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Title:	**Description of EQM**
CI-No:	150000

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Issue	Date	Sheet	Description of Change	Release
1	12.6.02	All	first issue	
1.1	17.6.02	10	§ 2.2: Update of RD list	
		14	§ 3: Modification of figure title	
		15	§ 4.2.2: Incorporation of cooler recycling angles	
		20	§ 5: Clarification of contents	
		22	§ 5.3: Incorporation of missing Figure numbers	
		45	§ 6.2.4: Comment to He flowchart	
		63 – 65	§ 6.3.1: Update acc. To results of PDR assessment meeting	
		76	§ 7.3.1: RD included and correction of referenced figure	
		77	§ 7.3.2: Update of chapter	
		all pages	CTA replaced by cooled plate	

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1 INTRODUCTION

The HERSCHEL program adapts a two model philosophy comprising

- an EQM (Engineering Qualification Model)
- a PFM (Proto Fight Model)

The PFM will be launched into orbit having run through its total qualification/acceptance sequence.

The tight PFM schedule makes it necessary to lower the development risk in certain areas by using and adapting the existing ISO-QM to the Herschel EQM within a reasonable effort and schedule to allow early testing in the following areas:

- Functional testing of scientific instruments in a flight representative environment
- EMC testing of FPUs in a representative environment.

Specific aims at flight representativity are:

  - L0, L1, L2 temperatures
  - correct harness
  - correct straylight background

Additional essential spin-off of integration and a.m. test activities relevant for PFM are:

- early verification of alignment operations
- potential “on line” optimisation of scientific software
- closer determination of L0, L1, L2 temperatures
- testing of ground operations

The subject of this document is a summary description of

- EQM design as derived from ISO-QM
- EQM integration and testing

The last point is described in detail in the “HERSCHEL PLM/EQM AIT Plan” (RD3) i.e. main emphasis of this document is on EQM-design.

The Herschel EQM will be based on the existing ISO-QM and is used as ground based test cryostat. It will see neither the launch environment nor orbital parameters.

2 DOCUMENTS AND ABBREVIATIONS

This document was compiled to explain the HERSCHEL EQM functionality and its relation to the PFM. It is not a specification and detailed technical information may be of exemplary character only, reflecting the status of the issue date.

2.1 Applicable Documents

HERSCHEL

Number	**Document Title**
AD-1	First/Planck Instrument Interface Document-Part A, SCI-PT-IIDA-04624, Issue 1.1 (redlined), 1/12/2000
AD-2	First/Planck Instrument Interface Document – Part B, SCI-PT-IIDB/HIFI-02125, Issue 1.0, 1/09/2000 and Comments, dated 30/05/01
AD-3	First/Planck Instrument Interface Document – Part B, SCI-PT-IIDB/PACS-02126, Issue 1.1 MPE, 10/05/01
AD-4	First/Planck Instrument Interface Document – Part B, SCI-PT-IIDB/SPIRE-02124, Issue 1.0, 1/09/2000 and updated section 5, Issue 2.1, dated 6/06/01
AD-5	Data for Selection of Space Materials, ESA-PSS-01-701
AD-6	MIL-HDBK-5, Metallic Materials + Elements for Aerospace Vehicle Structures

2.2 Reference Documents

RD-1	General Design and Interface Requirements, HP-1-ASPI-SP-0027, Issue 2.2, 4 July 2001
RD-2	ISO-PLM-QM, Configuration Status List Prior to Delivery to ESTEC, ISO-LI-B4330.013, issue 1
RD-3	HERSCHEL PLM/EQM AIT Plan, HP-2-ASED-PL-0022
RD-4	EMC Specification, Doc FP-ASPI-RS-1003
RD-5	Procurement specification for CVV/HTT/HOT forged and formed aluminium parts, HP-2-ASED-PS-0002
RD-6	ISO PLM Integration Dolly Technical Specification, ISO-VV-ZYYR-SP-0043
RD-7	MPT Item Specification XM-IS-APC-0098
RD-8	EDU Item Specification XM-IS-APC-0262
RD-9	ISO PLM Test Dolly Technical Specification, ISO-VV-ZYYX-SP-0473
RD-10	ISO PLM MGSE Hoisting Equipment Technical Specification, ISO-VV-ZYYY-SP-0048.
RD 11	Herschel PA Plan, HP-2-ASED-PL-0007
RD 12	Herschel Contamination Control Plan, HP-2-ASED-PL-0023

RD 13	Description of the PLM FM Cryo Control Instrumentation, HP-2-ASED-TN 0048, issue 1.
RD 14	Payload Module Instrumentation Specification, ISO-DS-BEE00.001. issue 1
RD 15	Trade off for the Herschel Cryo test adapter, HP-2- ASED-TN-0055
RD 16	H-EPLM PDR assessment meeting, 3- 5.06.2002, H-P-ASPI-MN-1564
RD 17	Instrument testing on PLM EQM level, HP-2-ASED-PL-0021
RD 18	Herschel Alignment Concept, HP-2-ASED-TN-0002

2.3 Abbreviations

AIT	Assembly Integration and Test
AVM	Avionics Module
AXT	Auxiliary Tank
BOLA	Bolometer Amplifier
C/L	Centre Line
CCH	Cryostat Control Harness
CCS	Central Check-out System
CCU	Cryo Control Unit
CFC	Carbon Fibre Composite
CIC	Cryo Instrumentation Components
CoC	Certificate of Compliance
CoG	Centre of Gravity
CM	Centimeter (Wavelength)
CQM	Cryo Qualification Model
CSS	Cryo Subsystem (Cryostat)
CTA	Cryo Test Adapter
CVSE	Cryo Vacuum Service Equipment
CVV	Cryostat Vacuum Vessel
CVVIP	Vacuum Vessel I/F Plate
DM	Decimeter (Wavelength)
DSPG	Distributed Single Point Grounding
EDU	Equipment Drive Unit
EGSE	Electrical Ground Support Equipment
EMC	Electromagnetic Compatibility
EQM	Electrical Qualification Model
FoV	Field of View
FPA	Focal Plain Assembly
GLC	Ground Loop Coupling
HIFI	Heterodyne Instrument for the Far Infrared
HOT	He I Tank
HTT	He II Tank
I/F	Interface
IMT	Integrated Module Test
IR	Infrared
ISO	Infrared Space Observatory

ITT	Invitation to Tender
LHe	Liquid Helium
LOU	Local Oscillator Unit
MGSE	Mechanical Ground Support Equipment
MLI	Multi Layer Insulation
MPT	Multi Purpose Trolley
MSS	Mechanical Support Structure
n/a	not applicable
MoI	Moment of Inertia
OB	Optical Bench
OSS	Optical Support Structure
PACS	Photodetector Array Camera and Spectrometer
PCH	Payload module Cryostat Harness
PFM	Proto Flight Model
PTR	Post Test Review
QM	Qualification Model
RF	Radio Frequency
SCOE	Special Check-Out Equipment
SE	Shielding Effectiveness
SFT	Short Functional Test
SIH	Scientific Instrument Harness
SPIRE	Spectral and Photometric Imaging Receiver
SST	Stainless Steel
SVM	Service Module
TBC	To be confirmed
TBD	To be defined
TM/TC	Telemetry/Telecommand
TRR	Test Readiness Review
TTC	Transport and Test Cover
TTD	Transport and Tilting Dolly
w/o	without
w.r.t.	with respect to
WU	Warm Unit
XMM	X-Ray Multi Mirror Satellite

2.4 Order of Precedence

If a discrepancy between this description and other documents is identified, such discrepancy shall be reported to Astrium GmbH.

3 COORDINATE SYSTEM

The Herschel EQM reference frame (O, X_{PLM} , Y_{PLM} , Z_{PLM}) is defined such that :

- O is located at the centre of the EQM, on the Interface plane to the SVM.
- X_{PLM} coincides with the nominal optical axis of the Herschel telescope. The positive X_{PLM} axis is oriented towards the target source. The X_{PLM} axis has an offset of 60 mm to the longitudinal X axis of the launcher.
- Z_{PLM} is in the plane orthogonal to the X_{PLM} axis, such that nominally the sun will lie in the (X_{PLM} , Z_{PLM}) plane (zero roll angle with respect to Sun). Positive Z_{PLM} axis is oriented towards the Sun.
  - Y_{PLM} completes the right handed orthogonal reference frame.

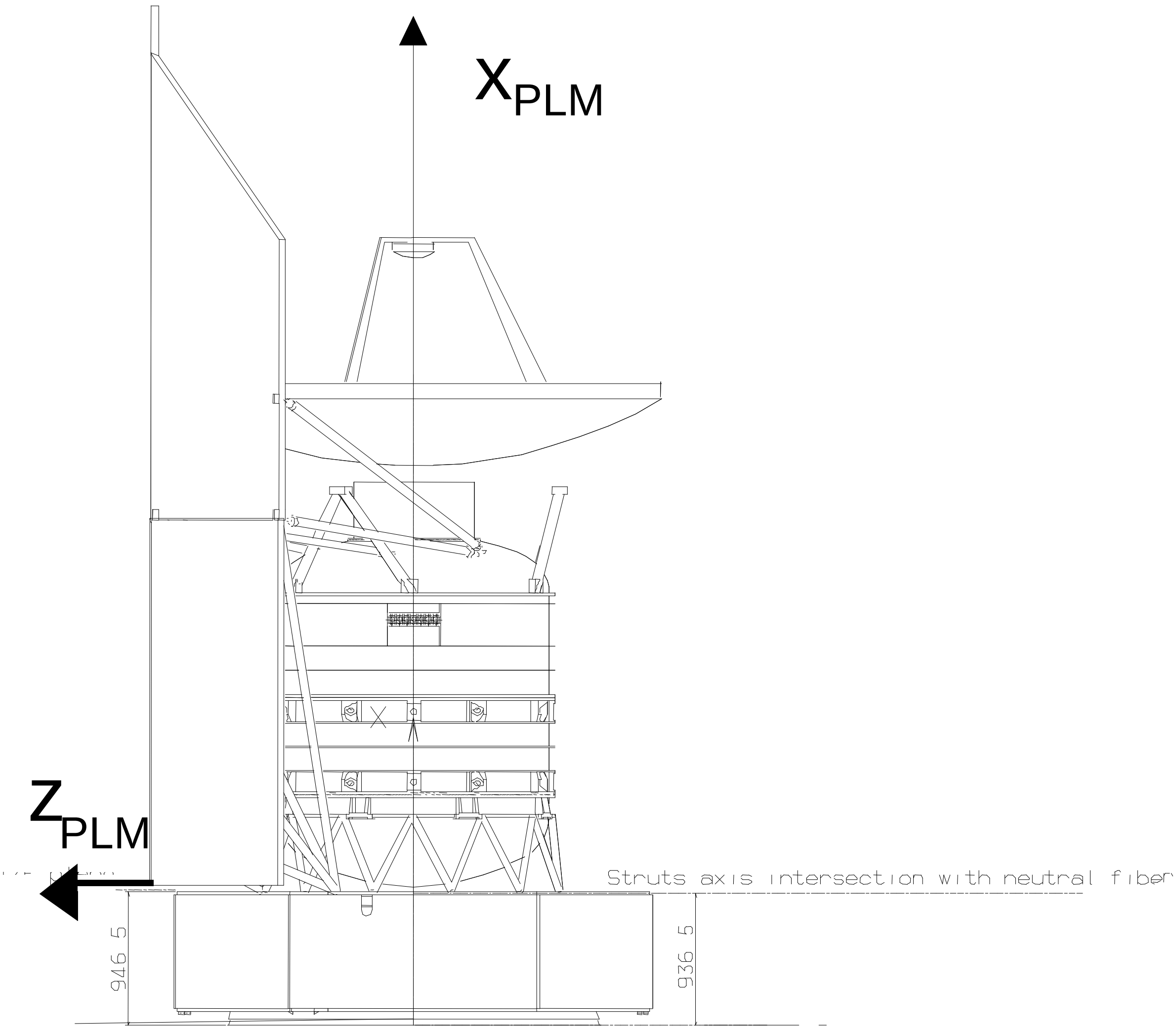


Figure 3-1: Herschel Coordinate System

4 EQM REQUIREMENTS AND DEVELOPMENT OVERVIEW

4.1 Fundamental Requirements and Constraints

- The EQM shall provide a test platform to allow early in the Herschel program a functional and EMC-testing of the Scientific Instruments.
- The EQM shall provide a flight representative environment to the Scientific Instruments as far as necessary for the conduction of a.m. tests.
- The EQM shall make use of the existing ISO-QM to the maximum extent possible.

4.2 EQM Performance Requirements

4.2.1 Thermal

- The EQM shall provide the correct L0, L1, L2 temperatures for the FPUs as required for on-orbit conditions.

  These requirements are compiled in the table below.

	Maximum Temp [K]			Average W.C. Dissipation [mW]
	HiFi	PACS	SPIRE	
Level 0	2	1.75	2	10
Level 1	6	5	6	25
Level 2	20	n/a	15	50

Table 4-1: Thermal Requirements of FPUs as taken from IID-A [AD 1]

- The L1 and L2 requirements shall be fulfilled with the nominal on orbit GHe mass flow calculated to about 2.2 mg/sec.
- The temperature of the Innermost Shield shall be adjustable by a selectable GHe mass flow to the predicted on orbit value of about 32K and/or to fine adjust the L2 temperature level.

4.2.2 Operational Requirements

- Nominal orientation of EQM for longer testing periods shall be horizontal, i.e. x-axis horizontal, - y-axis (LOU) upwards.
- For cooler recycling of FPUs a tilting of the EQM by at least 17deg around z-axis towards +y orientation shall be possible.

4.2.3 Interface Requirements

The EQM shall provide adequate and safe interfaces to

- the SVM simulator
- to all GSE as described in Para.6.3.

4.3 EQM Development Overview

These requirements determine in principle the EQM-configuration as outlined in the subsequent chapters, namely:

- Lower Part:
  - Removal of internal parts of ISO like OSS, Baffle, etc
  - use of existing ISO lower bulkhead CVV,
  - attachment of HERSCHEL SVM simulator for accommodation of Scientific Instrument warm boxes.
- Cylindrical Part: use ISO hardware unchanged
- Upper Part:
  - Replace Auxiliary Tank of ISO by the HERSCHEL – Optical Bench with integrated Instrument FPUs (identical to PFM).
  - Upper Bulkhead (CVV + Shields) must be consequently of HERSCHEL PFM Design including the Scientific Instrument Harness.
- An actively cooled plate in front of the instruments shall provide orbit representative background conditions to allow EMC susceptibility testing of the PLM, especially of the sensitive scientific instruments.

The SVM will be placed in the correct height, i.e. the distance LOU-SVM will be identical to that of Herschel-PFM.

Details of the EQM program should be taken from the subsequent chapters and RD3, "Herschel PLM/EQM AIT Plan". As an introduction a short summary of the activity flour is given in the figure below.

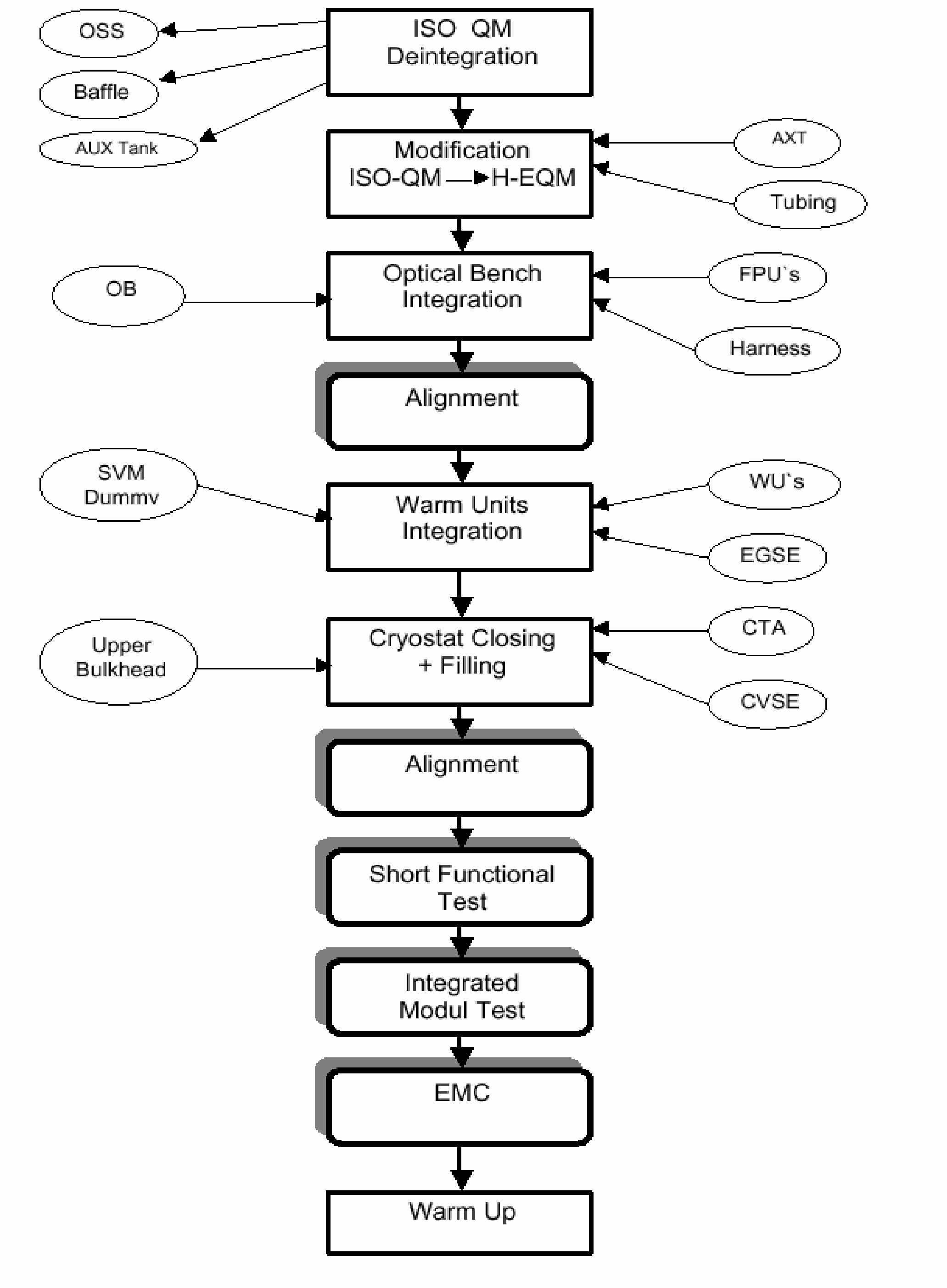


Figure 4-1: Summary of EQM Activities

Amongst detailed activities, the sequence comprises 3 essential activity blocks:

- ISO-modification
- Integration of Herschel specific components
- Tests

4.4 Interfaces to PFM Program

The PFM program is structured success oriented to a high degree. Nevertheless, a certain feedback from EQM to PFM with modifications of the latter are expected, as can be seen from the Schedule in Fig. 4-2.

