SPIRE Cryostat Integration and Test Plan

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Contents

1 Scope of Document

This document describes in detail how the SPIRE AIV facility will be integrated and tested in preparation for the STM and CQM testing, in particular the test cryostat and harness. It describes the step-by-step sequence of activities, high-level procedures, organisation, resources and facilities required. It does not describe the general facility build and telescope simulator integration and testing which will have been completed as separate tasks.

2 Documents

2.1 Applicable Documents

	Title	Author	Reference	Date
AD 1	AIV Facilities Requirements Specification	D. Smith	SPIRE-RAL-PRJ-000463 Issue 1.3	10-Apr-2001
AD 2	SPIRE Product Assurance Plan	D. Kelsh	SPIRE-RAL-PRJ-000017 Issue 1.0	11-Apr-2001
AD 3	Cleanliness Plan	B. Swinyard	SPIRE-RAL-DOC-1070 Issue 1.0	9-Jan-2002
AD 4	Cryostat pre-shipment review	E. Clark	SPIRE-RAL-MOM-001459	5¨Dec -2002
AD 5	Cryostat EIDP	A.S.Scientific	SPIRE-RAL-DOC-001471	13-Dec-2002

2.2 Reference Documents

	Title	Author	Reference	Date
RD 1	SPIRE EMC Control Plan	D. Griffin	SPIRE-RAL-PRJ-852 Issue 0.1D	7-Sep-2001
RD 2	Thermal test specification	S. Heys/ A.S.Goizel	SPIRE-RAL-DOC-	27-Feb-2001
RD 3	SPIRE MGSE Load Test Report	D. Smith / M. Trower	SPIRE-RAL-DOC-001423	21-Oct-2002

3 Acronyms

AD	Applicable Document
CQM	Cryogenic Qualification Model
EGSE	Electrical Ground Support Equipment
FTS	Fourier Transform Spectrometer
HOB	Herschel Optical Bench
MGSE	Mechanical Ground Support Equipment
N/A	Not Applicable
PFM	Proto-Flight Model
RAL	Rutherford Appleton Laboratory
RD	Reference Document
SPIRE	Spectral and Photometric Imaging Receiver
STM	Structural Test Model
TBC	To Be Confirmed
TBD	To Be Defined
TFCS	Test Facility Control System

4 AIV Facility Test Objectives

4.1 MGSE Integration

The SPIRE FPU and JFET boxes will be mounted on a HOB simulator plate supported in the cryostat by a framework structure. The instrument and HOB assembly will be moved between the integration area to the cryolab on a support trolley, Figure 1.

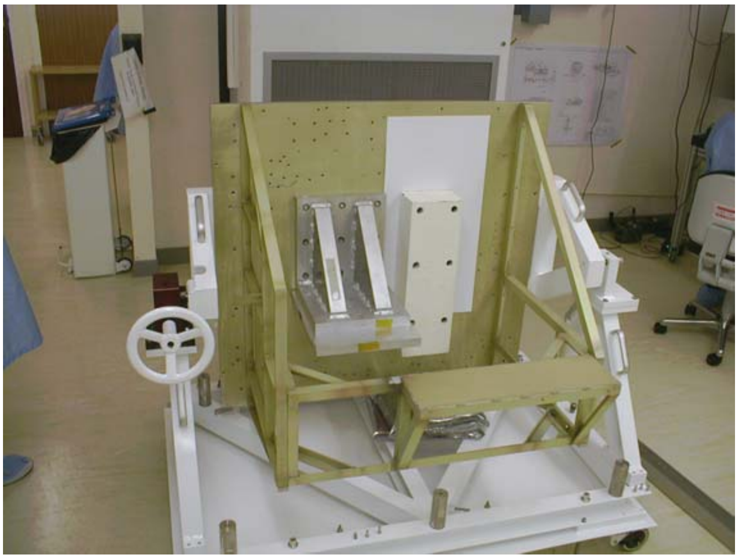


Figure 1: HOB simulator assembly and support trolley.

The MGSE components will be inspected on delivery, cleaned and trial fitted before final assembly following the sequence shown in Figure 4. At the time of writing a load test of the HOB frame and trolley had been performed with a load of approximately 250kg.

4.2 Cryostat

4.2.1 Installation

The cryostat will be delivered by AS Scientific ltd. after a delivery review board has been held to verify that the cryostat meets the basic design requirements, AD 4. Unloading and installation into the laboratory will be carried out according to AS Scientifics' own procedures supplied as part of the cryostat EIDP (AD 5).

Because the procedure involves opening external doors to move the cryostat into the laboratory there will be some contamination. However, care will be taken to minimise the levels of contamination by covering all optical benches, filters and restricting access to the lab to essential personnel. The external doors will only be opened when the cryostat is being wheeled into the building. Once the cryostat is in position the lab doors will be locked. AS Scientific will then move the cryostat into its final position, inspect for signs of damage and remove the transit packing. Once this has been completed the cryostat and laboratory will be cleaned to remove all surface contamination. The air filters will be switched on and the laboratory returned to class 1000 status.

4.2.2 Vacuum System

The vacuum system comprises a Pfeiffer TCM1601 turbo pump backed by a Unidry050-3 pump controlled by a TCS180 controller (Figure 2). After cleaning the cryostat, the turbo pump and gate valve will be mounted to the cryostat and connected to the backing pump and controller.

A test of the vacuum system will be performed to verify the following:

- That the vacuum system can pump the chamber to 10^{-6}mbar within 24 hours.
- The maximum pumping speed within the chamber is <50mbar/min
- The operation of the control system
- That there is no residual contamination from hydrocarbons

A residual gas analyser supplied by the RAL AIV facility (spec described in §9.2.1) will be mounted to the cryostat to monitor the partial pressures of any contaminants in the chamber.

A mild bakeout <50°C TBC will be performed to reduce the levels of hydrocarbons.

