	STM_ILT_ALIGN	Measure SOR wrt. HOR and D tool.	VRD-06, VRD-07, VRD-09, VRD-10
STM-2-9	Post test review			
STM-2-10	Warm up	CRY_WARM		
STM-2-11	Let up to air	CRY_LETUP		

Step	Activity	Identifier	Brief Description	Instrument Requirement
STM-2-12	Optical alignment check	STM_ILT_ALIGN	Measure SOR wrt. HOR and D tool.	VRD-06, VRD-07, VRD-09, VRD-10
STM-2-13	Remove from cryostat	CRY_DEINT	Disconnect FPU from cryostat, remove HOB simulator from cryostat and install on MGSE.	
STM-3	**FPU Integration**	**STM_ILT_INTG**		
STM-3-1	Transfer SPIRE to AIV clean room	STM_ILT_INTG	Bag up spire and move to AIV clean room. Remove from MGSE and lift onto optical bench.	
STM-3-2	Install STM Subsystems	STM_ILT_INTG		
STM-4	**STM Warm Vibration**	**STM_ILT_VIB**		
STM-4-1	Transfer SPIRE to vibration facility	STM_ILT_INTG	Bag up spire and move to vibration facility. Transfer FPU to vibration fixture.	
STM-4-2	Test Readiness Review			
STM-4-3	Perform optical alignment check	STM_ILT_ALIGN	Measure SOR wrt. HOR and D tool.	VRD-06, VRD-07, VRD-09, VRD-10
STM-4-4	Perform vibration tests	STM_ILT_VIB RAL_VIB	3 axis vibration of FPU structure	VRD-01 VRD-02
STM-4-5	Perform optical alignment check	STM_ILT_ALIGN	Measure SOR wrt. HOR and D tool. Check for changes in alignment	VRD-06, VRD-07, VRD-09, VRD-10
STM-4-6	Inspect structural integrity	ILT_INSP	Visual inspection of the SPIRE structure following vibration test.	VRD-02
STM-4-7	Post Test Review			
STM-5	**STM Interim Review**			
STM-6	**STM Cold Thermal Verification**	**STM_ILT_THER**		
STM-6-1	Integrate SPIRE onto support frame	STM_ILT_INTG	Lift instrument onto MGSE and build up support frame.	
STM-6-2	Transfer SPIRE to clean room	STM_ILT_INTG	Bag up the FPU and HOB simulator and transfer to cryolab. Remove from support frame and lift onto optical bench.	
STM-6-3	Install CQM Cooler	STM_ILT_INTG	Remove covers and install STM cooler.	
STM-6-4	Integrate SPIRE onto support frame	STM_ILT_INTG	Lift instrument onto MGSE and build up support frame.	
STM-6-5	Return STM to cryolab	STM_ILT_INTG	Bag up the FPU and HOB simulator and transfer to cryolab.	
STM-6-6	Integrate SPIRE into cryostat	CRY_INTG	Move instrument into cryostat, connect thermal straps, harness. Close up radiation shields, making light tight.	
STM-6-7	Test readiness review			
STM-6-8	Pump Down	STM_ILT_THER CRY_PUMP		