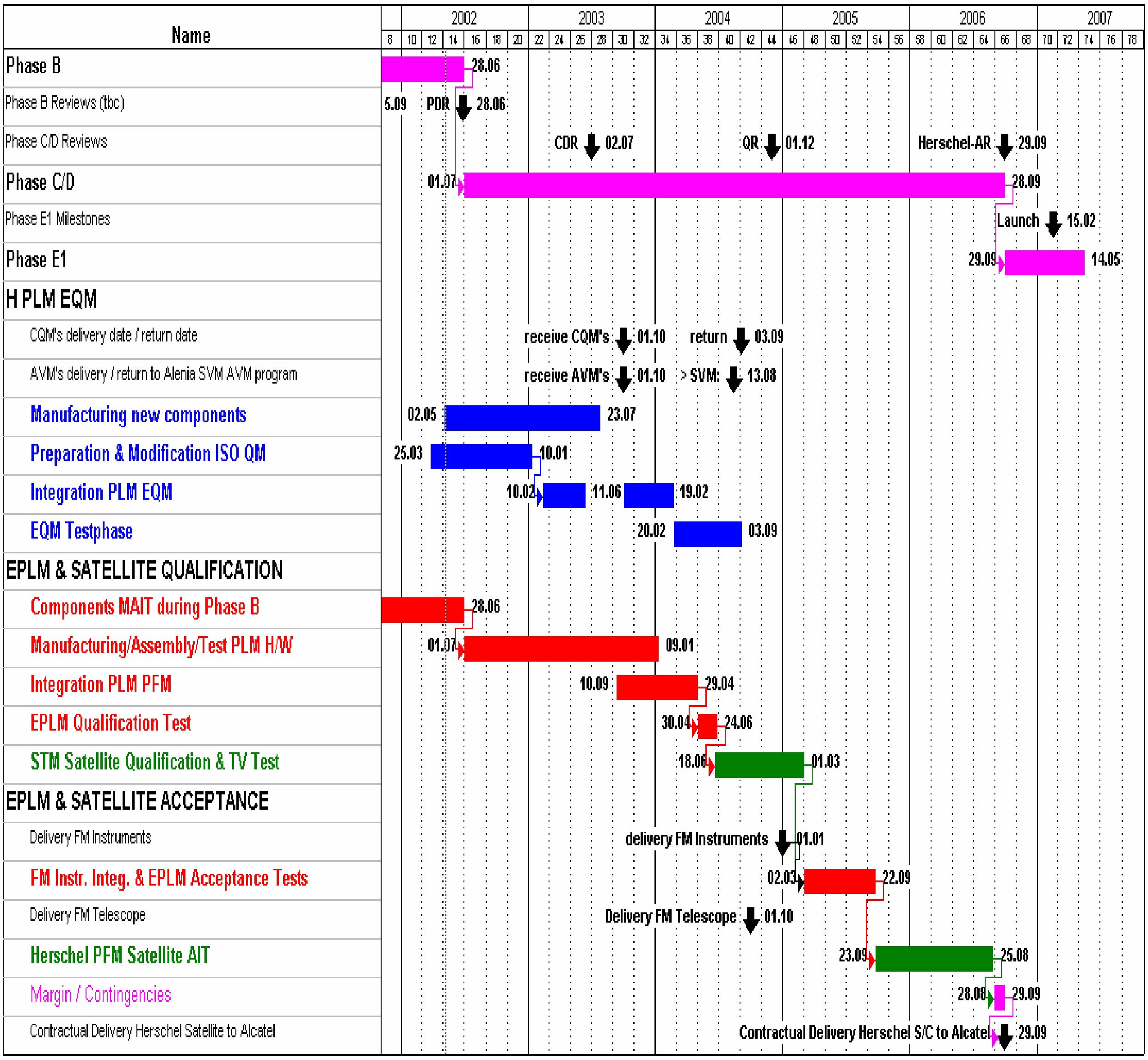


Figure 4-2: EQM Schedule

5 ISO – QM DESCRIPTION

This chapter summarizes the hardware development and performed tests within the ISO program.

The ISO – program was based on 3 models of the payload module i.e.

- 1 Structural model (STM),
- 1 Qualification model (QM), refurbished from the STM and now basis for the Herschel EQM
- 1 Flight model (FM).

5.1 Cryostat Design

The ISO STM/QM design is characterised by the overall Cryostat layout :

- Cryostat Vacuum Vessel (3 pieces), wrapped with external MLI with non – charging white coating
- 16 GFC/CFC tank support straps (chain design), and strap tensioning device
- Upper and lower spatial framework carrying the tank
- Main 2286 l He-II tank with related valves, safety devices, He-II-phase separator and tubing
- 60 l auxiliary tank for launch autonomy
- 3 vapour cooled shields (attached to straps) plus 1 OSS – attached shield, covering the FPUs, all equipped with MLI
- External He-piping with 4 valves, heater to avoid ventline freezing, and nozzles for momentum – free He – exhaust
- External and internal cabling
- Cryostat cover, consisting of:
  - Vacuum – tight shell
  - Clampband fixation to CVV
  - 4 MLI – insulated radiation shields, passively cooled by a total of 20 low force (500 N total force) thermal contacts: shields fixed by 8 GFC-beams
  - LHe –flush cooling of the innermost cover shield to provide 5 K background during dedicated FPU-operations on ground
  - 2 optical channels of 100mm diameter, with thermal filters each, thermally anchored to the 2 innermost shields

5.2 Performed Tests

The ISO STM/QM was planned for structural qualification of the PLM and for verification of the thermal mathematical model. In order to achieve these objectives all hardware consists of flight standard design and configuration.

The ISO PLM-STM testing on cryostat comprised:

- Ground lifetime test
- Functional tests (cryostat performance)
- Thermal vacuum test (early orbit and final equilibrium)
- Vibration tests (sine, low level) cold
- Static load testing of the suspended mass
- Vibration tests (sine, qual. level, two axes) warm

The PLM-QM consisted of the PLM-STM model with the dummy telescope replaced by the STM/QM telescope. The structural, cooling and insulation subsystems have been refurbished from the STM to the maximum extent. All subsystems and units were qualification units. Experiment focal plane units (FPU) were alignment mass and thermal models.

The test program of the ISO PLM-QM was separated into two sequences:

PLM QM Test Phase I – test sequence prior to QM system tests comprising:

- Cooldown and filling of the cryostat with LHe I
- Functional test of the cryostat
- Cold Vibration Test of the cryostat

PLM QM Test Phase II – test sequence after QM system tests comprising:

- De-integration of the QM telescope for inspection /test
- Integration of baffle plate for focus shift measurement
- Closure of cryostat
- Focus shift measurement 1 (warm) opt. Reference measurements
- Cooldown and filling of the cryostat with LHe I
- Focus shift measurement 2 (cold, LHe I)
- LHe II production and LHe II top up
- Launch operation s activities with an ARIANE IV – Fairing Mock-up
- Filling of He-I tank (V502 ventline/nozzle venting)
- Focus shift measurement 3 (cold, He-I)
- Depletion and controlled warm-up of the cryostat
- Focus shift measurement 4 (warm)
- Bake out of cryostat
- Storage of the ISO PLM QM

5.3 Curriculum Vitae of the ISO QM

07.1989 – 01.1990	Integration of the ISO STM/QM at ASTRIUM (Figure 5-1)
02.1990 – 12.1990	1st Cooldown, He-II-Production, TV-Test (Figure 5-2), Vibration Test (cold & warm; Figure 5-3)
01.1991 – 06.1991	Modification STM -> QM, Vibration test (cold)
07.1991 – 02.1992	Transport to AS – Cannes in cold condition (Figure 5-4); System Integration; System Qualification Tests: Vibration, Acoustic Noise, Alignment, CoG, Warm up, De-mating, Transport of warm PLM to OTN
03.1992 – 12.1992	QM Testphase–II: Integration QM-Telescope, Alignment Verification, Bake-out, Launcher I/F-Tests,
01.1993 – 12.1993	Diverse Tests in warm and cold conditions, transport (warm) to ESTEC
06.1994	Fit Check of the PLM in the TV-Chamber – LSS at ESTEC
10.1994	Removal of the Cryostat Cover and installation of cover plate; re-evacuation
08.1996	Installation into the ISO Transport Container for storage
07. 2001	Opening of the Container and 1st check at ESTEC (Figure 5-5)
09. 2001	Transport of the ISO-QM in the Transport Container to ASTRIUM OTN
12.2001	Installation of the PLM in the Cleanroom facility of ASTRIUM OTN (Figure 5-6)
since 04.2002	Start of Inspection and De-integration for modification to HERSCHEL – EQM (Figure 5-7 and Figure 5-8)