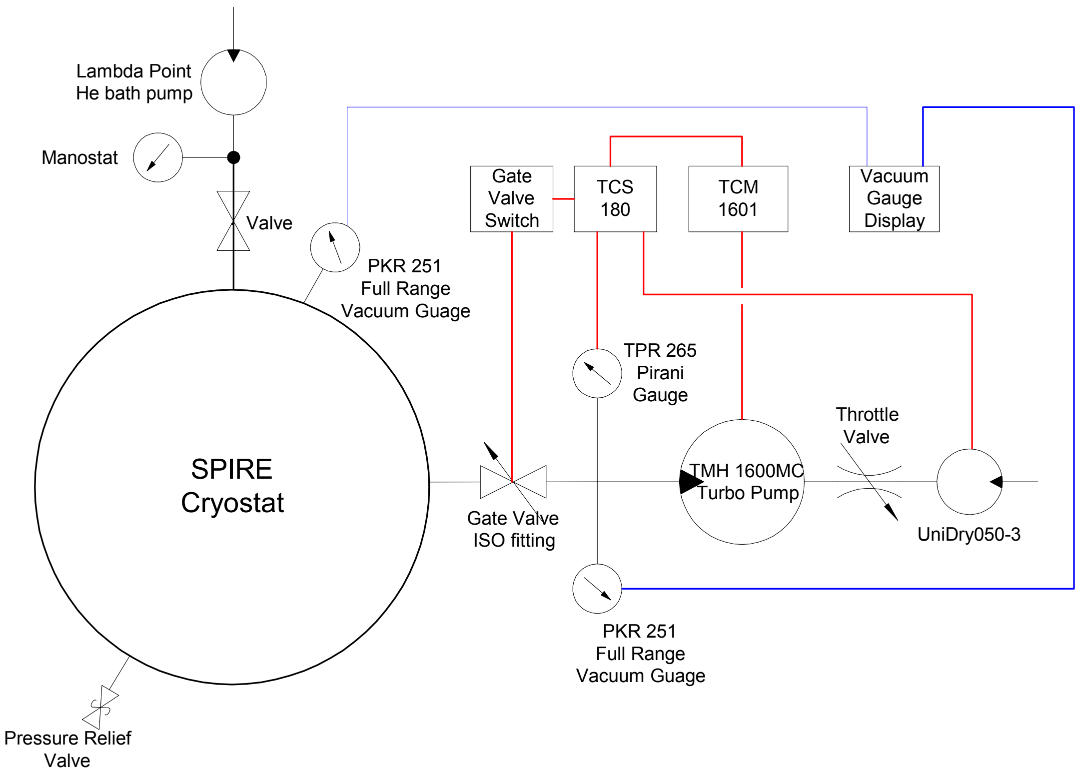


Figure 2: Schematic of cryostat vacuum system.

4.2.3 Cryogenic Testing

The cryostat manufacturers will have demonstrated the cryogenic performance of the cryostat before delivery to RAL (AD 4, AD 5). Therefore the tests to be performed at RAL are not necessarily a demonstration of the design requirements, but rather as a run through of the cryostat operating procedures before the first tests with the STM. The main goals for the commissioning trials are:

- Cool the main stages of the cryostat to their operational temperatures, i.e. 77K, 10K, 4.2K and 1.7K.

- Establish the cryogen hold times once the required interface temperatures have been and stabilised. With no instrument present the hold times should be at least 3 days.

- Determine the cool down and warm up times.

- Optimise the cryostat operating procedures, in particular the initial filling of the tanks, and control of the 10K and 1.7K temperature stages.

- Measure background radiation – a Cardiff supplied photodetector attached to the 1.7K stage will measure the background signal within the cryostat to determine any stray light.

4.3 Vacuum Window

The vacuum window for the optical alignment tests comprises a 300mm diameter pieced of fused quartz. Because of its size, there is the potential risk that small micro-fractures could cause the window to fail catastrophically when it is first used on the vacuum chamber. To avoid damaging the cryostat, a simple test will be performed on the window by connecting it to a pump via a vacuum flange and pulling a vacuum down to 10^{-2} mbar. If the window does not fail then it will be mounted to the main vacuum chamber.

4.4 TFCS Acceptance Tests

The vacuum gauges, Lakeshore temperature monitors and cryogen level sensors will be connected to the TFCS before the vacuum test. The tests will verify the following functions:

- Activation of the TFCS functions
- Logging, display and playback, of vacuum pressures
- Logging, display and playback, of temperatures
- Communication of with SCOS-2000, command and telemetry responses
- Uninterrupted operation.

For the vacuum tests, the cryogen level sensors will not be active and some temperature sensors will not be connected.

4.5 Cryoharness Testing

A series of tests will be conducted to verify that the basic electrical and thermal requirements of the main test cryo-harness are met, before the CQM tests when the instrument will be integrated with the detectors. The very tight AIV schedule and budget does not permit the full set of set of those originally identified by JPL (ref note). Therefore, only the most essential tests have been included in the test plan. The tests fall into two main groups: 1) Measurements to be performed by supplier prior to delivery to RAL and 2) Measurements performed during STM cold tests

4.5.1 Measurements to be performed by supplier

These measurements will be performed using the manufacturers own Automatic Test Equipment (ATE) The data will be supplied to RAL on floppy disks.

4.5.1.1 Electrical continuity and shorts to grounds.

These measurements are performed at each stage of manufacture and especially before final potting of the connectors when rework will no longer be possible.

4.5.1.2 Measure resistance of each wire

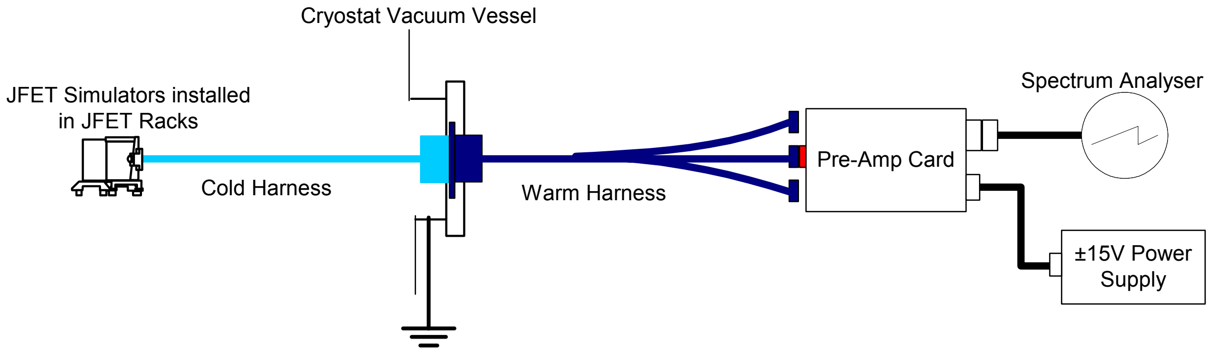
Each cryogenic section of the test-harness will undergo at least two thermal cycles to 77K to relieve any internal stresses. The electrical resistances will be measured before and after each cycle and any changes in performance noted. Significant (>5%) changes in the properties will lead to a review board and could result in the harness being rejected.

4.5.1.3 Measure capacitance

Although capacitances can be measured on the suppliers ATE, it is not practical or meaningful to measure the capacitances for every combination of conductor. Therefore capacitance measurements will be made for a subset of the signal lines relative to their local grounds with the assumption that this will be a representative measurement of the whole batch.