Step	Activity	Identifier	Brief Description	Instrument Requirement
STM-6-9	Cool to operating temperatures	STM_ILT_THER CRY_COOL		VRD-12, VRD-14
STM-6-10	Measure thermal performance	STM_ILT_THER		VRD-12, VRD-14
STM-6-11	Test review			
STM-6-12	Warm up	STM_ILT_THER CRY_WARM		VRD-12, VRD-14
STM-6-13	Let up to air	STM_ILT_THER CRY_LETUP		
STM-6-14	Remove from cryostat	CRY_DEINT	Disconnect FPU from cryostat, remove HOB simulator from cryostat and install on MGSE.	
STM-7	**STM Cold Vibration**	**STM_ILT_VIB**		
STM-7-1	Prepare SPIRE for shipping to CSL	STM_ILT_INTG	Bag up the FPU and HOB simulator and transfer to cryolab. Remove from support frame and lift into transport container.	
STM-7-2	Ship to CSL			
STM-7-3	Unpack SPIRE and inspect on arrival at CSL	ILT_INSP	Visual inspection of the SPIRE structure following transportation.	VRD-10
STM-7-4	Transfer SPIRE to vibration rig	STM_ILT_INTG	Transfer FPU to vibration fixture.	
STM-7-5	Test Readiness Review			
STM-7-6	Perform optical alignment check	STM_ILT_ALIGN	Measure SOR wrt. HOR and D tool.	VRD-06, VRD-07, VRD-09, VRD-10
STM-7-7	Perform vibration tests	STM_ILT_VIB CSL_VIB	3 axis vibration of FPU structure at cryogenic temperatures.	VRD-01 VRD-02
STM-7-8	Perform optical alignment check	STM_ILT_ALIGN	Measure SOR wrt. HOR and D tool. Check for changes in alignment	VRD-06, VRD-07, VRD-09, VRD-10
STM-7-9	Inspect structural integrity	ILT_INSP	Visual inspection of the SPIRE structure following vibration test.	VRD-02
STM-7-12	Post test review			
STM-7-13	Prepare SPIRE for shipping to RAL	STM_ILT_INTG	Remove from vibration fixture and install into transportation container on HOB simulator.	
STM-7-14	Ship to RAL			
STM-7-15	Unpack SPIRE and inspect on arrival at RAL	ILT_INSP	Visual inspection of the SPIRE structure following transportation.	VRD-10
STM-8	**STM Cold Thermal Verification**	**STM_ILT_THER**	**Repeat thermal verification test after cold-vibration.**	
STM-8-1	Integrate SPIRE onto support frame	STM_ILT_INTG	Lift instrument onto MGSE and build up support frame.	
STM-8-2	Transfer SPIRE to cryolab	STM_ILT_INTG	Bag up the FPU and HOB simulator and transfer to cryolab. Remove from support frame and lift onto optical bench.	

Step	Activity	Identifier	Brief Description	Instrument Requirement
STM-8-6	Integrate SPIRE into cryostat	CRY_INTG	Move instrument into cryostat, connect thermal straps, harness. Close up radiation shields, making light tight.	
STM-8-7	Test readiness review			
STM-8-8	Pump Down	CRY_PUMP		
STM-8-9	Cool to operating temperatures	CRY_COOL, STM_ILT_THERM		VRD-12, VRD-14
STM-8-10	Measure thermal performance	STM_ILT_THERM		VRD-12, VRD-14
STM-8-11	Test review			
STM-8-12	Warm up	CRY_WARM, STM_ILT_THERM		VRD-12, VRD-14
STM-8-13	Let up to air	CRY_LETUP		
STM-8-14	Remove from cryostat	CRY_DEINT	Disconnect FPU from cryostat, remove HOB simulator from cryostat and install on MGSE.	
STM-9	**STM De-Integration**			
STM-9-1	Transfer SPIRE to clean room	STM_ILT_INTG	Bag up the FPU and HOB simulator and transfer to cryolab. Remove from support frame and lift onto optical bench.	
STM-9-2	Remove sub-system STMs	STM_ILT_INTG	Remove covers and STM subsystems.	
10	**STM Post Test Review**			

6 Test Procedure List

This section lists the main test procedures to be used for the STM AIV. For each major step there is a high level procedure that references other standard procedures such as those for operating the facilities. All necessary test procedures must be approved at the test readiness reviews.