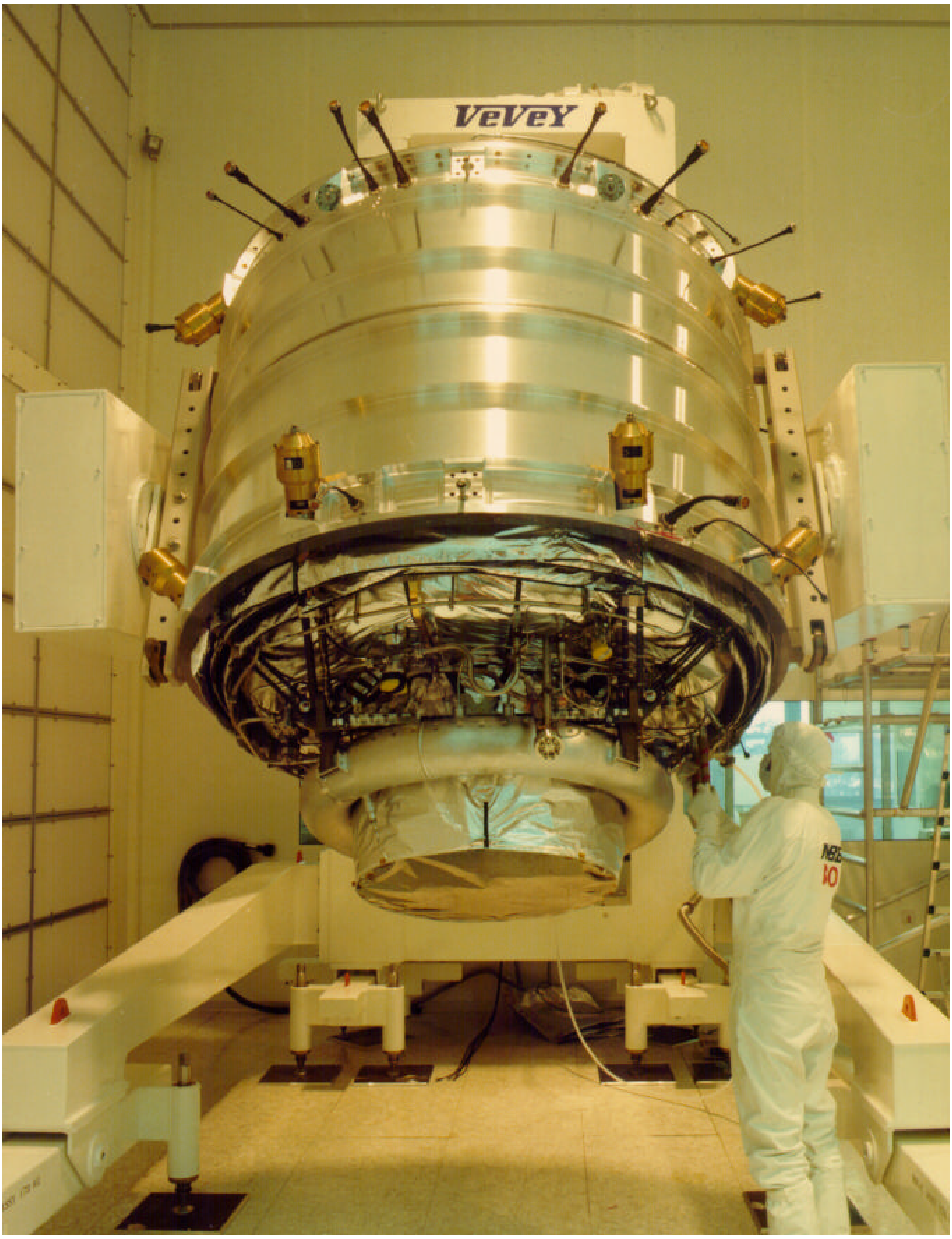


Figure 5-1: ISO PLM Integration in Cleanroom class 100 at ASTRIUM in Ottobrunn

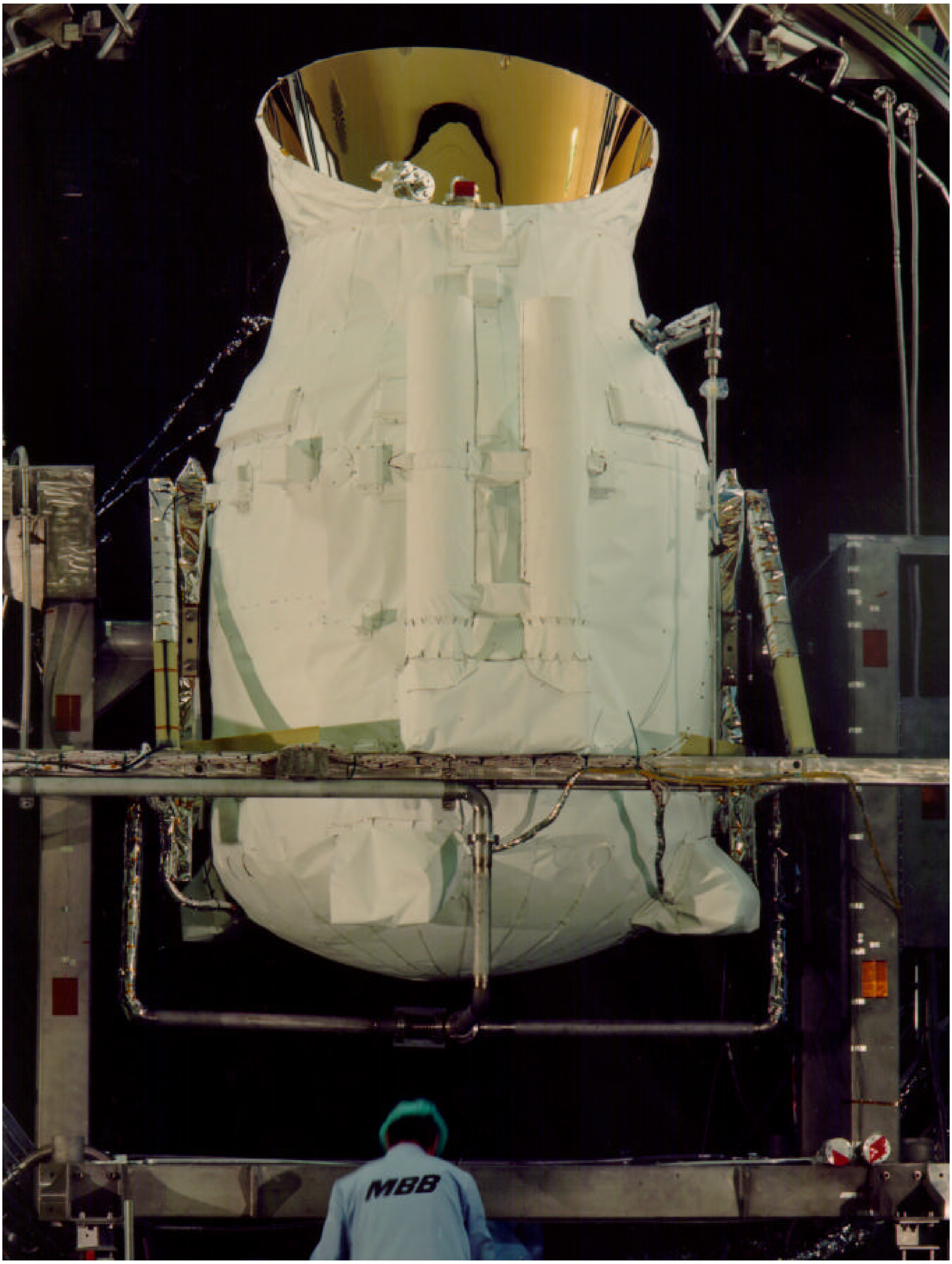


Figure 5-2: Preparation of the ISO PLM for the TV – Test at IABG

Figure 5-3: Preparation of the ISO PLM for the Vibration Test at IABG

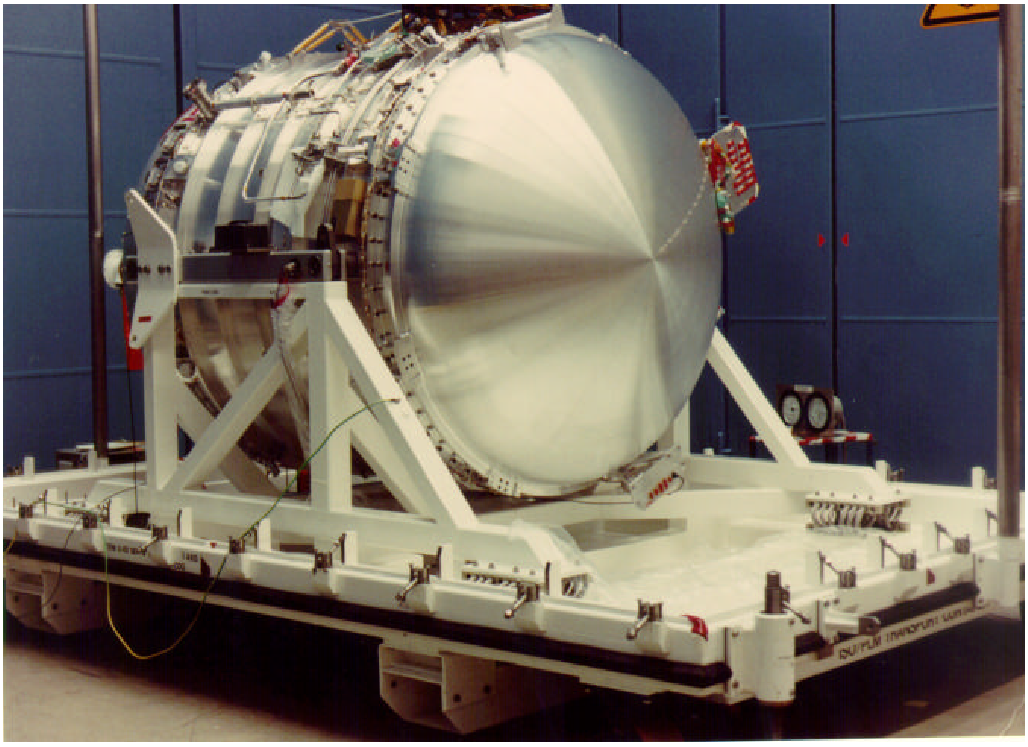


Figure 5-4: ISO PLM mounted in the Transport Container

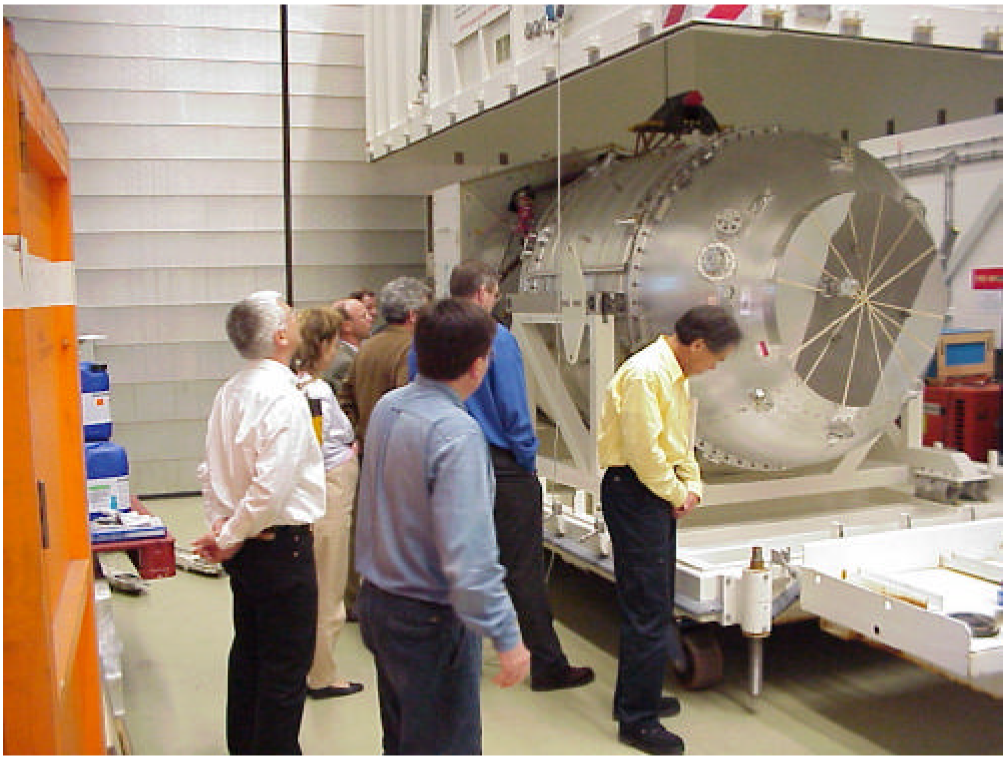


Figure 5-5: ISO PLM in the opened Transport Container at ESTEC

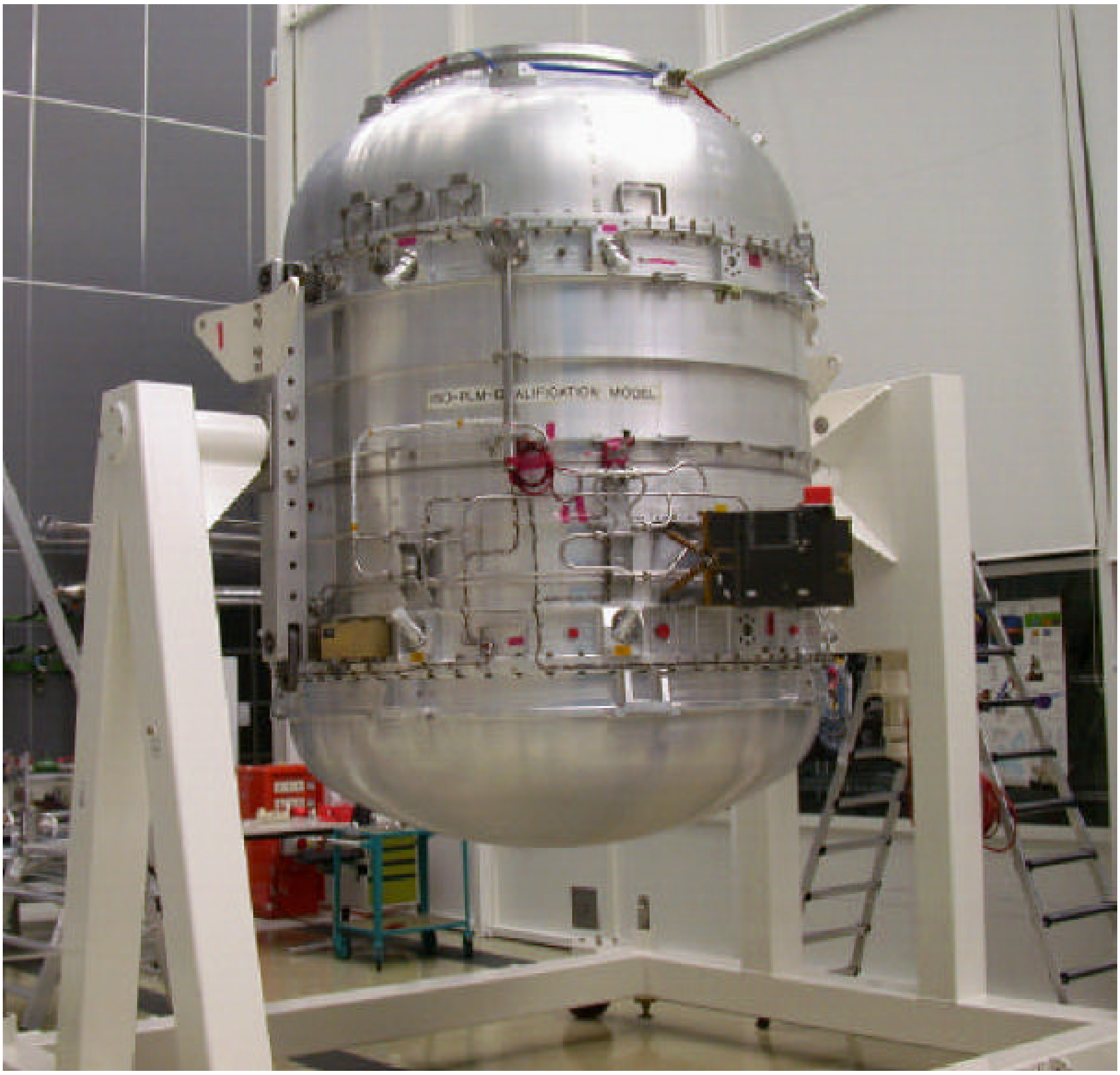


Figure 5-6: ISO-QM in Transport Dolly at ASTRIUM, in preparation to conversion to HERSCHEL EQM

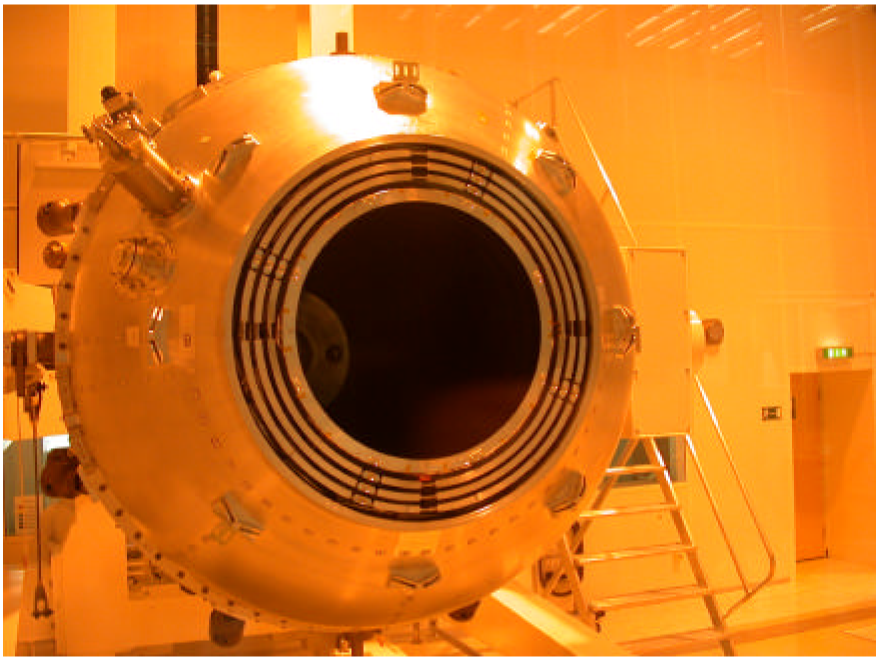


Figure 5-7: Open Cryostat in Integration Dolly in Clean Room 100 at ASTRIUM Ottobrunn

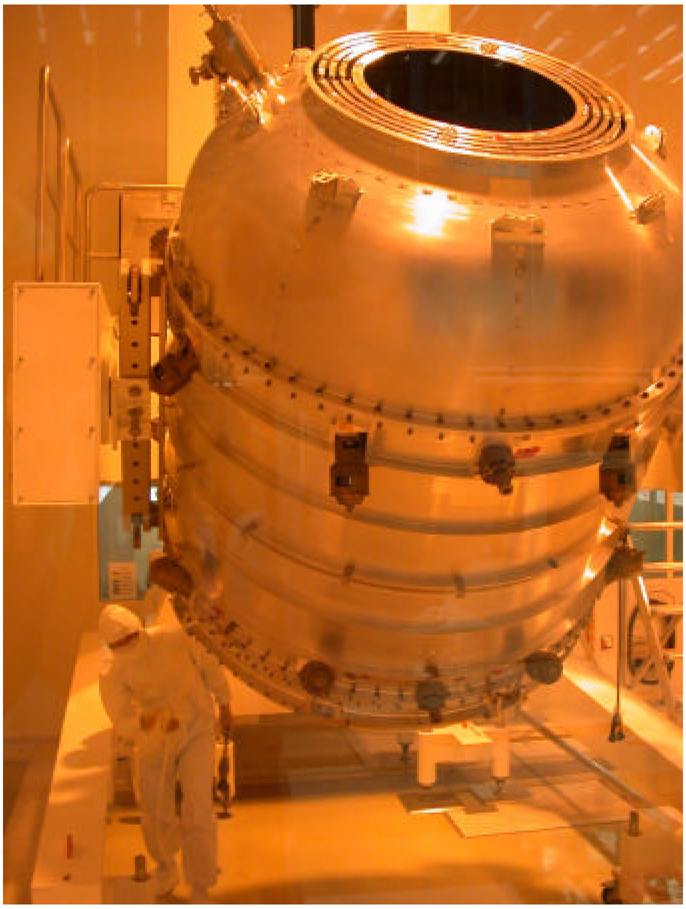


Figure 5-8: Cryostat tilted in Integration Dolly in Clean Room 100 at Astrium Ottobrunn

6 ISO MODIFICATIONS AND HERSCHEL EQM DESIGN

6.1 EQM configuration

Main Modifications of the ISO/QM to Herschel-EQM:

The main components of the Herschel EQM are (see Figure 6-1 and Figure 6-2):

- Cryostat
  - Main tank (torus) used as He I reservoir for the ventline-cooling of the heatshields only
  - New auxiliary tank as He II reservoir instead of the ISO auxiliary tank for ventline-cooling of payloads as well as for cooling of the instrument LO-interfaces
  - Internal harness/sensors electrically representative to PFM (as far as useful)
  - ISO Baffle dismounted
  - ISO OSS dismounted
- Optical bench and instrument shield in Herschel FM design with HIFI-, PACS-, and SPIRE Focal Plane Units mounted on the optical bench and the HIFI LOU and PACS BOLA mounted on the outside of the CVV, all these instrument units with cryogenic qualification status
- Instrument cryo harness plus LOU waveguide assembly, both flight representative
- CVV upper part identical to Herschel FM (including shields and MLI)
- Additional connector ring for scientific instrument harness vacuum feedthroughs
- Additional He S/S components for new EQM design (e.g. burst disc for aux. tank)
- Additional ventline for auxiliary tank
- He S/S internal tubing adapted to new EQM design
- PLM Test Cavity to close the cryostat and to simulate orbital representative background conditions,
- SVM platform with support frame, equipped with warm units AVMs. Arrangement of SVM platform representative to PFM in position and size (wave guide configuration and external instrument harness routing identical to PFM)