4.5.2 Measurements performed during STM cold tests

4.5.2.1 Measure background noise and microphonics spectra

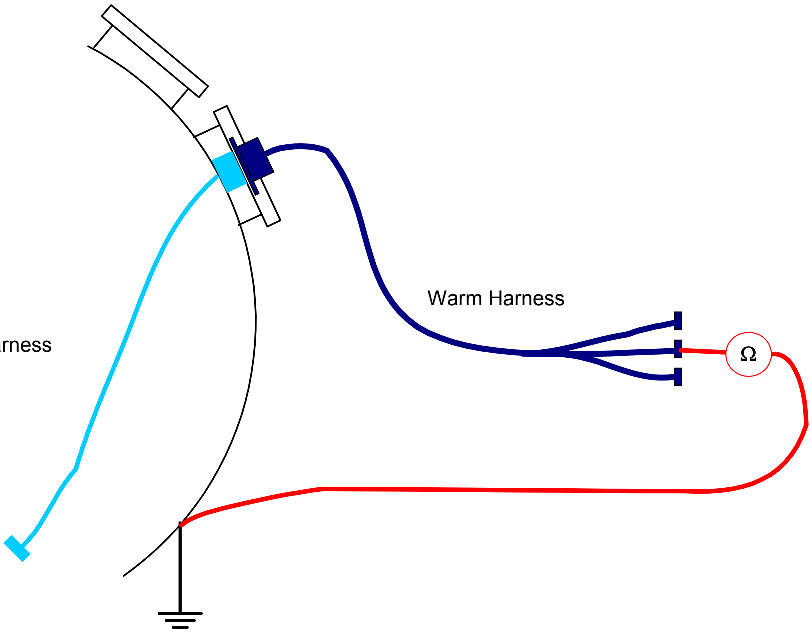


The noise spectra for a subset of the harness will be measured between 1Hz < f < 10kHz using the configuration shown above. The 24 channel pre-amplifier board supplied by JPL will be of the type used for the BODAC tests. This will be powered by a ±15V DC power supply provided by JPL (TBC). The cold harness will be connected to JFET simulators provided by JPL. An RAL supplied spectrum analyser will measure the noise spectrum. The test will be performed at ambient and cryogenic conditions.

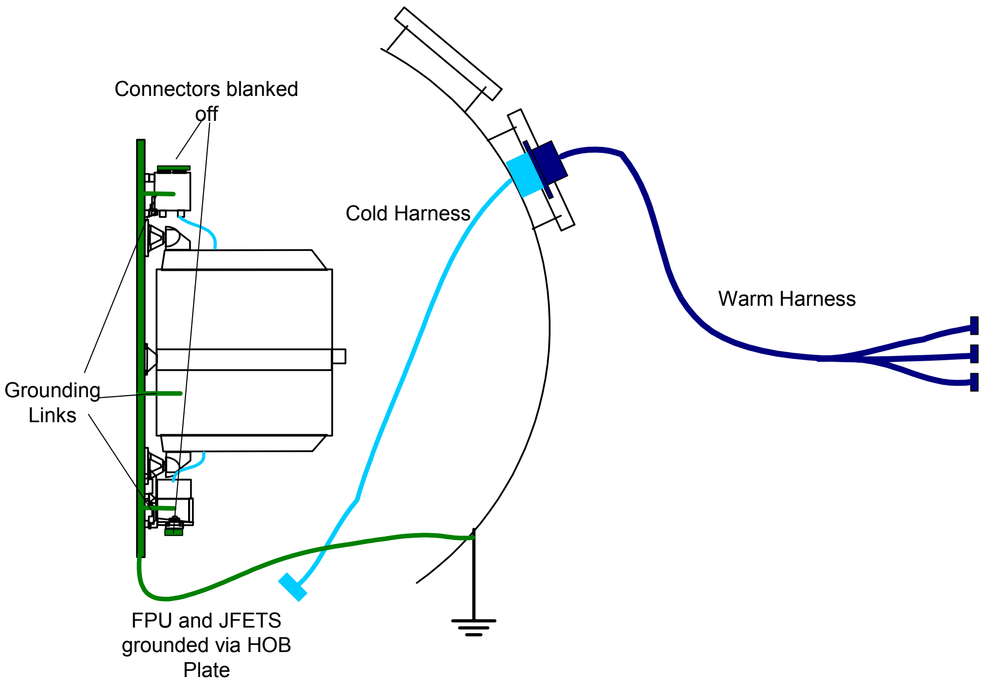
4.5.2.2 Measure shorts to grounds

This test forms part of the integration procedure of the instrument into the test cryostat. The outline procedure for this test is described as follows.

1. Measure shorts to ground of installed harness.
The harness will be pre-installed in cryostat with the external shields isolated from the tank. The electrical isolation between the harness shields and ground will be verified.



2. Move SPIRE into cryostat.
The FPU and JFET units will be integrated on the HOB simulator plate with links to ground as shown in the diagram below. All instrument connectors will have blanking covers to protect against ESD. The HOB plate will be grounded at all times during the installation until the final connection to the DCU has been made.

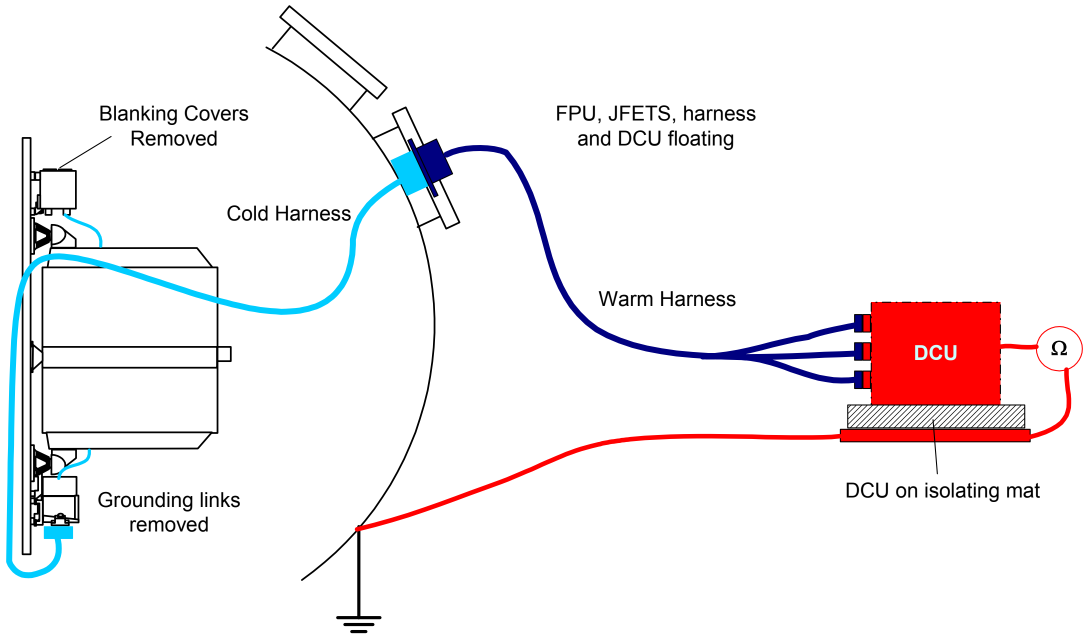


3. Connect Cold Harness to SPIRE.

Once the instrument has been moved into the chamber and locked into position, the cold harness will be connected to the JFETS first with the bias connector blanked off. After all JFETS have been connected, the bias harness will be connected to the bias connectors. The warm harness will then be connected with the DRCU mounted on an isolating sheet.