Title	ID	Resp.	Description
STM Optical Alignment Procedure	STM_ILT_ALIGN	RAL/LAM	Procedure for all optical alignment activities defined in AD 6, including the alignment tests to be performed during mechanical integration and the cold test campaigns.
STM Thermal Verification Procedure	STM_ILT_THER	RAL	Procedure will describe the full sequence of activities for the thermal verification tests. The test conditions, instrument performance tests and all success failure criteria will be defined.
STM Vibration Procedure	STM_ILT_VIB	MSSL/ RAL	The procedure will be based on the TBD plan and will define the input levels, the instrument functional tests, optical alignment checks and all success failure criteria.
Visual inspection	ILT_INSP	MSSL	Describes how the visual inspection of the mechanical structure is to be performed upon delivery of the instrument to RAL, before and after environmental test campaigns (i.e. vibration, thermal) and upon delivery to ESA.
FPU Integration Procedure	ILT_INTG	MSSL	This will describe the full sequence of activities to integrate the SPIRE structure.
Cryostat integration procedures	CRY_INT CRY_DEINT	RAL	SPIRE test facility procedures describing the steps to prepare and install SPIRE into the test cryostat (CRY_INT) and removal of SPIRE from the test cryostat (CRY_DEINT)
Cryostat operations procedures	CRY_PUMP CRY_COOL CRY_WARM CRY_LETUP	RAL	This will be a set facility procedures describing the safe operation of the calibration cryostat. The procedures will cover the sequence for pumping down (CRY_PUMP), cryogenic cool-down (CRY_COOL), operation at test conditions, warm-up (CRY_WARM) and let-up to air (CRY_LETUP).
Warm Functional Test	WFT	RAL	Basic test to be performed at room temperature. The main purpose will be to check that electrical connections are intact.
Cold Short Functional Test	CSFT	RAL	The minimum level of test required to check that the subsystem is functioning correctly.
Cold Full Functional Test	CFFT	RAL	Thorough test verifying the performance of the instrument subsystem. This test would normally be performed
RAL Vibration facilities procedures	RAL_VIB	RAL	This will be a standard facility procedure for the preparation and safe operation of the vibration facility.

Title	ID	Resp.	Description
CSL vibration facilities procedures	CSL_VIB	CSL	This will be a set of standard procedures for the preparation and safe operation of the cryogenic vibration facility.