Cryostat harness shall be electrically representative to PFM

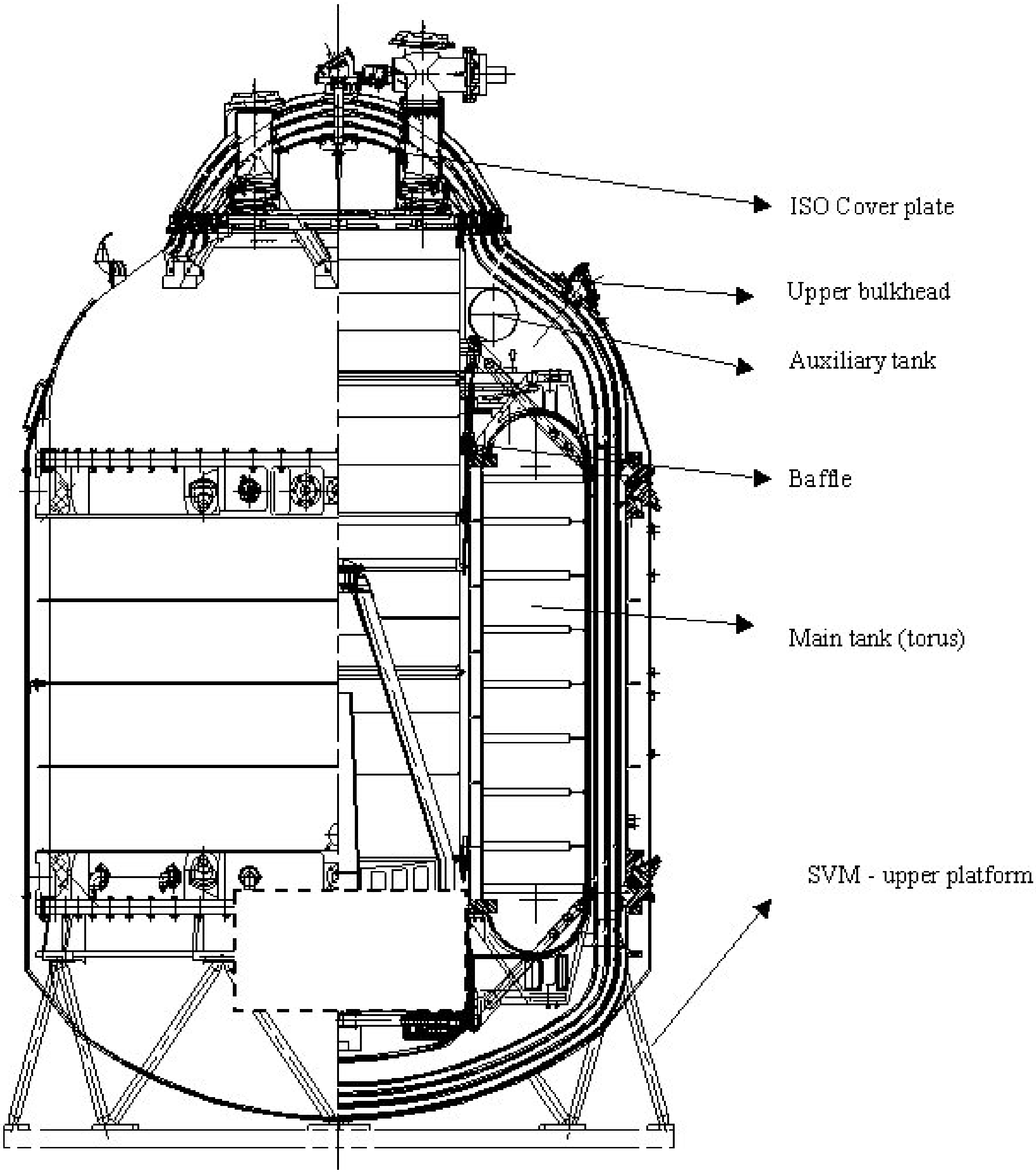


Figure 6-1: ISO-QM basic design

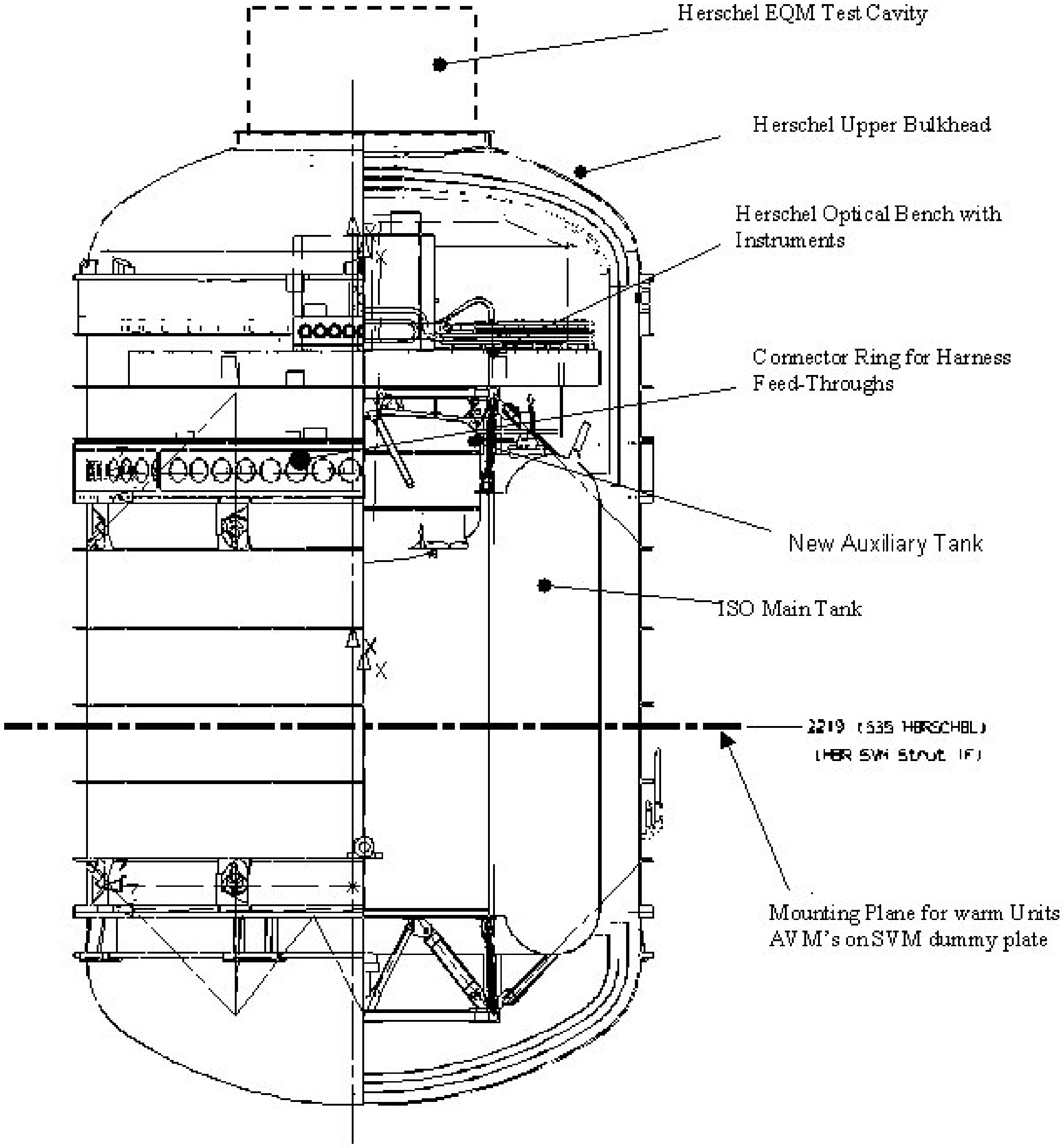


Figure 6-2: Modifications from ISO-QM to Herschel-EQM

6.2 Subsystems description

6.2.1 Structure

The EQM structure consists of three main groups:

1. Those parts/components, which will be used unchanged from ISO QM.
2. Those parts/components, which will be used from ISO QM with some modifications.
3. Those parts/components, which shall be build for EQM application only, in close accordance with PFM design, either to substitute the respective ISO QM components or to be built for specific EQM needs.

6.2.1.1 Unchanged parts/components

The following components will be used structurally unchanged from ISO QM:

- ISO QM lower structure with CVV Lower Bulkhead and Cylinder
- ISO QM Lower Thermal Shields and Cylindrical Shield Assembly
- ISO QM He II Tank
- Lower and Upper Spatial Framework and Tank Suspension

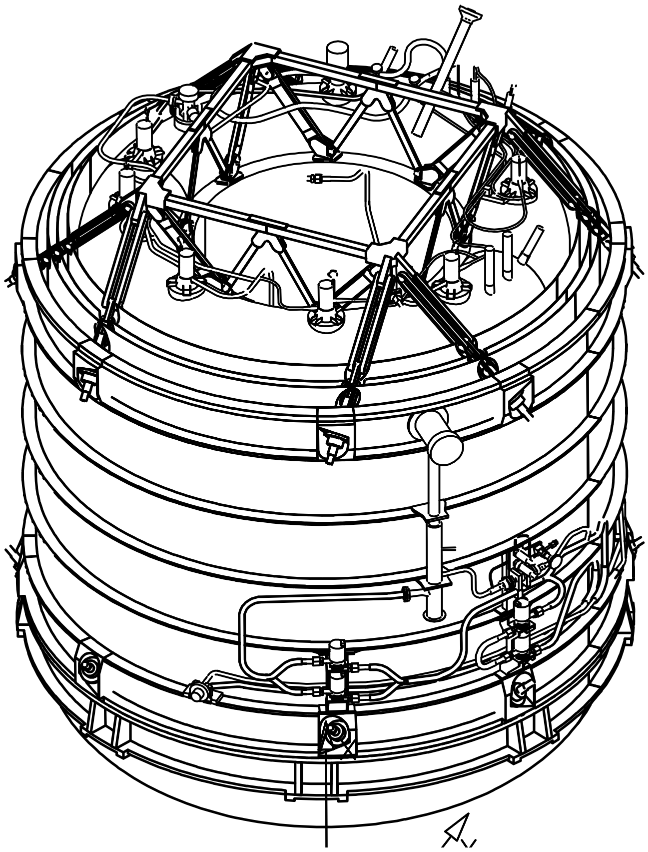


Figure 6-3: ISO QM lower structure

6.2.1.2 Modified parts/components

The internal He Tubing system is adapted to the new EQM He flow schematics shown in Figure 6-13.

The adaptation is focussed on the re-routing of the internal He - tubing system with update of the allocation concerning the He-components mounted on the He-II Tank.

6.2.1.3 New parts/components

The following components will be designed for EQM needs:

1. CVV intermediate ring
2. CVV upper bulkhead
3. Upper thermal shields
4. OB Fixation
5. Auxiliary Tank AXT
6. SVM simulator structure

<u>CVV Intermediate Ring:</u>

This component is part of the EQM external structure with following main mechanical interfaces:

- CVV cylinder - flange I/F with vacuum sealing (screw pattern to be used from ISO QM)
- CVV upper bulkhead - flange I/F with vacuum sealing similar to CVV cylinder
- 63 electrical feedthroughs with 100 pins (size and quantity TBC.)
- He – ventline wit V 512 (TBD)

This ring has been implemented mainly for the integration of the large number of electrical feedthroughs located in the level of the upper tank suspension on PFM side.

The intermediate ring shall be manufactured out of the same aluminium alloy as for all EQM/PFM CVV parts according to the procurement spec. (HP-2-ASED-PS-0002).

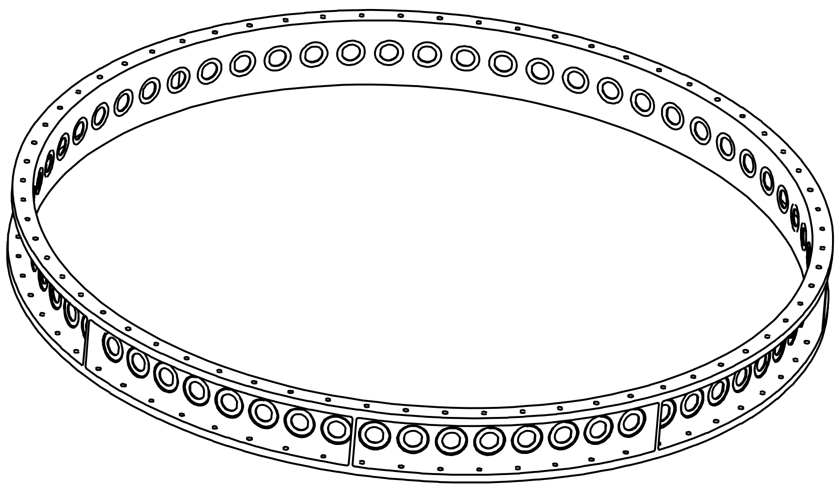


Figure 6-4: EQM CVV Intermediate Ring principle design

<u>CVV Upper Bulkhead:</u>

The overall dimensions of the intermediate ring together with the upper bulkhead shall be in accordance with the overall dimensions of the PFM upper bulkhead.

Following main mechanical interfaces are used for the EQM:

- CVV intermediate ring - flange I/F with vacuum sealing similar to CVV cylinder
- Beam entrance (cover I/F not used)
- Cooled plate interface
- MGSE interface
- LOU interface with optical windows
- Filling port
- Pumping port (2 ports)

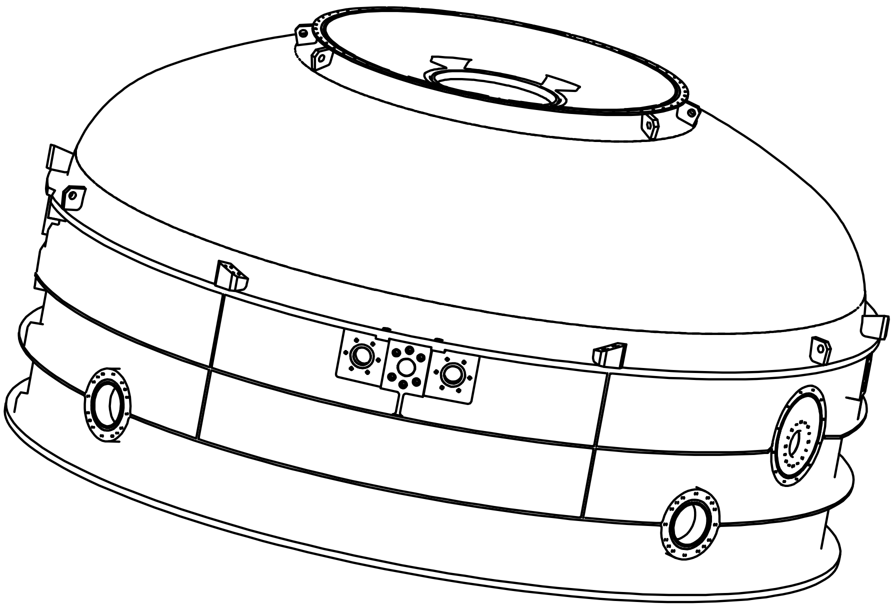


Figure 6-5: EQM CVV Upper Bulkhead

Upper Thermal Shields:

The upper shields shall be in accordance with the upper thermal shields of the PFM. For assembly reasons, the shields need to be split at the level of the intermediate ring. At this level a screwed interface shall be integrated similar to the screwed interface at the cylinder level.

Following main interfaces need to be taken into account:

- Cylindrical shields
- Filling port
- Pumping port (safety valve)
- Beam baffle
- Optical windows (straylight baffle TBD)
- Additional ventline
- Temperature sensors

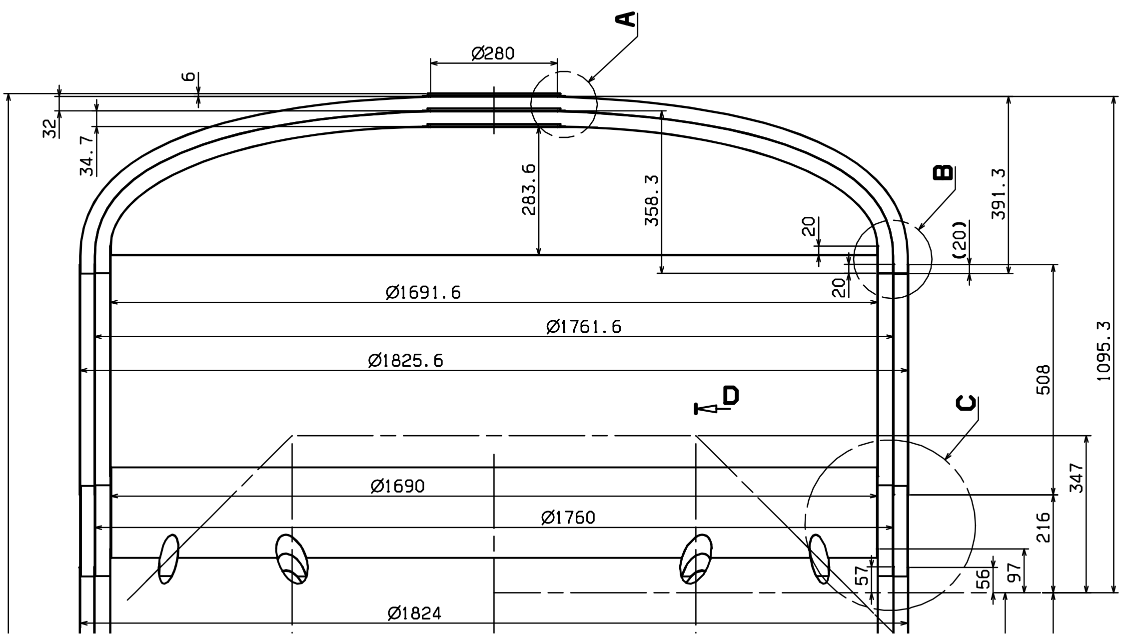


Figure 6-6: Upper Thermal Shields

Optical Bench (OB) - Fixation:

The interface of the Herschel Optical Bench to the ISO EQM spatial framework shall be adapted in the following way:

The aluminium based Herschel Optical Bench will be mounted inside the PFM on a spatial framework made from aluminium alloy. This is different to the ISO spatial framework, which used a CFC main frame and titanium corner brackets. The fixation of the flight representative OB on the EQM (ISO QM) spatial framework therefore has to be designed for thermal displacements in the range of 2,5mm from the x-axis down to 10K operating temperature.