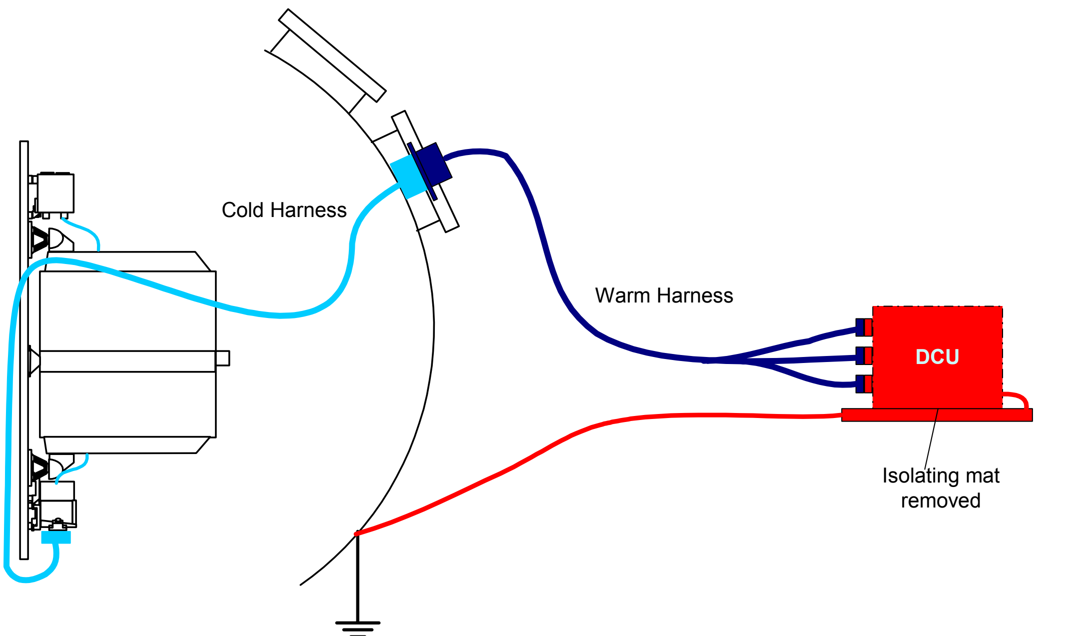
4. Measure isolation

Once all connections have been made the links to grounds will be removed so that the SPIRE FPU, JFETS, harness and DRCU should be floating. The isolation from ground will then be measured. This will have to be repeated as the cryostat end caps are installed.



5. Ground DCU

After completion of the integration, the DRCU will be grounded and the insulating mat removed.



5 AIV Flowchart

The flowcharts in Figure 4 to Figure 10 shows the sequence of activities from integration of the HOB simulator and MGSE, cold tests and preparation for the STM tests.

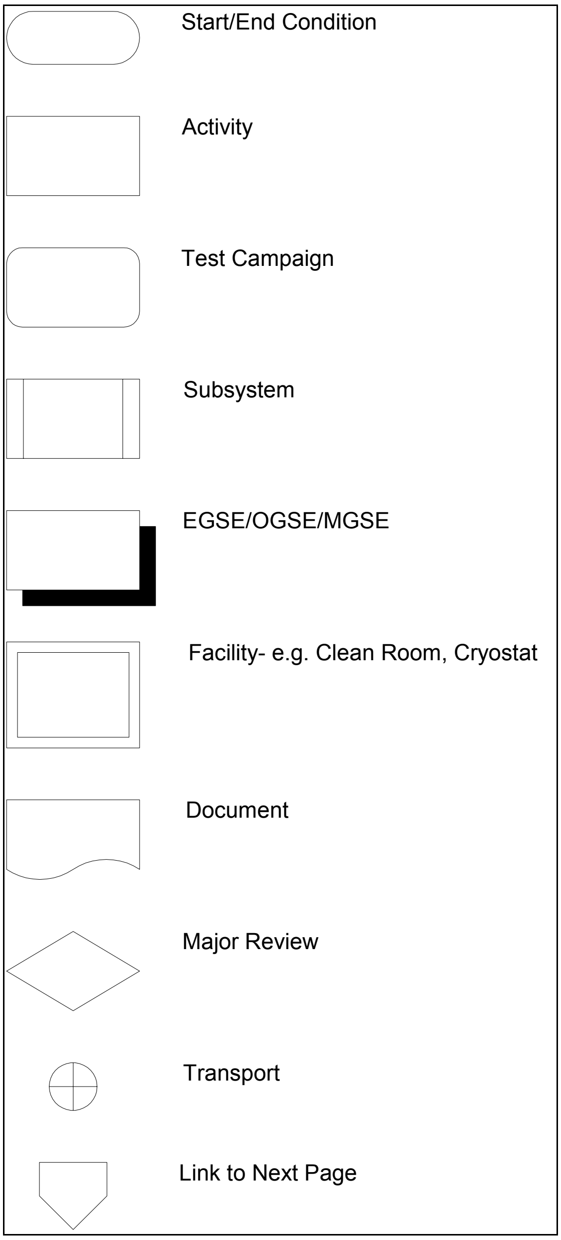


Figure 3: Legend for AIV Facility Integration and Test Flow Chart. Key Inspection Points are indicated by (**K**), Mandatory Inspection Points are indicated by (**M**).