7 Organisation
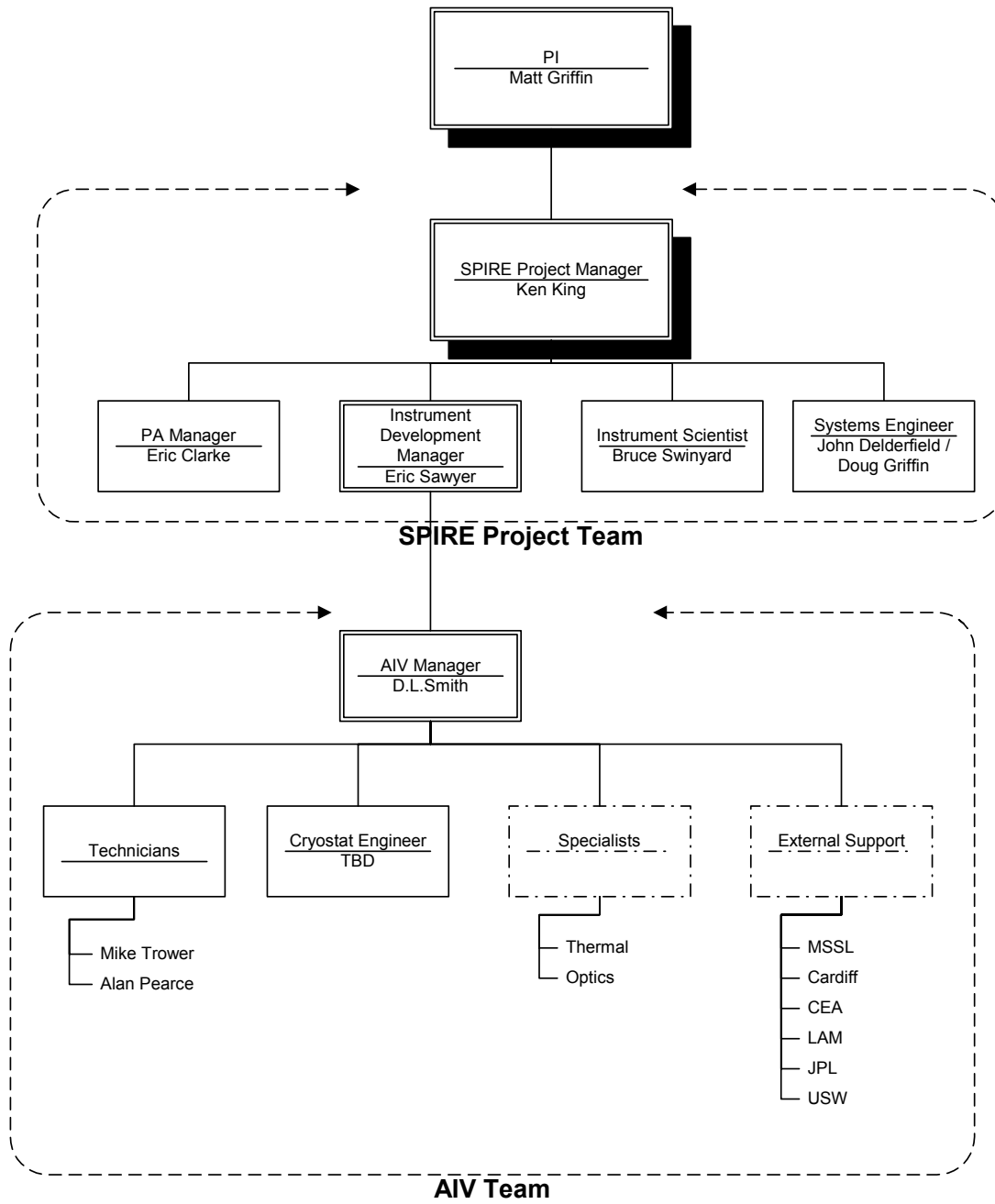
STM AIV Organisation

8   Resource Requirements

8.1   Manpower

This section describes the roles and responsibilities of the personnel required to support the STM integration and test activities. The majority of the team will be from RAL, but specialists from the SPIRE subsystem providers will also be required to support the AIV activities.

8.1.1   AIV Team

8.1.1.1   AIV Manager

- Planning and co-ordinating the AIV activities including the mechanical and electrical integration, verification tests and calibration.
- Responsible for obtaining agreement, prior to the commencement of any activity, of test plans and procedures.
- Responsible for decisions requiring work-around plans, modification of test procedures, repeat tests etc arising from non-conformance reports.
- Co-ordinate activities of technical experts, technicians during AIV phase.
- Prepare review documentation and acceptance data packs.
- Reports to Instrument Development Manager

8.1.1.2   Cryostat Engineer

- Preparation of cryostat for instrument tests
- Operation of cryostat during instrument tests
- Ensure supply of cryogens
- Clean room maintenance

8.1.1.3   Technicians

- Mechanical integration of instrument
- Test support
- Preparation of instrument for testing and transport

8.1.2   Specialist Support

8.1.2.1   Optics Specialist

- Optical alignment verification
- Stray light analysis

8.1.2.2   Thermal Engineer

- Thermal modeling and analysis
- Thermal test plan
- Support for thermal tests.

8.1.3   SPIRE Project Team

8.1.3.1   SPIRE Project Manager

- SPIRE Project Management
- UK SPIRE Management

8.1.3.2   Instrument Development Manager

- Subsystem Development
- Subsystem Deliveries

- Instrument Deliveries

8.1.3.3   Instrument Scientist

- Instrument performance
- AIV Plan
- Calibration Plan
- Optical Straylight Analysis

8.1.3.4   Systems Engineer

- Systems engineering
- System thermal design
- Parts procurement

8.1.3.5   PA Manager

- Product assurance
- Quality assurance
- Acceptance data packages

8.1.4   External Support

Support from the instrument subsystem providers will be required during the AIV activities. They will not be expected to perform the integration tasks but rather be on hand to provide technical support when needed.

8.1.4.1   MSSL

- Support mechanical integration, optical alignment and thermal tests.

8.1.4.2   LAM

- Support optical alignment activities.
- Support the integration and testing of the STM SMEC.

8.1.4.3   Cardiff

- Support integration of the SCAL, PCAL, 300mK strap system, optical filters and thermal verification tests.

8.1.4.4   JPL

- Support integration and alignment of detector modules, and integration of JFET units.

8.1.4.5   ATC

- Support integration and testing of the BSM units.

8.1.4.6   Grenoble

- Support integration of the cooler systems and thermal verification tests.

8.1.4.7   USW

- Support integration and tests of the STM shutter.