The present fixation concept is based on the design of the PFM with four blades and a screwed interface on OB side, but a clamp interface on spatial framework side. The final material and the detailed design layout is to be defined.

A preliminary design is shown in the following figure:

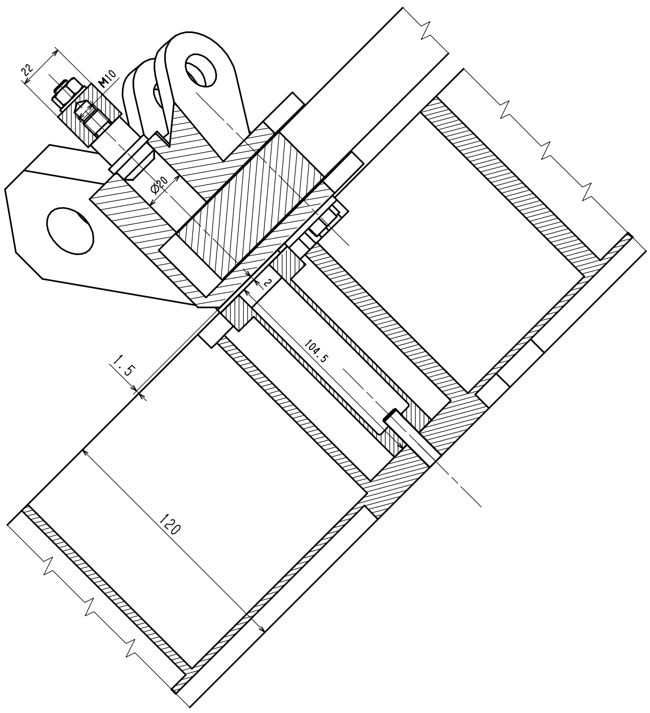


Figure 6-7: Principle OB fixation for EQM

Auxiliary Tank (AXT)

The AXT is a major part of the Herschel-EQM and shall serve as the reservoir for the liquid helium (He II) foreseen to provide the cooling power for the actively cooled components on the optical bench.

The principal Herschel-AXT design, also showing the fixation is given in the figure below:

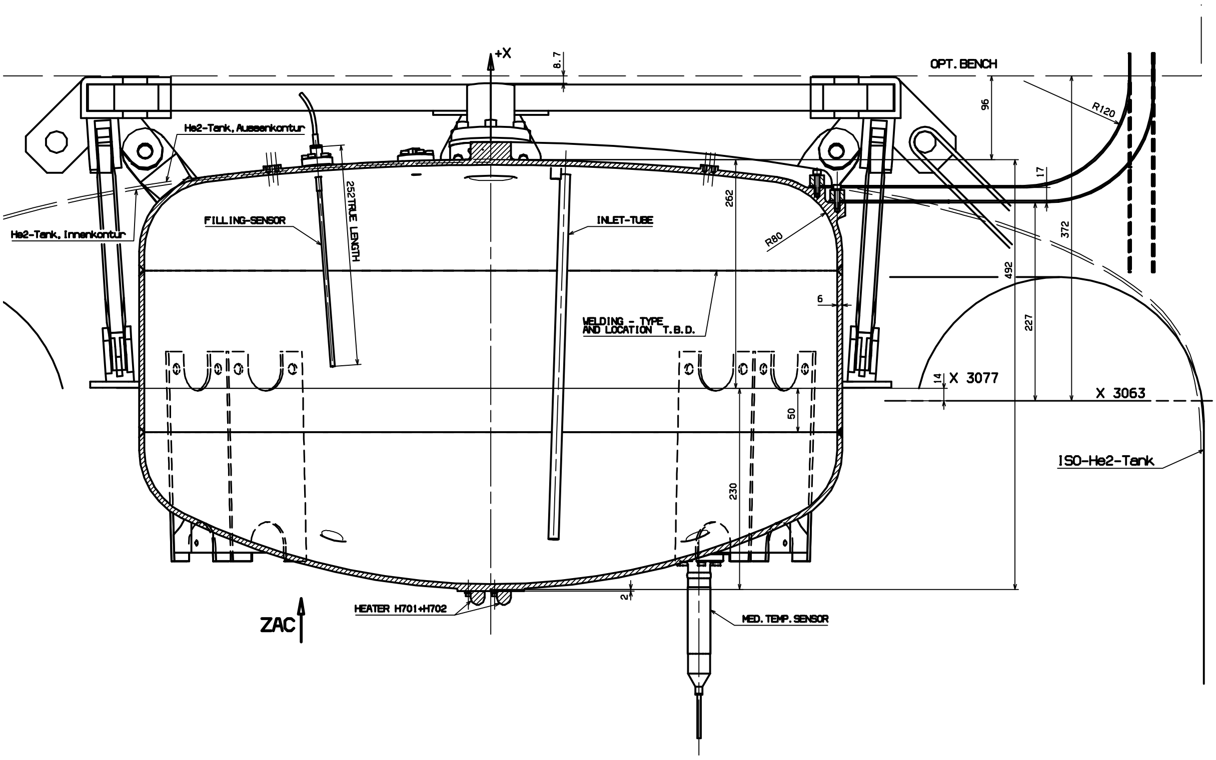


Figure 6-8: AXT principle design

The AXT is attached to the Upper Flange of the ISO-Main Tank using the existing 8 CFC support blades which were formerly foreseen to support the ISO-Main Baffle. This Baffle is no longer used and will be removed. The supporting blades will be adapted to the correct length to position the AXT for Herschel EQM in the planned height.

The objective of these supporting blades is two fold:

- mechanical fixation of the AXT to the Upper Flange of the Main Tank
- Thermal isolation from the Main Tank as far as the cross sections of the supports blades allow

6.2.2 SVM Simulator for Warm Units

6.2.2.1 Conceptual description

The EQM/SVM simulator is a structure to support the instrument CQM warm units (WU) during the EQM test program. The SVM simulator is a non flight item. A major step in the EQM test program is a radiated (TBC) EMC test with the EQM together with the SVM simulator. To allow representative EMC predictions for the PFM, certain conformities (EMC aspects) between the EQM/SVM simulator and the PFM/SVM are requested. Basic conformities will be as follows:

- EQM/SVM simulator position in PLM X-direction identical as for PFM
- identity of the SVM structure (EMC aspects) w.r.t. basic dimensions and materials
- routing and fixation of the external instrument harness
- configuration and routing of the waveguides
- as far as possible placement of the warm units
- as far as possible configuration and dimension of the warm units

Stability of the structure must allow tilting of the EQM together with the SVM and WUs during tests. Relative shift of the coordinate system between SVM and PLM of 60 mm in +Z direction shall be regarded. Dismounting of the WU boxes during testing must be possible, also if the EQM is mounted in the test dolly. Mobility of the equipped SVM simulator is requested.

6.2.2.2 Design description

The SVM simulator is an octagonal structure and consists of the following major parts:

- Two centering rings connected by a self-supporting aluminum profile structure
- 8 I/F clamps to mount the SVM simulator to the PLM
- Shear plates to ensure high rigidity of the structure
- 8 lateral panels with aluminum face-sheets and inserts to accommodate the WUs
- segmented (easiness for integration and accessibility to SVM equipment) upper closure panel to provide support for the harness and harness connector brackets
- detachable set of wheels mounted at the bottom side of the structure to move the SVM simulator without PLM

SVM simulator technical details and dimensions are shown in the drawings on the next pages.

SVM simulator equipment

The following WUs are foreseen to be mounted to the structure:

No.	Warm Unit	No. of Units	Total Weight of Units [kg]	Remark
1	PACS	TBD	TBD	
2	SPIRE	TBD	TBD	
3	HIFI	TBD	TBD	