Figure 4: Flowchart showing the integration of the HOB simulator and MGSE

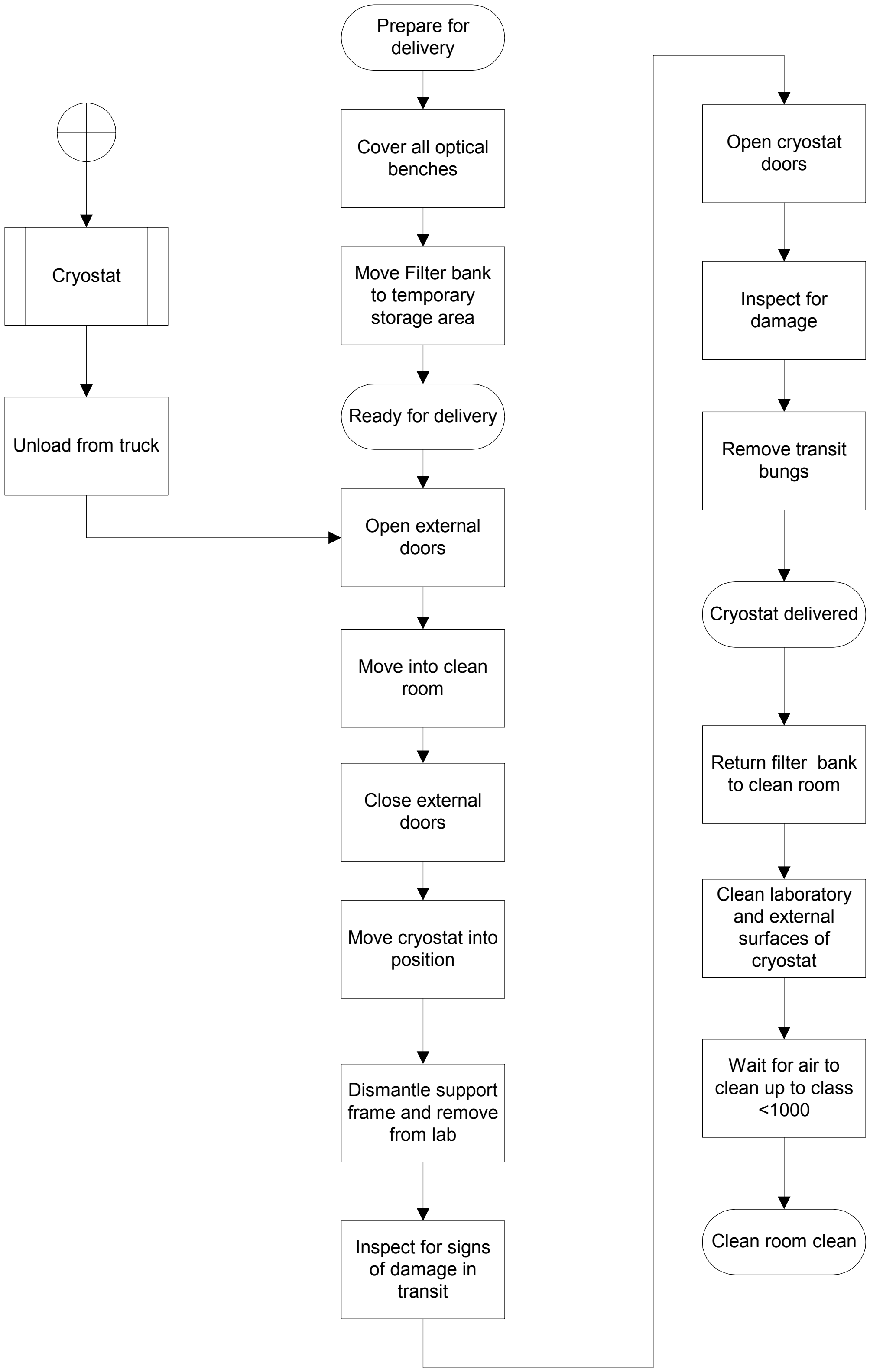


Figure 5: Flowchart showing the installation of the SPIRE test cryostat into the cryolab.

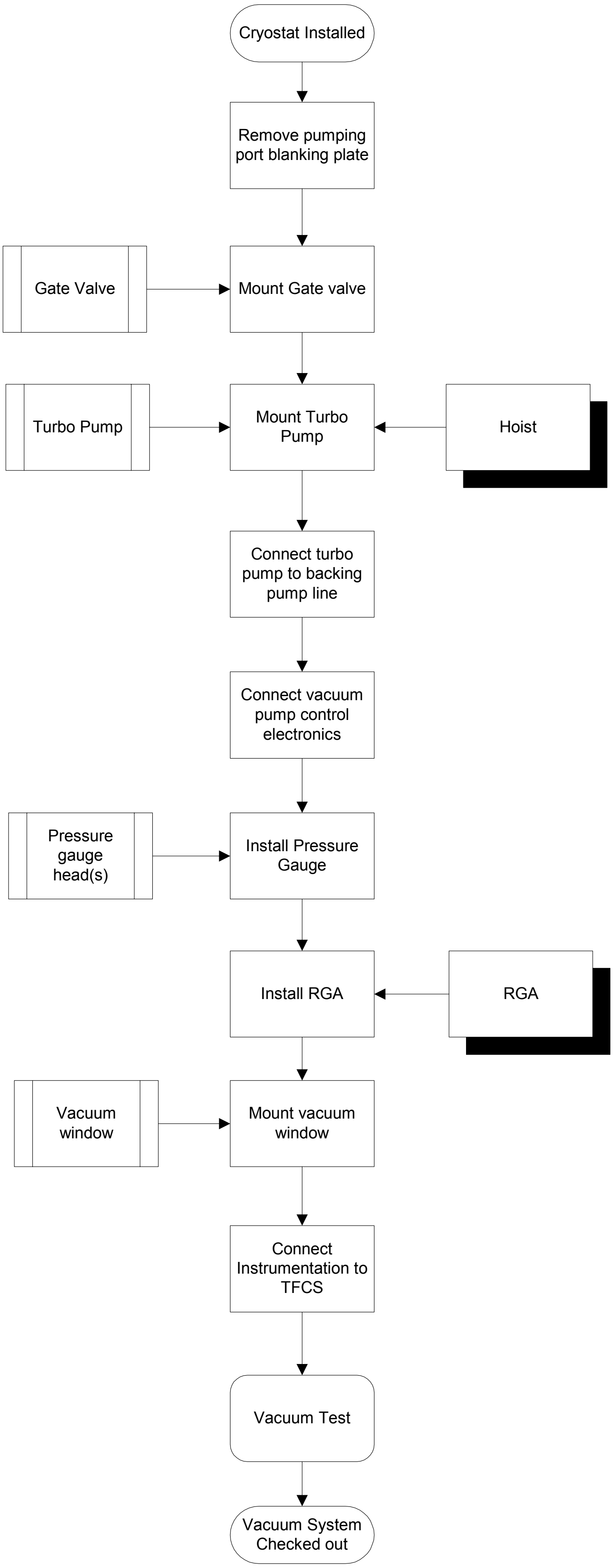


Figure 6: Flowchart showing the integration and testing of the vacuum system on the test cryostat.