8.2   Facilities

The following facilities are required for the SPIRE STM AIV activities.

8.2.1   Cryogenic Test Facility

The SPIRE dedicated cryostat facility will be used for the cold optical alignment and thermal verification tests [RD 3]. The instrument and cryostat will be in a class 1000 clean area. Access to the clean room will be limited to key personnel to minimise any potential contamination of the optics.

For the optical alignment tests the cryostat will house only the cold FPU. Because the alignment will be performed at visible wavelengths, the instrument filters will not be installed and the cryostat filters will be replaced with quartz windows. This will obviously affect the thermal loads on the instrument and hence the performance of the cryostat.

The cryostat will be reconfigured for the thermal verification tests, replacing the quartz windows with the blocking filters supplied by Cardiff University.

8.2.2   Assembly Clean Rooms

Mechanical and electrical integration of the SPIRE FPU will be conducted in Clean Room 2 within building R25 at RAL. The room comprises[1]

- Main area: 12m x 7m class 10,000
- Horizontal laminar flow unit: 5m x 3m at class 100
- 2 laminar flowbenches: 1m x 0.5m at class 100
- Central changing room: lockers for up to 20 people
- Cleaning facility: Ultrasonic bath,fume cupboards

8.2.3   Mechanical Inspection Facility

The 3D metrology of the SPIRE structure and optical interfaces will be performed at the RAL inspection facility. This has temperature-controlled inspection facilities having the ability to measure components by conventional or optical means. Co-ordinate Measuring Machines (CMM) are also available. These can be used conventionally, or in a non-contact mode using an optical microprobe.

8.2.4   Warm Vibration Facility
The vibration facility at RAL will be used for the warm vibration tests. Details of this facility can be found in RD 4.

8.2.5   Cryogenic Vibration Facility

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[1] Extracted from RAL document ISO9:SPAP/AIV/000

8.3 EGSE

For the STM instrument level test campaign the warm electronics units (DRCU, DPU) will not be present. Therefore the full EGSE-ILT configuration (see RD 5) will not be required since there will be no instrument commanding and telemetry. Nevertheless, EGSE will be required to monitor and control the cryostat, the STM cooler and the instrument temperatures.

The Test Facility Control System will be required for monitoring the cryostat temperatures, cryogen levels and vacuum pressure during the STM tests. Control and monitoring of the telescope simulator is also required for the optical alignment checks. For the STM tests the TFCS will be run autonomously (i.e. not from SCOS-2000) and will therefore be required to log all data from the test campaigns.

In addition to the cryostat temperatures, it will be necessary to provide monitoring of the instrument thermometers and control the STM subsystem heaters. The EGSE requirements for this are TBD.

The STM will have a mechanically representative cooler that will be supplied with its own EGSE including drive electronics, temperature readout, heater control and data logging system.

8.4 OGSE

8.4.1 Alignment Tools
A suite of dedicated alignment tools will be provided by LAM as defined in AD 9.

8.4.2 Telescope Simulator
The telescope simulator will be used for the end-to-end alignment tests at cryogenic conditions.

8.5 MGSE

8.5.1 Transportation Container
A purpose built (TBC) transportation container provided by MSSL will be used whenever SPIRE is to be moved between facilities (i.e MSSL, RAL, CSL, ESTEC).

8.5.2 HOB Simulator
The HOB simulator will be the primary mechanical interface between the SPIRE FPU and the calibration cryostat. It will have a number of optical references to enable optical alignment measurements to be performed. To ensure that optical alignment between the references on the SPIRE optical bench and the HOB are maintained throughout integration and testing, the HOB simulator will act as the main integration plate and will travel with the instrument in the transportation container.

8.5.3 Support Trolley
SPIRE will be mounted on the HOB simulator with the +X axis up during mechanical integration and transport. However, because the SMEC cannot work against gravity the instrument has to be rotated by 90° so that the +Y axis is up. A purpose built support trolley will be provided to rotate the integrated FPU and JFET units on the HOB simulator about 90° in a controlled manner. The trolley will also allow the instrument to be moved between the AIV clean rooms and the cryogenic test facility.