Table 6-1: Warm Units

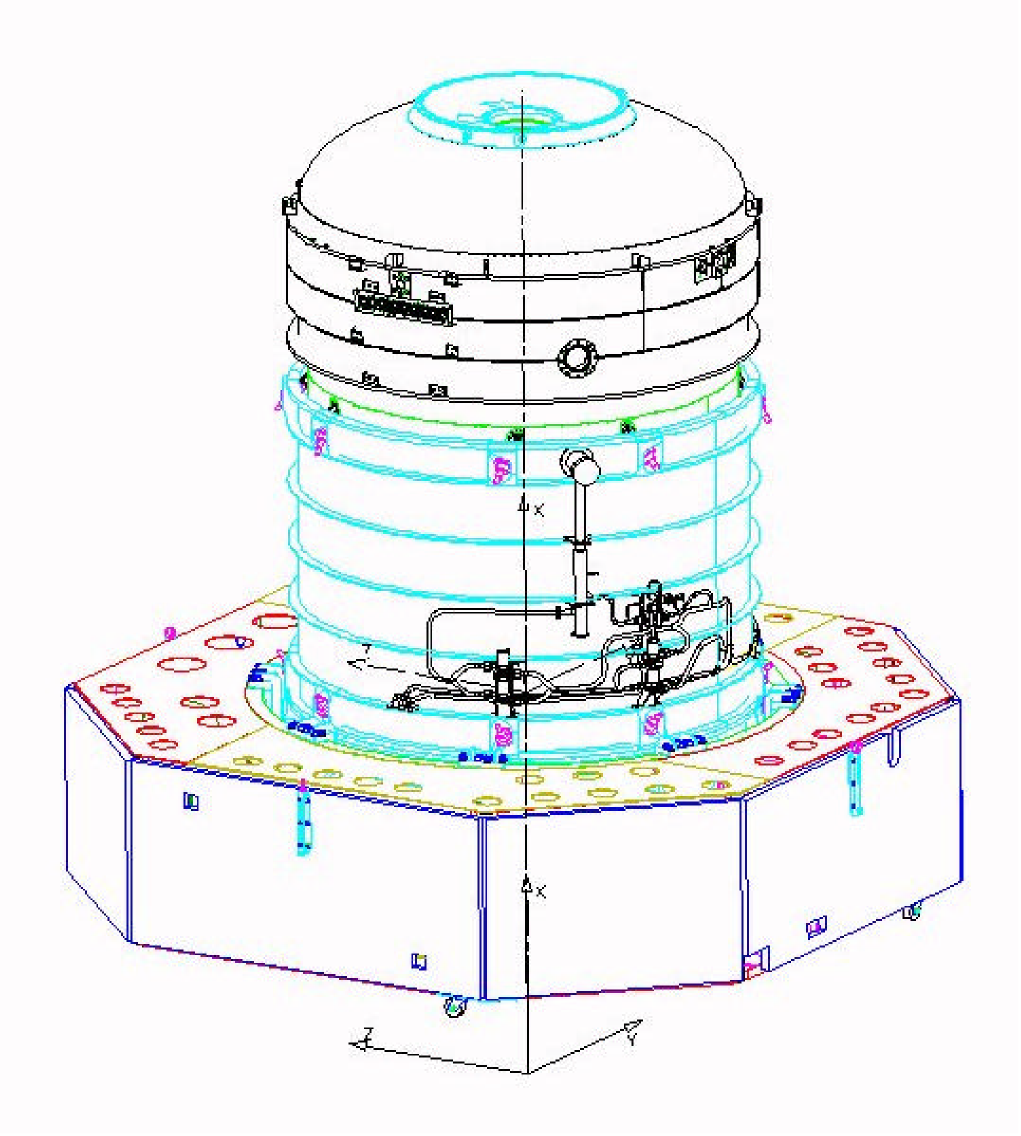


Figure 6-9: 3D view of SVM simulator with PLM/EQM

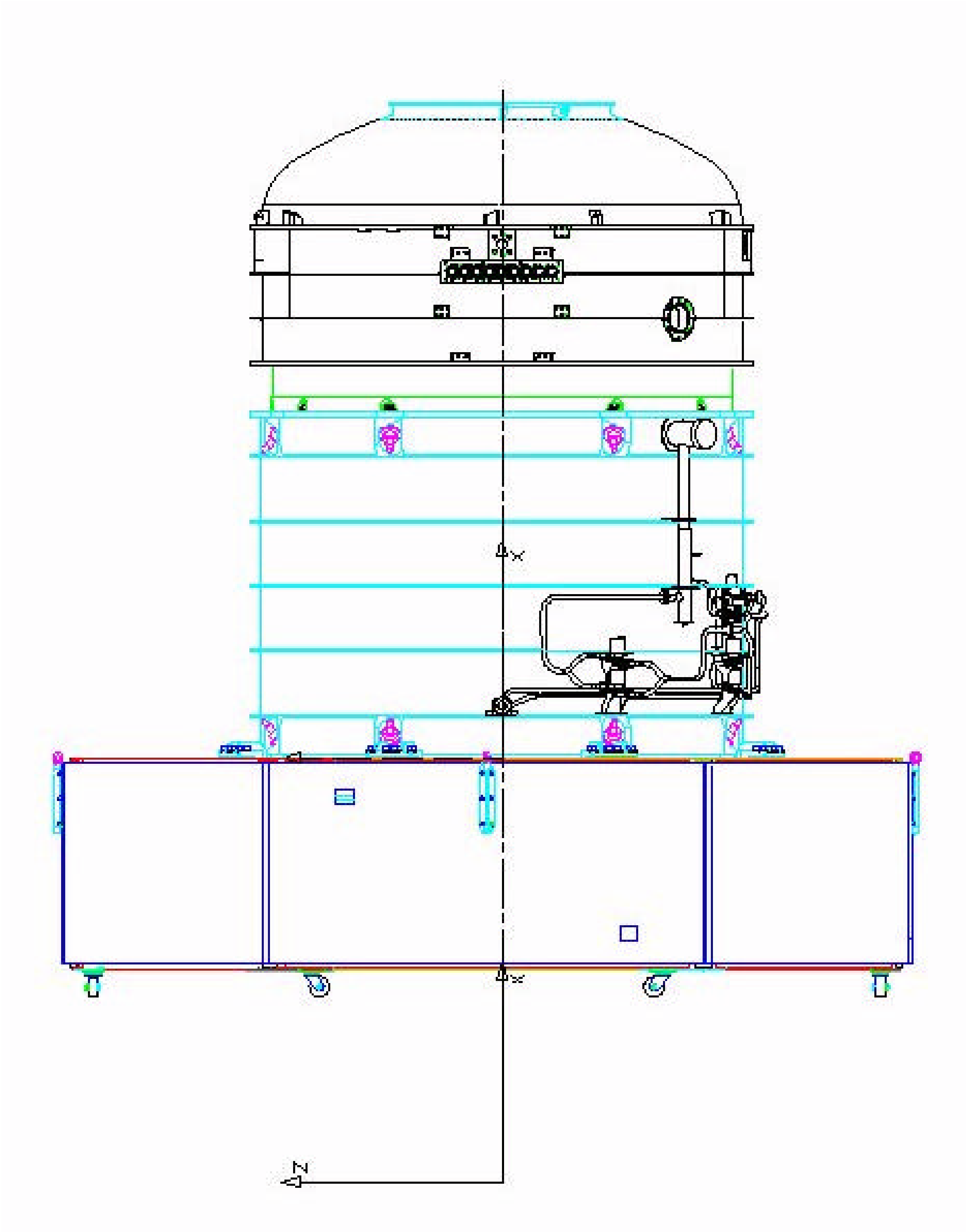


Figure 6-10: Side view SVM simulator with PLM/EQM

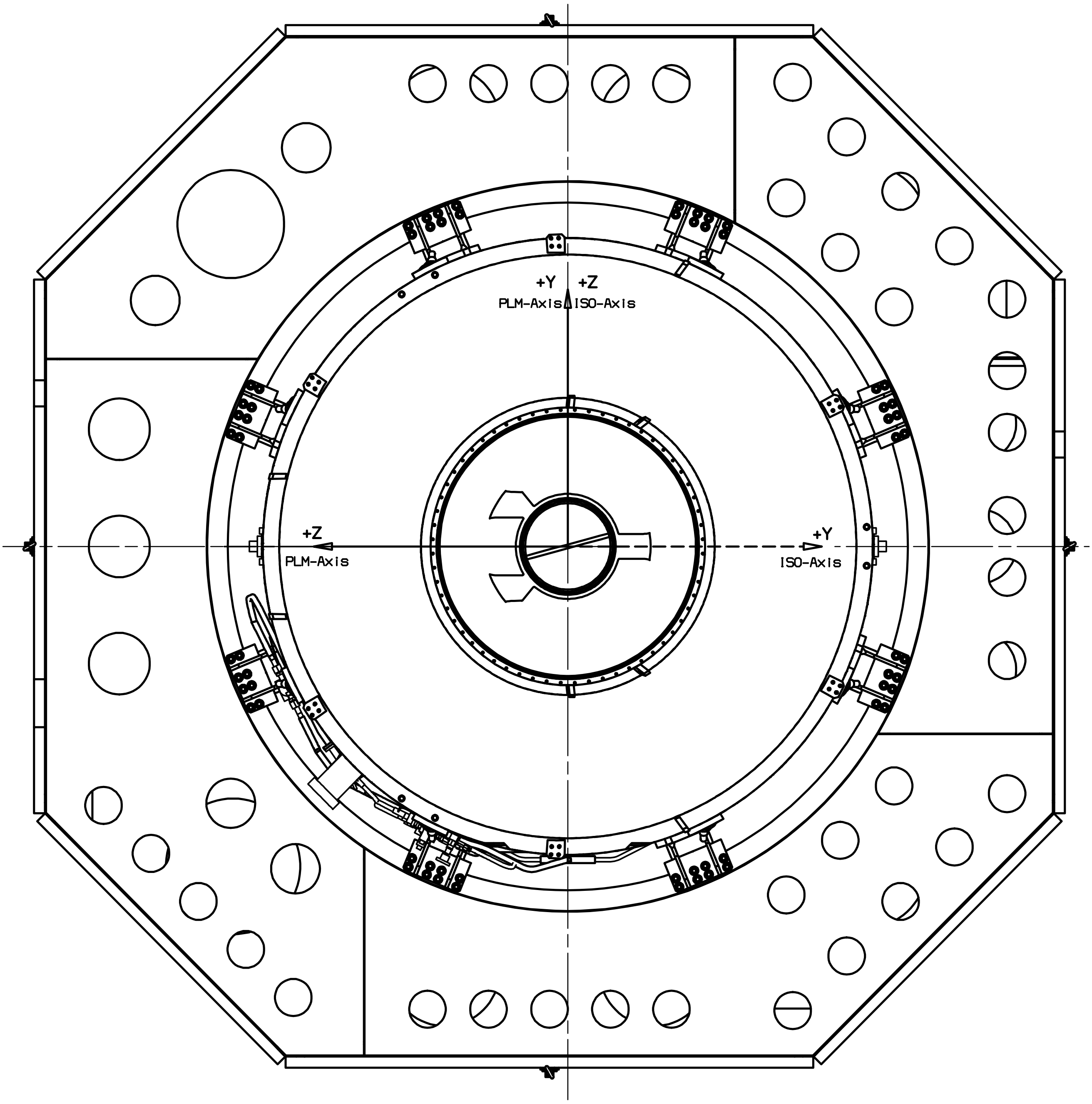


Figure 6-11: Top view of SVM Simulator

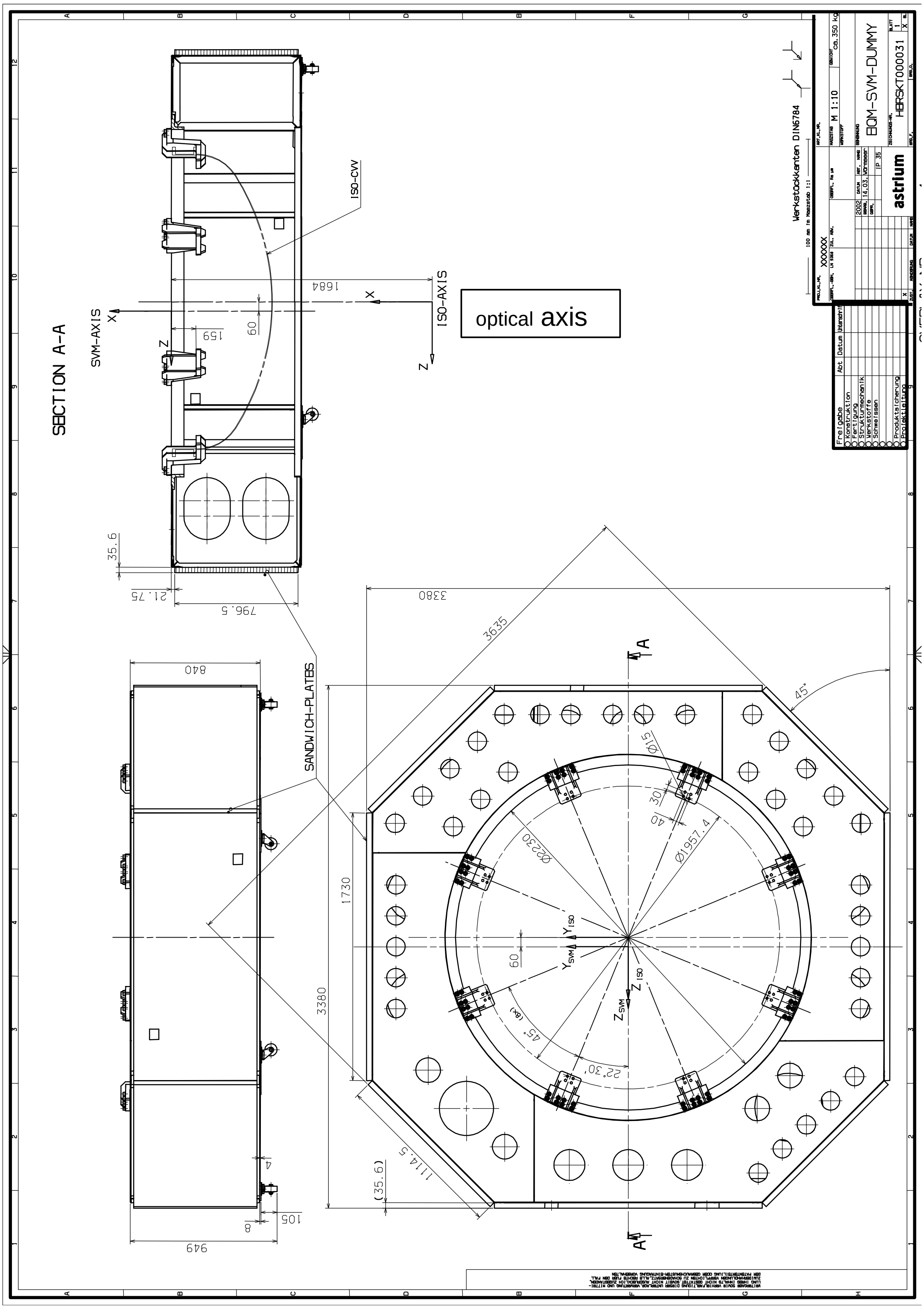


Figure 6-12: Basic dimensions of SVM simulator

6.2.3 He S/S Thermal

In order to fulfil the above given requirements for instrument testing the EQM He subsystem will be realised as given in figure below.

Main characteristics of this concept are as follows:

- The main tank will be filled with He-I at 4.2 K. For instrument testing it will be used to cool down the shields only (bypassing the optical bench) to nearly orbital temperature, i. e. approx. 30 K at the innermost shield. This temperature condition will be achieved by heating the main tank accordingly. The main tank is venting via V502 to ambient environment
- The aux. tank will be located within the upper part of the torus main tank. The shape of the upper part of the aux. tank will be similar to the shape of the Herschel EPLM main tank which will support a EPLM representative thermal coupling by Cu straps to the instruments
- The fixation of the aux. tank to the main tank will be realised by isolated CFK blades (shortened ISO baffle suspension)
- The auxiliary tank will be used as a He-II tank, to cool down the optical bench with the required flight representative mass flow of approx. 2.2 mg/sec. This will be realised by pumping at the new additional aux. tank ventline that is connected with the Herschel payload ventline. The adjustment of the required mass flow will be done by heating of the aux. tank and throttling the pumping capacity

6.2.4 Thermal Insulation

The thermal insulation of the ISO QM will be used and completed to Herschel EQM needs with adequate quality standards.

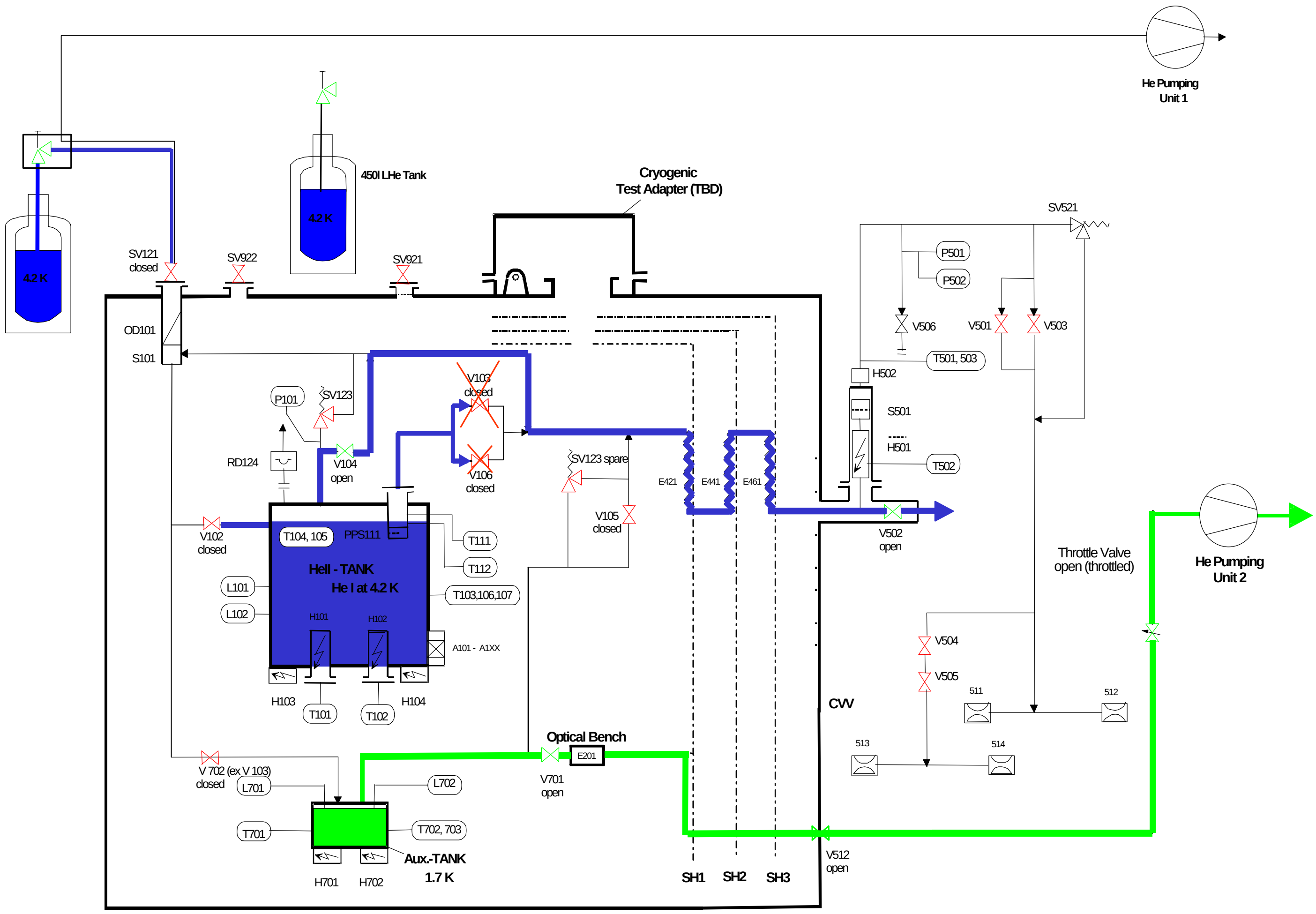


Figure 6-13: EQM He Flowchart

The valves V103 and V106 will be deactivated, V103 will be used as V701.

6.2.5 Electrical S/S

6.2.5.1 CCU

Integration and Operation of the CCU is nominally not foreseen during the HERSCHEL EQM Program. The complete Cryo Control Instrumentation will be connected to the EQM Cryo SCOE. From this Cryo SCOE the Instrumentation will be controlled and monitored, special functions of the CCU (e.g. DLCM) are not necessary for the EQM and therefore not considered. Instrumentation Components which are representative of the HERSCHEL FM (e.g. OB) are accessible via the relevant CCH on the FM comparable Interface Bracket (SVM Interface Bracket) and can be disconnected according to the FM from the SCOE and operated from the CCU if requested, see sketch below.

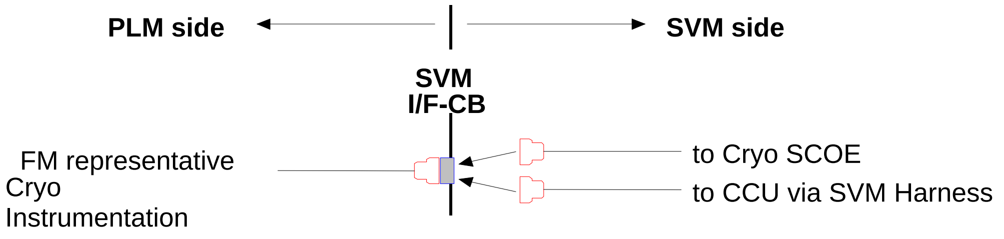


Figure 6-14: SVM Interface Bracket

6.2.5.2 Cryo Control Instrumentation

6.2.5.2.1 Cryo Control Instrumentation Overview

The HERSCHEL EQM and the respective cryo control instrumentation is a composition of the following main groups:

- the former ISO QM
- HERSCHEL FM representative items
- New special HERSCHEL EQM items.

The Cryo Control Instrumentation of these main groups delivers:

- sensor information to monitor the status of the Cryostat like
  - temperature
  - pressure
  - liquid level
- control of the Cryostat status by means of proper sensor outputs like
  - heaters
  - valves

6.2.5.2.2 Functional Allocation

Considering the use of different main groups and the functional allocation of the cryo instrumentation components the cryo control instrumentation itself can be split into the following groups:

Herschel ⇒ all components which are representative to FM

ISO ⇒ components used from the former ISO EQM

EQM ⇒ components for the new special EQM Subsystems

FM test ⇒ components installed on representative FM subsystems/parts, used during EQM program only for test and verification.

To deliver the required information about the operational status of the Cryostat, the Cryo Control Instrumentation itself is subdivided in several Cryo Instrumentation Components (CIC) subdivided into the following main categories:

- Heater
- Liquid Level Sensor
- Pressure Sensor
- Temperature Sensor
- Valve
- Vacuum Gauge

6.2.5.2.3 Mechanical Allocation

The cryo instrumentation components are allocated to the main groups of the EQM which are further subdivided into parts/subsystems. In the following table the distribution to these parts and the number of installed components is given.

main group	Parts/ Components	Mounting Location	Category						Total	Remark
			Electrical Latch Valve	Heater	Liquid Level Sensor	Pressure Sensor	Temperature Sensor	Vacuum Gauge		
ISO EQM	Shield Group	1st Shield (innermost)					3		3	
		2nd Shield					3		3	
		3rd Shield					3		3	
	CVV	CVV					2	2	4	
		Main LHe Tank	3	7	2	1	9		22	
		GHe S/S, outside CVV	4	1		1	2		8	
	Support Structure	Upper spatial framework					2		2	Sensors representative to FM
		Harness					8		8	
		Support Straps					8		8	
Herschel FM	OB	Bench					49		49	
		SPIRE FPU					18		18	
		Instrument Shield					3		3	
	CVV external parts	BOLA					2		2	
		LOU					5		5	
	Upper Cone Shield Group	1st Shield (innermost)					2		2	
		2nd Shield					2		2	
		3rd Shield					2		2	
New EQM	Auxiliary He-Tank		2	4	2	1	8		17	
	Cooled Plate			6			16		22	
		Total:	9	18	4	3	147	2	183	

Table 6-2: EQM Cryo Instrumentation: Components Mounting Position, Component Types

The cryo instrumentation main categories as described in para. 6.2.5.2 consists of several single components. These single components are adapted to their application and the relevant operational conditions. The following table gives an overview of the individual type and number of components intended for installation in the Herschel EQM.

Category	Component type	Number of component	Connected to		
			CCU	EGSE	EXT
Electrical Latch Valve	Electrical Latch Valve	9		9	
Heater	DLCM Heater brass, 50Ω cold	2		2	
	Depletion Heater high load resistor 50Ω ambient; 46Ω at 4.2K	4		4	
	Valve Heater foil, R=90Ω	5		5	
	GHe external depletion heater resistance 3.8Ω	1		1	
	Type of Cooled plate Heater = TBD	6		6	
Liquid Level Sensor	super-conducting probe	4		4	
Pressure Sensor	Main He-II tank pressure sensor BHL-4201-01	1		1	
	GHe external pressure sensor BHL 4105-00	1		1	
	Auxiliary tank Pressure Sensor = TBD	1		1	
Temperature Sensor	C10	5		5	
	C100	71	30	71	
	PT500	23		23	
	PT1000	47	10	47	
	Thermoelement NiCrNi	1		1	
Vacuum Gauge	Penning Gauge	2			2
	Total number:	183	40	181	2

Table 6-3: Component type Overview

6.2.5.2.4 *Electrical Connection*

Each of the individual Cryo Instrumentation Components (CIC) is electrically connected to the EQM CCH (Cryostat Control Harness). Commanding, Readout and Control of the CICs will be performed by the EGSE (Cryo SCOE). If requested, the Herschel representative instrumentation components can be connected to a CCU. Readout of the vacuum gauges will be performed by their own electronics, readout can be sent via an analogue output to the Cryo SCOE for monitoring and data storage. Table 6-4 also gives an overview of the electrical connections of the components.