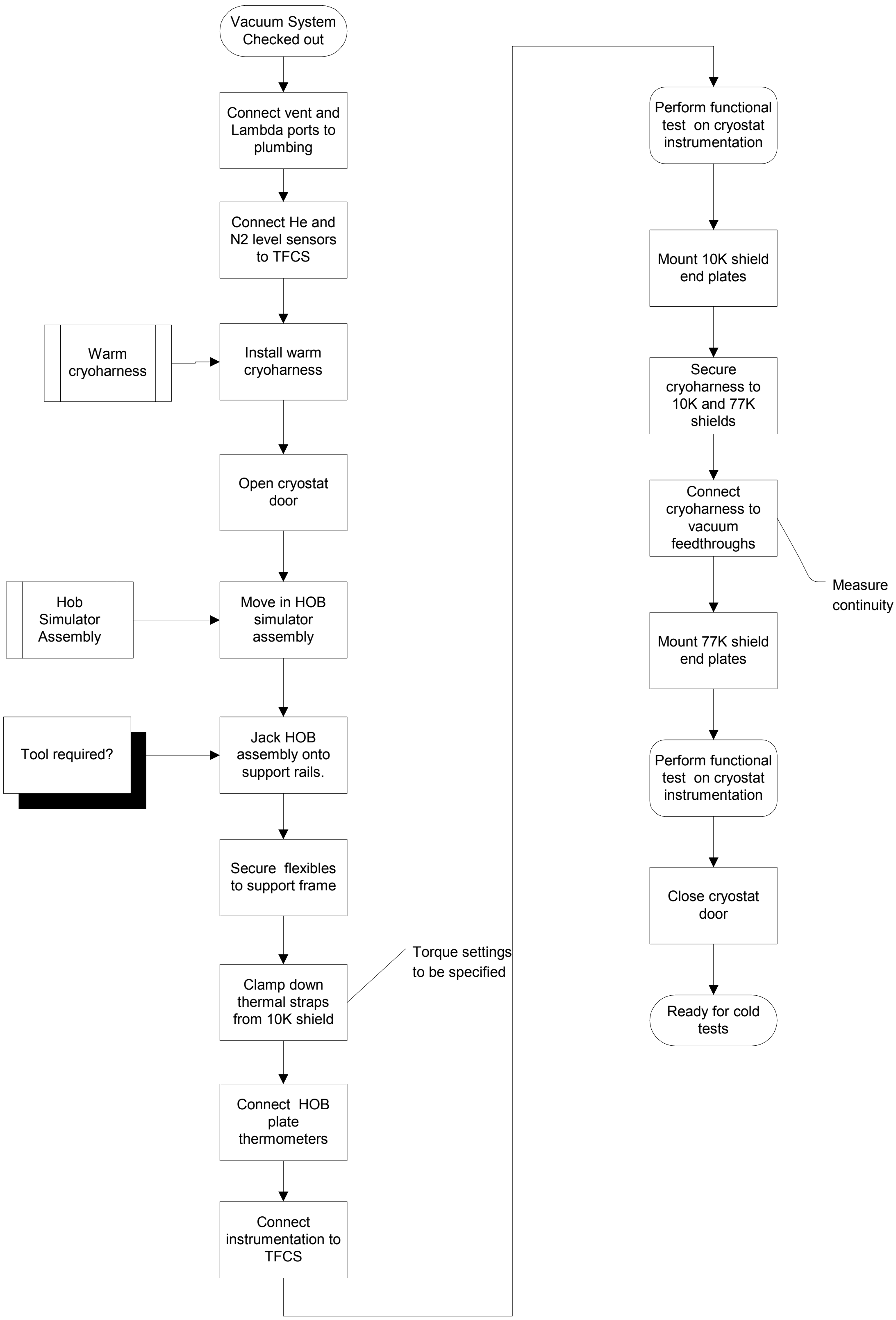


Figure 7: Flowchart showing the preparation of the cryostat for cold testing.

Figure 8: Flowchart showing sequence of activities for cold trials

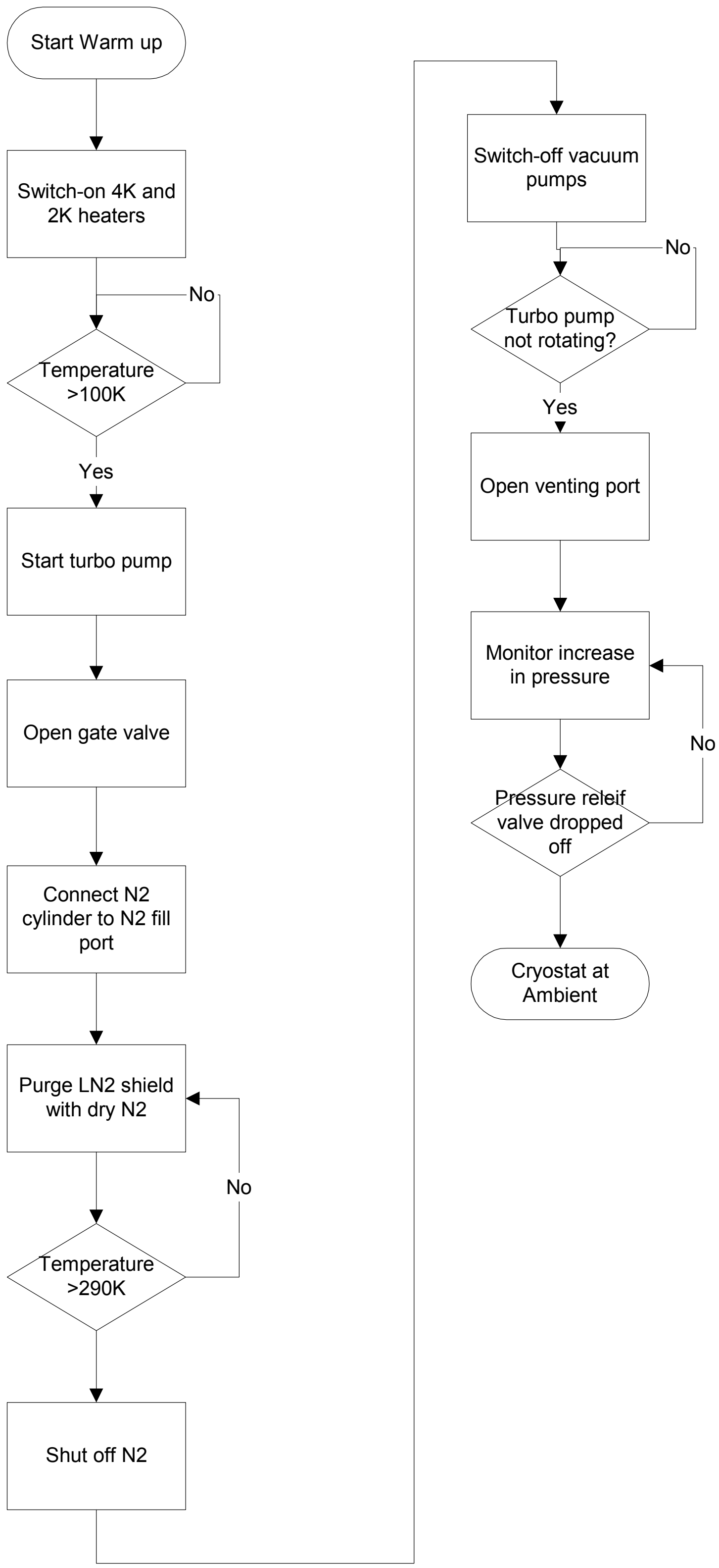


Figure 9: Flowchart showing warm-up sequence after cold trials.

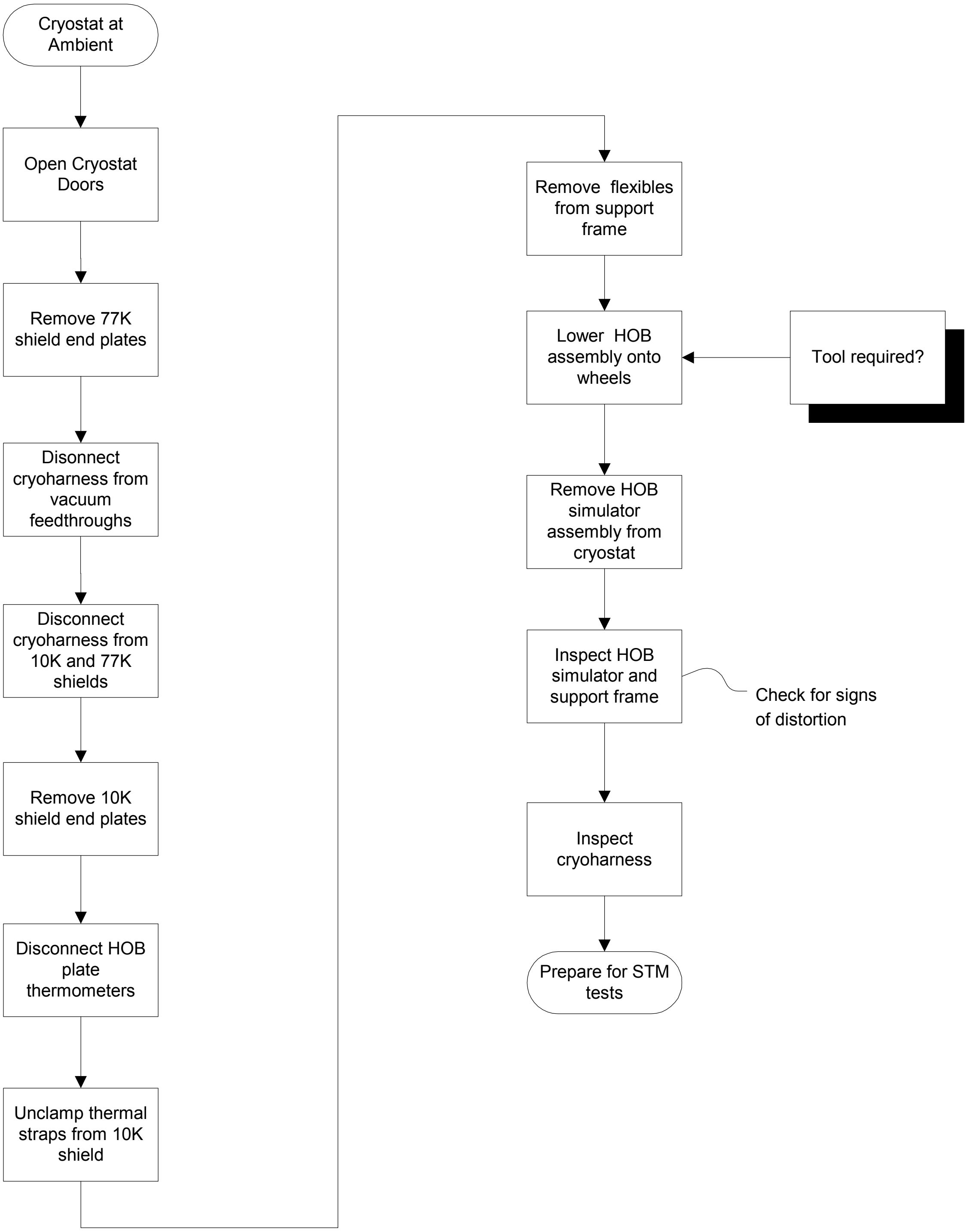


Figure 10: Flowchart showing preparation of cryostat for STM cold optical alignment tests.

6 Task List

The following table defines the step-by-step sequence of activities for the AIV Facility Integration and Test Plan.

Step	Activity	Identifier	Notes	Requirement
1.	**MGSE Integration**			
1.1	Parts delivery and inspection		MGSE parts delivery (HOB simulator, support trolley, support frame)	
1.2	Clean components		Clean components and bag up according to SSTD procedures	
1.3	Make up sub-assemblies			
1.4	Mount HOB simulator to trolley			
1.5	Mount support frame to HOB simulator			
1.6	Mount fluid pipe support brackets			
1.7	Mount Thermometers		Attach Si Diodes to HOB simulator and support trolley	
1.8	Mount Harness clamps and supports			
1.9	Install cryoharness		Trial fit at first to check routing then clamp down.	
2.	**Cryostat Installation**			
2.1	Cover all optical benches		Ensure that all optical surfaces are protected during installation of cryostat.	R3-1, R3-2, R3-3
2.2	Move filter bank to temporary storage area		May be left in laboratory if space permits.	
2.3	Cryostat delivered		Remove from truck – inspect for any external signs of transport damage.	
2.4	Open external doors		To minimise risk of contamination, clean room doors should be opened at last minute. Tacky mats should be placed inside entrance to clean off worst levels of dirt from wheels (if practical)	

Step	Activity	Identifier	Notes	Requirement
2.5	Move cryostat into clean room		Cryostat will be installed on mobile cradle with jacking wheels.	
2.6	Close external doors		Once the cryostat is within the clean room the doors should be shut to minimise contamination	
2.7	Move cryostat into position		The cryostat will be wheeled into the position as indicated on the cryolab floor plan. The centre position of the cryostat has been marked by a X on the lab floor.	
2.8	Dismantle support frame and remove from lab			
2.9	Inspection		Inspect for signs of damage in transit.	
2.10	Return filter back to operating position			R3-1, R3-2, R3-3
2.11	Clean laboratory and external surfaces of the cryostat		Start with cryostat external surfaces – level of cleaning required will depend on condition when it arrives Order special clean for laboratory once cryostat is prepared	R3-1, R3-2, R3-3
2.12	Wait for clean room to reach <class 1000		This may take several days to achieve depending on the level of contamination	R3-1, R3-2, R3-3
3.	**Cryostat Integration (1)**		**Vacuum pump installation and checkout**	
3.1	Remove pumping port blanking plate			
3.2	Mount gate valve		Gate valve may already be installed depending on ASSP integration tests	R1-20
3.3	Mount turbo pump		Will need lifting hoist and support frame.	
3.4	Install pressure gauges		TPR265 Pirani gauge and PKR251 Full range gauges	R1-23
3.5	Install RGA		RGA to be loaned from RAL SSTD space test facility	R1-24
3.6	Mount vacuum window			R1-26 R1-28

Step	Activity	Identifier	Notes	Requirement
3.7	Connect instrumentation to TFCS		Perform functional test to check that all thermometers are connected and vacuum gauges are operational.	
3.8	Vacuum Test			
4.	**Vacuum Test**			
4.1	Close doors and start pumping system			
4.2	Plot pump down time and ultimate pressure.		Pressure <10^{-7} mbar (for clean and empty cryostat) Check for leaks	R1-16 R1-17
4.3	Inspect RGA spectra for contamination			R1-19 R1-24
4.4	Let-up to air			
5.	**Cryostat Integration (2)**		**Preparation for cold test**	
5.1	Connect venting and Lambda bath pumping ports to plumbing			
5.2	Connect He and N2 level sensors to TFCS			
5.3	Install warm cryoharness		Warm harness connectors will be mounted to ISO250 flanges.	
5.4	Open cryostat door			
5.5	Move in HOB simulator assembly		Monitor cleanliness Check clearances	
5.6	Jack HOB assembly onto rails		Requires special tool	
5.7	Secure flexibles to support frame			
5.8	Clamp down thermal straps from 10K shield		Torque settings to be specified	
5.9	Connect HOB plate thermometers			
5.10	Connect instrumentation to TFCS			
5.11	Perform functional test on cryostat instrumentation		TFCS self test	

Step	Activity	Identifier	Notes	Requirement
5.12	Mount 10K shield end plates		Torque settings?	
5.13	Connect cryoharness to vacuum feedthroughs			
5.14	Mount 77K shield end plates			
5.15	Repeat functional test on cryostat instrumentation		TFCS self test	
6.	**Cryogenic Cooldown**			
6.1	Test Readiness Review			
6.2	Functional test of TFCS		TFCS self test	
6.3	Pump Down			
6.4	Switch-on RGA		At 10^{-3}mbar	R1-19 R1-24
6.5	Monitor pump down			
6.6	Fill N2 vessel		At 10^{-6}mbar Check RGA Spectrum and make sure that there are no leaks. Gate valve will shut automatically if pressure rises above 10^{-1} mbar	R1-16 R1-17
6.7	Close gate valve		Check that cryopumping is taking place	
6.8	Fill He can with LN2			
6.9	Cool shield and HOB plate to <100K			
6.10	Boil off and pump LN2 in He cans		Heater power required TBD	
6.11	Flush 4K vessel with gaseous He			
6.12	Fill 4K vessel with He			
6.13	Fill 2K vessel with He			
6.14	Wait for HOB simulator to cool to 15K			
6.15	Start pumping on Lambda bath		Record lowest temperature acheived	
6.16	Control at 1.8K			
6.17	Hold for 72 hours			
7.	**Warm Up**		**Return Cryostat to Ambient Conditions**	
7.1	Switch-On 4K and 2K heaters			
7.2	Wait for temperatures to reach 100K			
7.3	Start Turbo Pump		Wait for pressure each side of gate valve to balance	
7.4	Open Gate Valve			