6.2.5.2.5 *Summary Overview*

The following figure shows a summary of all sensors, the following table gives a summary of the cryo instrumentation components, the functional location, types, group allocation and the number.

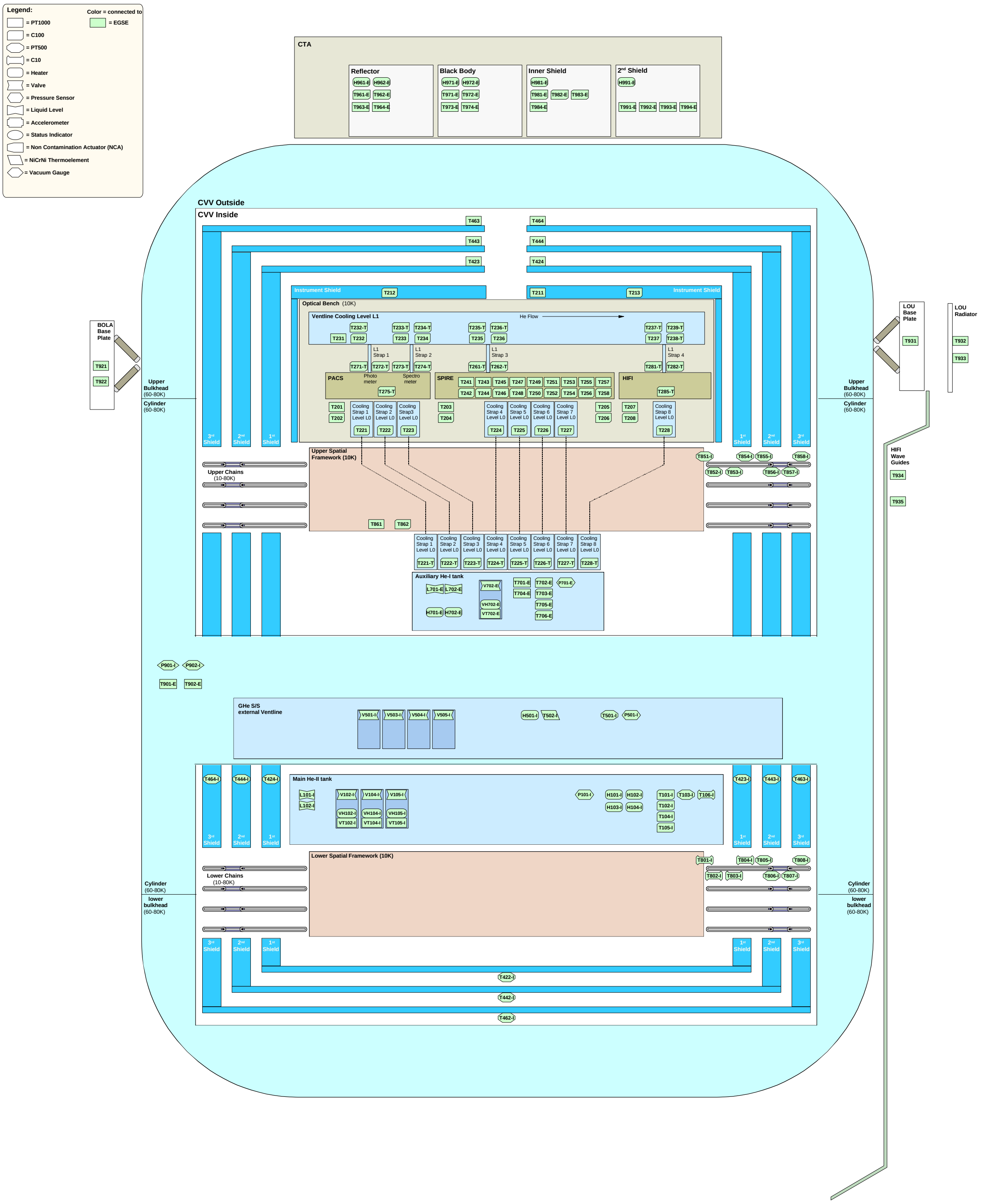


Figure 6-15: EQM Cryo Instrumentation Components Allocation Overview

Component Category ⇒		Temperature Sensors					Vacuum Gauge	Pressure Sensors			Heater					Valves	Liquid Level Sensors	
Functional location	Group Allocation	C10	C100	PT500	PT1000	Thermo-element NiCrNi	Penning Gauge	Main He-II tank pressure sensor BHL-4201-01	GHe external pressure sensor BHL-4105-00	Auxiliary tank Pressure Sensor = TBD	DLCM Heater brass, 50Ω cold	GHe external depletion heater resistance 3.8Ω	Valve Heater foil, R=90Ω	Depletion Heater high load resistor 50Ω, ambient 46Ω at 4.2K	Type of Cooled Plate Heater = TBD	Electrical Latch Valve	super-conducting probe	Total
OB	Herschel		20		6													26
	ISO																	
	EQM																	
	FM Test		26															26
SPIRE FPU	Herschel		9		9													18
	ISO																	
	EQM																	
	FM Test																	
1st Shield (innermost)	Herschel				2													2
	ISO			3														3
	EQM																	
	FM Test																	
2nd Shield	Herschel				2													2
	ISO			3														3
	EQM																	
	FM Test																	
3rd Shield	Herschel				2													2
	ISO			3														3
	EQM																	
	FM Test																	
Main LHe Tank	Herschel																	
	ISO	1	4	1				1			2			2		3	2	16
	EQM				3								3					6
	FM Test																	

Component Category ⇒		Temperature Sensors					Vacuum Gauge	Pressure Sensors			Heater					Valves	Liquid Level Sensors	Total
Functional location	Group Allocation	C10	C100	PT500	PT1000	Thermo-element NiCrNi	Penning Gauge	Main He-II tank pressure sensor BHL-4201-01	GHe external pressure sensor BHL-4105-00	Auxiliary tank Pressure Sensor = TBD	DLCM Heater brass, 50Ω cold	GHe external depletion heater resistance 3.8Ω	Valve Heater foil, R=90Ω	Depletion Heater high load resistor 50Ω, ambient 46Ω at 4.2K	Type of Cooled Plate Heater = TBD	Electrical Latch Valve	super-conducting probe	
CVV	Herschel				7													7
	ISO																	
	EQM				2		2											4
	FM Test																	
GHe S/S, outside CVV	Herschel																	
	ISO			1		1			1			1				4		8
	EQM																	
	FM Test																	
Upper spatial framework	Herschel		1		1													2
	ISO																	
	EQM																	
	FM Test																	
Harness (on straps)	Herschel																	
	ISO	4		4														8
	EQM																	
	FM Test																	
Support Straps	Herschel																	
	ISO			8														8
	EQM																	
	FM Test																	
Auxiliary He-Tank	Herschel																	
	ISO															2	2	4
	EQM		4		4					1			2	2				11
	FM Test																	

Component Category ⇒		Temperature Sensors					Vacuum Gauge	Pressure Sensors			Heater					Valves	Liquid Level Sensors	
Functional location	Group Allocation	C10	C100	PT500	PT1000	Thermo-element NiCrNi	Penning Gauge	Main He-II tank pressure sensor BHL-4201-01	GHe external pressure sensor BHL-4105-00	Auxiliary tank Pressure Sensor = TBD	DLCM Heater brass, 50Ω cold	GHe external depletion heater resistance 3.8Ω	Valve Heater foil, R=90Ω	Depletion Heater high load resistor 50Ω, ambient 46Ω at 4.2K	Type of Cooled Plate Heater = TBD	Electrical Latch Valve	super-conducting probe	Total
Cooled plate	Herschel																	
	ISO																	
	EQM		7		9										6			22
	FM Test																	
total number of Herschel:			30		29													59
total number of ISO:		5	4	23		1	2	1	1		2	1		2		9	4	55
total number of EQM:			11		18					1			5	2	6			43
total number of FM Test::			26															26
Total:		5	71	23	47	1	2	1	1	1	2	1	5	4	6	9	4	183

Table 6-4: EQM Cryo Instrumentation Components Type and Allocation Overview

6.2.5.2.6 Cryo Control Instrumentation Development Program

6.2.5.2.6.1 Herschel EQM Temperature Sensor Configuration

The temperature sensors in the Herschel EQM are composed of :

- ISO used temperature sensors, mounted at ISO-structure parts, actually used in the Herschel EQM
- New Herschel temperature sensors, mounted at Herschel specific structure areas.

The ISO sensors in the Herschel EQM are Rosemount Platin Pt500– and Allen Bradley C10 and C100 carbon sensor types.

Due to increased accuracy in temperature measurement for Herschel, the C10 carbon sensors have been replaced by C100 and the Pt500 Platin Sensors have been replaced by Pt1000 (Rosemount-Type)

Another advantage of the C100 is the lower power dissipation than the C10. The excitation current of the C10 sensor of 100µA (C100: 10µA) generates a large amount of dissipated power in the harness.

To reduce the inaccuracy of the Pt500 temperature measurement in the area between 13 and 20 K the Pt500 will be replaced by a Pt1000. (Higher Voltage output)

The new Herschel temperature sensors Pt 1000 and C100 will be mounted/glued in one aluminium sensor housing, mechanically identical for both sensor types. This housing is designed for reliable mechanical/thermal fixation of the sensor at the required temperature measurement area by screws and for easy electrical connection of the excitation current and sensor signal via connector. Depending on the mechanical condition of the temperature measurement area, some temperature sensors may be glued directly at those areas because the sensor housing cannot be screwed or is not able to contact the specific measurement point . E.g. PPS, DLCM, Tubing, Thermal straps, Valve Body.

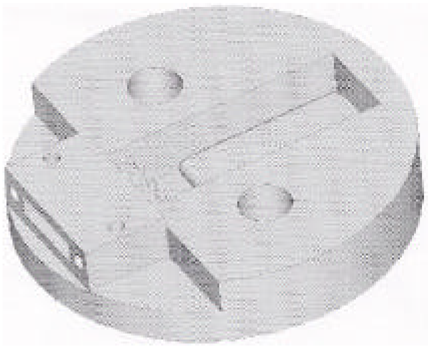


Figure 6-16: Concept of the new Herschel Temperature Sensor Housing.

A modified/improved concept is under design.

Herschel Temperature Sensors - Accuracies and Calibration Groups									
	System Requirements		**Accuracy w.r.t 15µV Limit ***		**Sensor Calibration Requirements**				
Meas. Area/ Meas-Mode	**Temp. Range**	**Accuracy**	**Temp. Range**	**Readout-Accuracy**	**Sensor Type**	**Temp. Range**	**Accuracy**	**Calibration Group**	
DLCM, PPS	1,5K -2,2K 1,6K-1,8K	+/- 10mK rel.+/-0,25mK	1,5K -2,2K 1,6K-1,8K	+/- 10mK rel.0,25mK (with C100)	**C100**	1,5K -10K 1,6K-1,9K	+/-10mk <1mK	**Cal. Group1** 1,5K to 20K - C100 -	**C100**
Level 0 Cooling Straps	1,5K -2,2K 1,7K-1,9K	+/- 10mK rel.+/-0,25mK	1,5K -2,2K 1,7K-1,9K	+/- 10mK rel.0,25mK (with C100)		10-20K	+/-(50-100) mK		
Level 1 (Ventline)	2K-10K	+/-10mK	2K-6K 6-10K	+/- 10mK +/-(10-45)mK (withC100)					
Level 1	3K-20K	+/-100mK at 20K	3K-12K 12K-20K	+/- (10-65) mK +/- (65-500)mK (with C100)	**C100**	1,5K-15K	+/-50mK	**Cal. Group2** 1,5K to 20K	
Level 2 Opt. Bench	2K-10K 3K-20K	+/-10mK +/-100mK at 20K	2K-12K 12K-20K	+/- (10-65) mK +/- (65-500)mK (with C100)		15K-20K	+/-(50-100) mK		
Level 2 Opt. Bench	12-20K	+/-100mK at 20K	13-20K	+/- (70-25)mK (with Pt1000)	**Pt1000**	13K-20K 20K -370K	+/-50mK +/-500mK	**Cal. Group 3** 13K-20K 20K-370K Pt1000	**Pt1000**
Shields	13K -370K	+/- 1K	13K -370K	+/- (70-25)mK (with Pt1000)	**Pt1000**	13K-370	+/-500mK	**Cal. Group 4** 13K-370K Pt1000	

ISO EQM Temperature Sensors			
Sensor-Type	Temp. Range	Accuracy	Readout-Accuracy w.r.t 15µV Limit *
Pt500	13K to 370K	13K: +/- 5K 20K: +/-3K 300K:+/-1,5K	+/- 300mK
C10	1,5K -2,2K 2K-4,2K 3K-30K	10mK 50mK 0,1-1K	2,5-mK 2-15mK 6,8-1500mK
C100	see above - Herschel Accuracies		

Note: Excitation Currents

Pt500:	1mA
Pt1000:	1mA
C100:	10µA
C10:	100µA

* 15µV Limit means:
The temperature measurement inaccuracy caused by 15µV voltage measurement inaccuracy.
The amount of this failure is depending on the inclination of the R vs. T curve of the sensor.

Table 6-5: Temperature Sensors used in ISO EQM and Temperature Sensors selected for Herschel

6.2.5.2.6.2 Herschel Temperature Sensors Development Program.

The sensor housing with screw interface for mounting at the satellite structure shall be equipped with a Nanonix connector for easier integration and test performance. This sensor housing with sensor and connector shall be qualified for Herschel w.r.t.:

Mechanical requirements

The forces induced by vibration/cold vibration must not affect/destroy the

- sensor case (glass-ceramic or carbon body)
- the potting material (no particles may be emitted during thermal or mechanical stress)
- the calibration curve
- the thermal contact between sensor – potting material – sensor housing.
- the fixation of the connector

Electrical requirements

- The electrical connection of the sensor to the S/C harness via Nanonix connectors (receptacle and plug) shall be reliable during thermal and mechanical stress.

Thermal requirements

- The self-heating of the sensor (potted into the sensor housing) may not affect the measurement accuracy if the sensor is exposed to the specified excitation current.
- The thermal contact between : sensor – potting material – sensor housing – measurement area shall allow an acceptable thermal response time for temperature measurements.
- The thermal expansion coefficients of sensor case (ceramic or carbon-body), potting material and aluminium sensor shall not result in cracking of sensor body or mechanical pressure to the sensor which could falsify the calibration curve. The thermal expansion-contraction shall be reduced by “pre-ageing” (tempering by cryo cycles) of the complete sensor.