Step	Activity	Identifier	Notes	Requirement
7.5	Warm to Ambient		Purge vessels with dry N2	
7.6	Shut off N2 supply		When temperatures reach >290K	
7.7	Switch off vacuum pumps		Wait for turbo pump to stop rotating	
7.8	Backfill with dry N2		Open the venting valve. Monitor the rise in pressure and wait for the relief valve to drop.	
8	**Prepare for STM tests**			
8.1	Open cryostat door			
8.2	Remove 77K shield			
8.3	Disconnect harness from 10K shield			
8.4	Remove 10K shield			
8.5	Unclamp thermal straps from 10K shield.			
8.6	Remove fluid pipes from support frame.			
8.7	Lower support frame onto rails.			
8.8	Move support frame out of cryostat onto trolley.			
8.9	Attach HOB plate to MGSE trolley and lock frame into position.		Inspect the HOB plate and harness for signs of mechanical distortion.	
8.10	Disconnect cryoharness from frame.			

7 Test Procedure List

This section lists the main test procedures that will be used and developed during the AIV facility integration. These procedures will then be used for the instrument AIV acitivities.

Title	ID	Resp.	Description
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).

8 Organisation

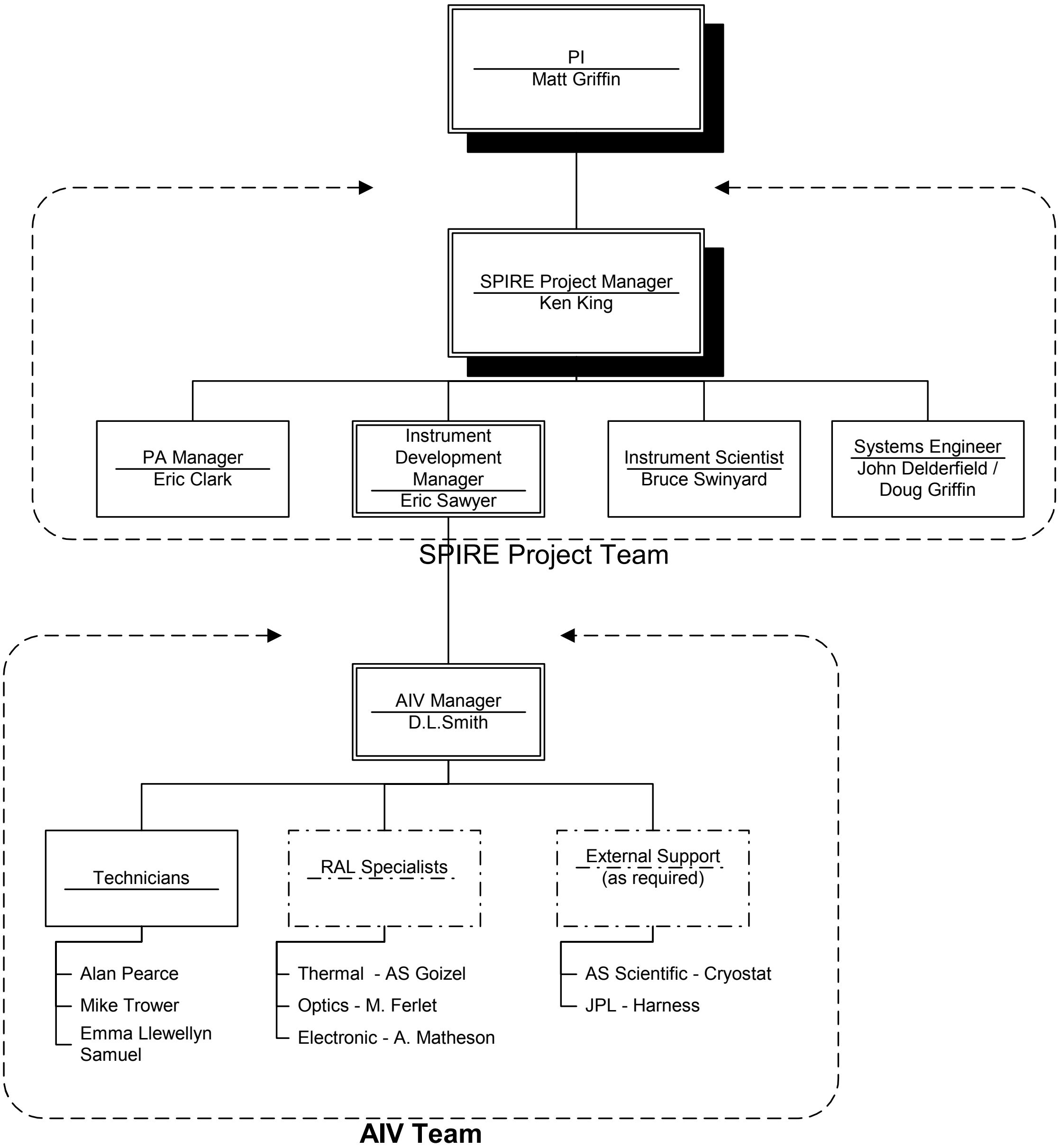


Figure 11: Organisation for AIV facility integration

9 Resource Requirements

9.1 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.

9.1.1 AIV Team

9.1.1.1 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

9.1.1.2 Cryostat Engineer

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

9.1.1.3 Technicians

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

9.1.2 RAL Specialist Support

9.1.2.1 Optics Specialist

- Optical alignment verification
- Stray light analysis

9.1.2.2 Thermal Engineer

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

9.1.2.3 Electronics Specialist

- TFCS software support

9.1.3 SPIRE Project Team

9.1.3.1 SPIRE Project Manager

- SPIRE Project Management
- UK SPIRE Management

9.1.3.2 Instrument Development Manager

- Subsystem Development
- Subsystem Deliveries
- Instrument Deliveries

9.1.3.3 Instrument Scientist

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

9.1.3.4 Systems Engineer

- Systems engineering
- System thermal design
- Parts procurement

9.1.3.5 PA Manager

- Product assurance
- Quality assurance
- Acceptance data packages

9.1.4 External Support

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

9.1.4.1 AS Scientific Ltd.

- Support as required during cryostat testing.

9.1.4.2 JPL

- Support integration testing of the test cryoharness.

9.2 Test Equipment

9.2.1 Mass Spectrometer

MKS Instruments microvision + mass spec, It is has a complete service once a year and it's operation is characterised against a known trace gas.

9.2.2 Photodetector

9.2.3 Harness Test Equipment

9.2.3.1 Amplifier card and adaptor

9.2.3.2 JFET Simulators

9.2.3.3 JFET Power supply

9.2.3.4 JFET box blanking plugs

9.2.3.5 DCU blanking plugs

9.2.3.6 DAQ system/Spectrum Analyser

9.2.3.7 Ohmmeter

9.3 SPIRE MGSE

9.3.1 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.

9.3.2 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.