The actually required qualification flow for the Herschel Temperature Sensors in its Housing is shown below:

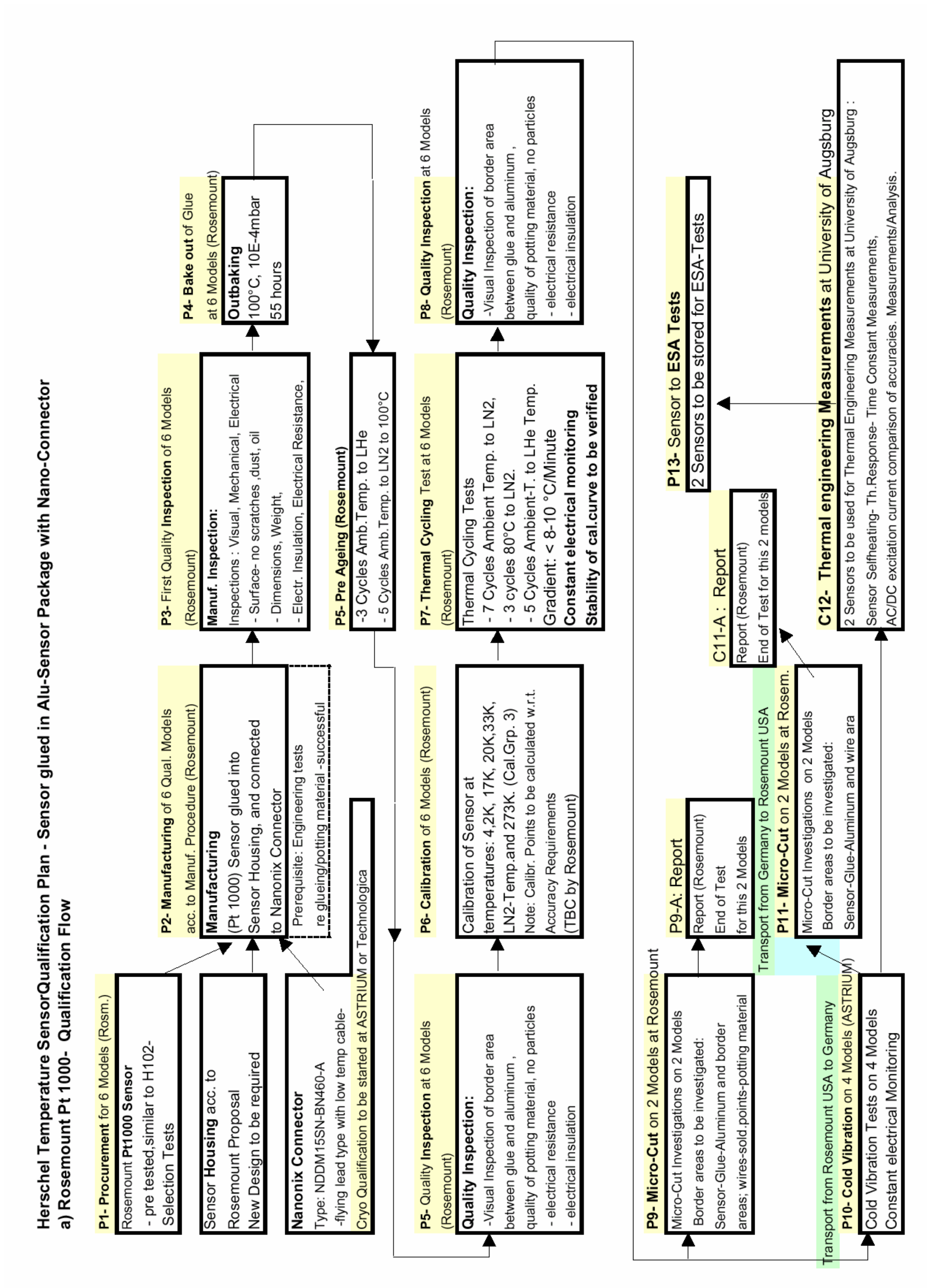


Table 6-6: Qualification plan for temperature sensors

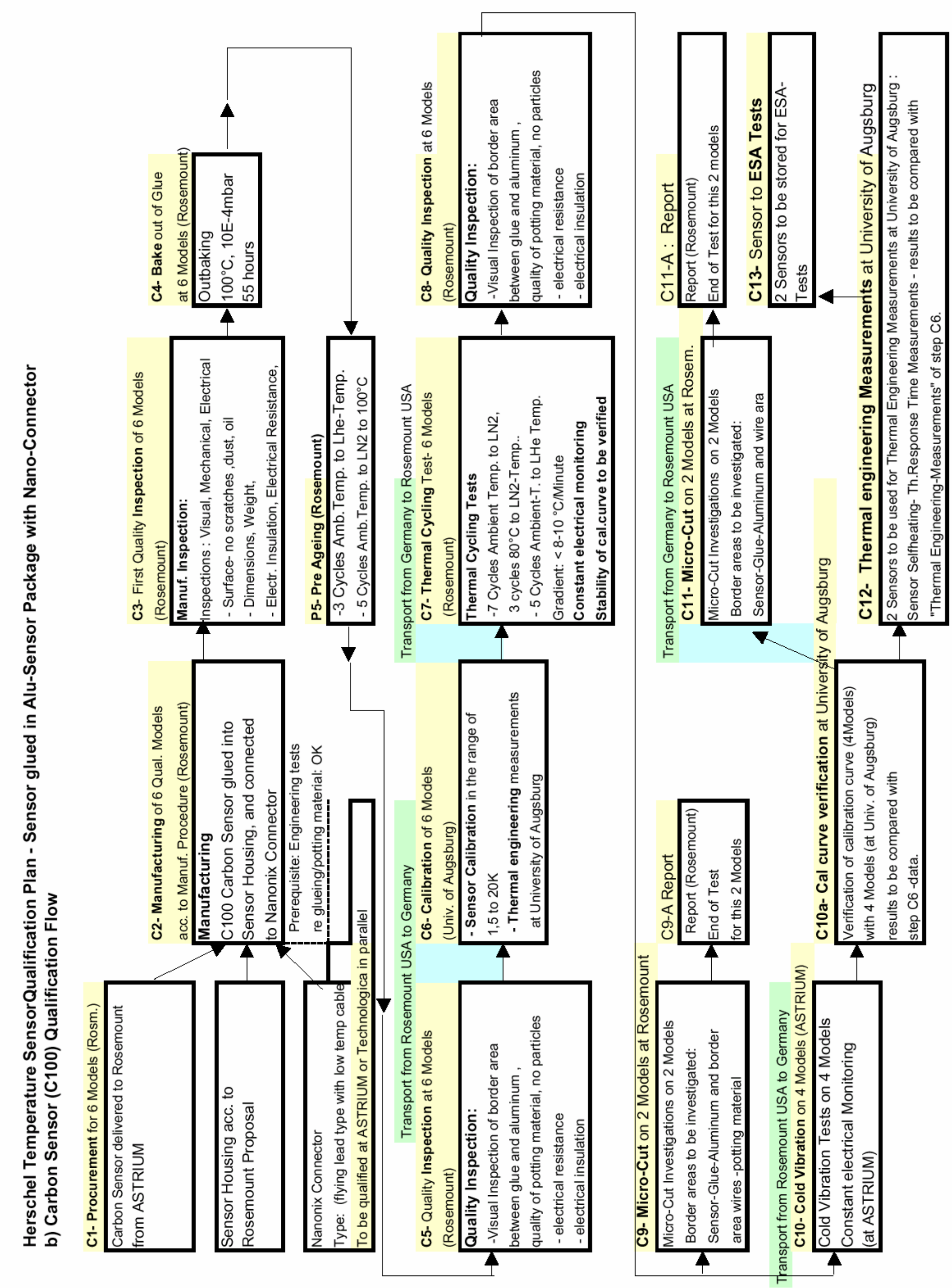


Table 6-7: Qualification plan for temperature sensors (cont´d)

6.2.5.3 Harness

6.2.5.3.1 General Overview

Corresponding to the FM, the EQM Payload Module Cryostat Harness (PCH) consists of

- the Scientific Instrument Harness (SIH)
- the Cryostat Control Harness (CCH), including external S/Ss

The Scientific Instrument Harness (SIH) provides all necessary connections between

- the Scientific Instrument Warm Units installed in the SVM Simulator
- the CVV-Units installed on outside of CVV (BOLA on cylindrical part, LOU on the upper cone)
- the Focal Plane Units (FPUs) installed in the Cryostat onto the Optical Bench.

The Cryostat Control Harness interconnects the Cryostat Control Instrumentation to the

- EGSE (Cryo SCOE)
- Cryostat Control Electronic (CCU) for FM representative instrumentation components if requested

Both harnesses, SIH completely and CCH partly, shall be FM representative.

Deviating from the FM design, the vacuum feedthroughs of the FM representative harness bundles will be installed in the CVV intermediate ring (see para. 6.2.1.3) instead of the middle and the upper ring as designed in the FM. The middle connector ring does not exist in the ISO EQM CVV cylindrical part and in the upper ring the vacuum feedthroughs can not be positioned due to the already existing holes for the old ISO harness. Compensation of the differences in the length of the harness bundles due to the different position of the vacuum feedthroughs between FM and EQM is under investigation. Harness which is already installed in the former ISO EQM will be reused as far as possible and removed if necessary.

6.2.5.3.2 *Scientific Instrument Harness (SIH)*

The Scientific Instrument Harness (SIH) installed in the EQM shall be corresponding in form and function to the SIH for the FM. Consequently, the routing of the harness bundles, fixation and thermal connections shall be according to the FM design, all the way from the optical bench up to the CVV inner side. From the CVV inner side up to the vacuum feedthroughs the bundles will be adapted, the vacuum feedthroughs themselves shall be installed in the CVV Intermediate Ring near their FM positions. The figure below gives an overview of the preliminary EQM SIH design.

Design and Development, Manufacturing and Qualification of the SIH will be performed as required for the FM Harness.

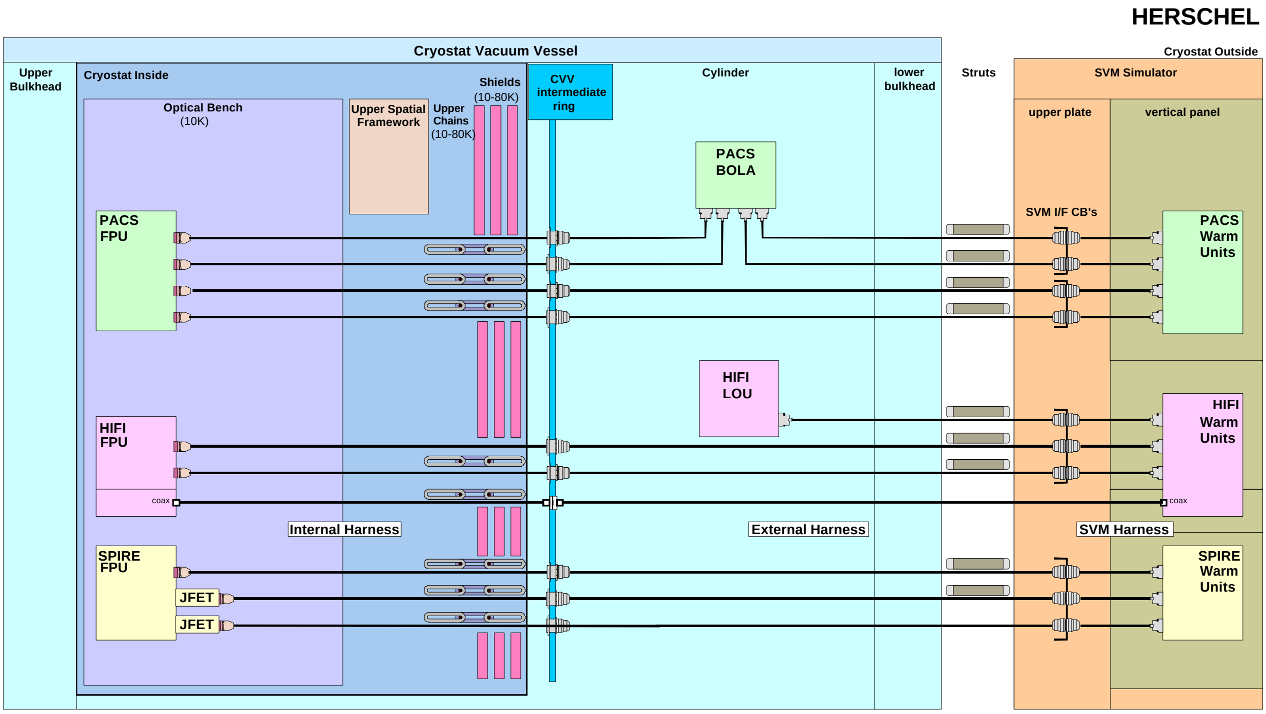


Figure 6-17: EQM SIH Preliminary Overview

6.2.5.3.3 Cryostat Control Harness (CCH)

According to the EQM cryo control instrumentation the EQM CCH is also a composition of the following main parts:

- the former ISO EQM Instrumentation Harness (Instrumentation group ISO)
- HERSCHEL FM representative CCH (Instrumentation group Herschel)
- CCH for the new special HERSCHEL EQM Subsystems. (Instrumentation group EQM test and EQM only)

The already installed former internal ISO harness will be reused as far as possible. Also the vacuum feedthroughs shall remain on their old position in the upper and lower connector ring. It is necessary to get free areas for the Scientific Instrument Harness along the straps. Relevant CCH bundles will be removed, adapted and routed alternately. All respective external harness bundles will be removed and replaced by a testharness directly connected to the vacuum feedthroughs. This establishes the electrical connection between the ISO harness I/F on the CVV and the EGSE Cryo SCOE I/F (SCOE Interface ⇒ same design as for FM).

For the HERSCHEL FM representative subsystems including instrumentation components (group Herschel)

- OB (Optical Bench) inclusive Instrument Shield
- Upper cone Shield group (1st, 2nd and 3rd shield)
- CVV external parts (BOLA baseplate, LOU baseplate and LOU waveguides)

a FM representative CCH will be manufactured and installed.

The internal CCH bundles shall be routed according to the FM design, the vacuum feedthroughs shall be installed in the CVV Intermediate Ring (see para. 6.2.1.3) near their FM positions. External CCH bundles coming from the vacuum feedthroughs and from the externally installed instrumentation components will also be routed as far as possible to FM positions up to the relevant SVM Interface Bracket mounted onto the SVM simulator. From this bracket the CCH is connected via a testharness to the Cryo SCOE. The FM representative cryo control instrumentation can also be connected to the CCU, if requested. Either a testharness or the relevant SVM harness bundles can be used. Harness bundles coming from the additional test instrumentation on OB (group EQM test), which is installed and used in the EQM only, will be separately routed from the FM bundles up to the main He-II tank, along the tank to the lower spatial framework, and to the vacuum feedthrough installed in the lower ring in an unused hole of an old ISO SIH connector. The external harness bundles will be similar to the “group ISO” harness bundles and connected directly between the vacuum feedthroughs and the EGSE Cryo SCOE I/F.

On the new EQM Subsystems

- Auxiliary He-I tank (AXT) and respective internal ventline
- Cooled plate

a newly manufactured CCH will be installed.

The Auxiliary He-I Tank internal harness bundles coming from the new tank (SST cables = TBD) will be routed from the AXT to the main He-II tank to the lower spatial framework and to the vacuum feedthrough installed in the lower ring in an unused hole of an old ISO SIH connector. The external harness bundles will be similar to the “group ISO” harness bundles and connected directly between the vacuum feedthroughs and the EGSE Cryo SCOE I/F. Design and routing of the Cooled plate harness is still TBD. The figure below gives an overview of the preliminary EQM CCH design.

Design and Development, Manufacturing and Qualification of the FM representative CCH parts will be performed as required for the FM Harness. EQM parts of the CCH will be manufactured with proper materials and manufacturing methods. The testharness will be manufactured as a standard harness.

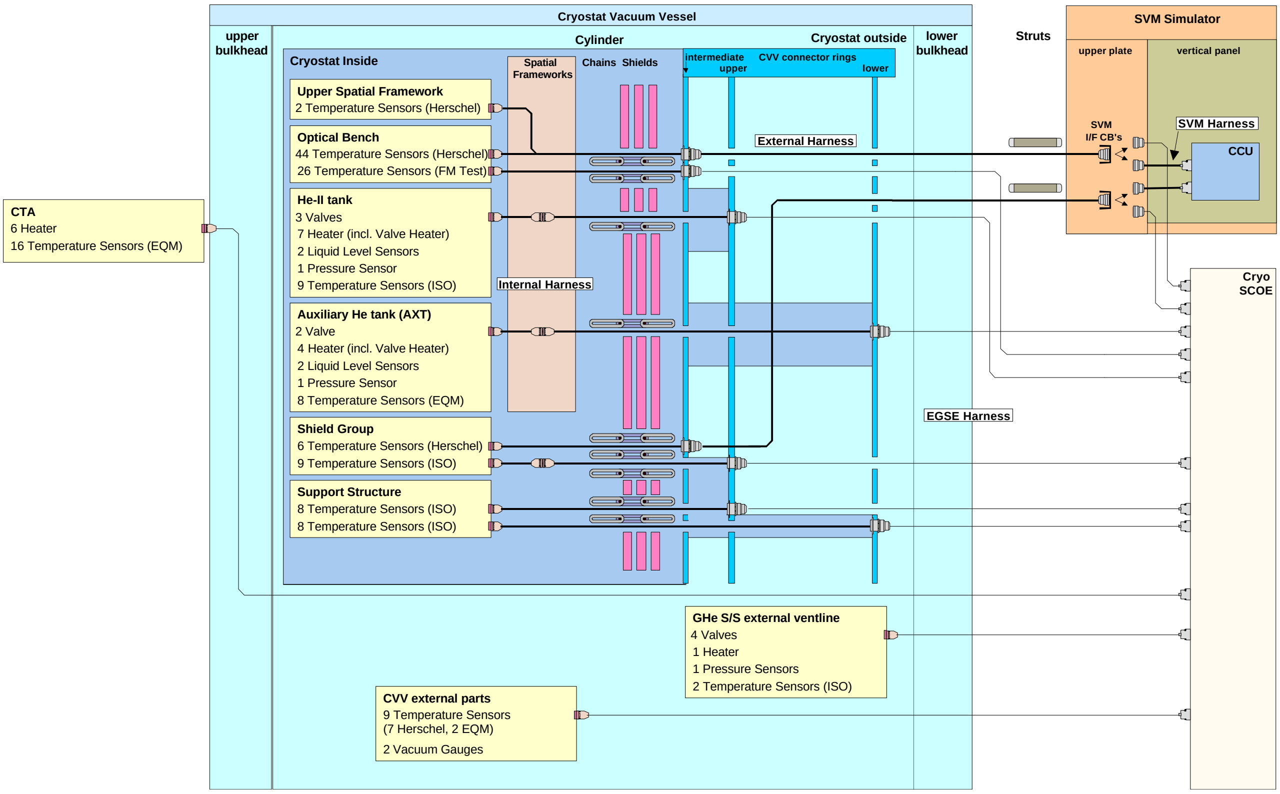


Figure 6-18: EQM CCH Preliminary Overview

6.3 EQM GSE

6.3.1 Active Cooled Plate

During the Herschel test programme the appropriate test environment shall be simulated.

For functional tests of HIFI, PACS and SPIRE instruments the correct thermal background (i.e. dark background) shall be replicated as shown below.

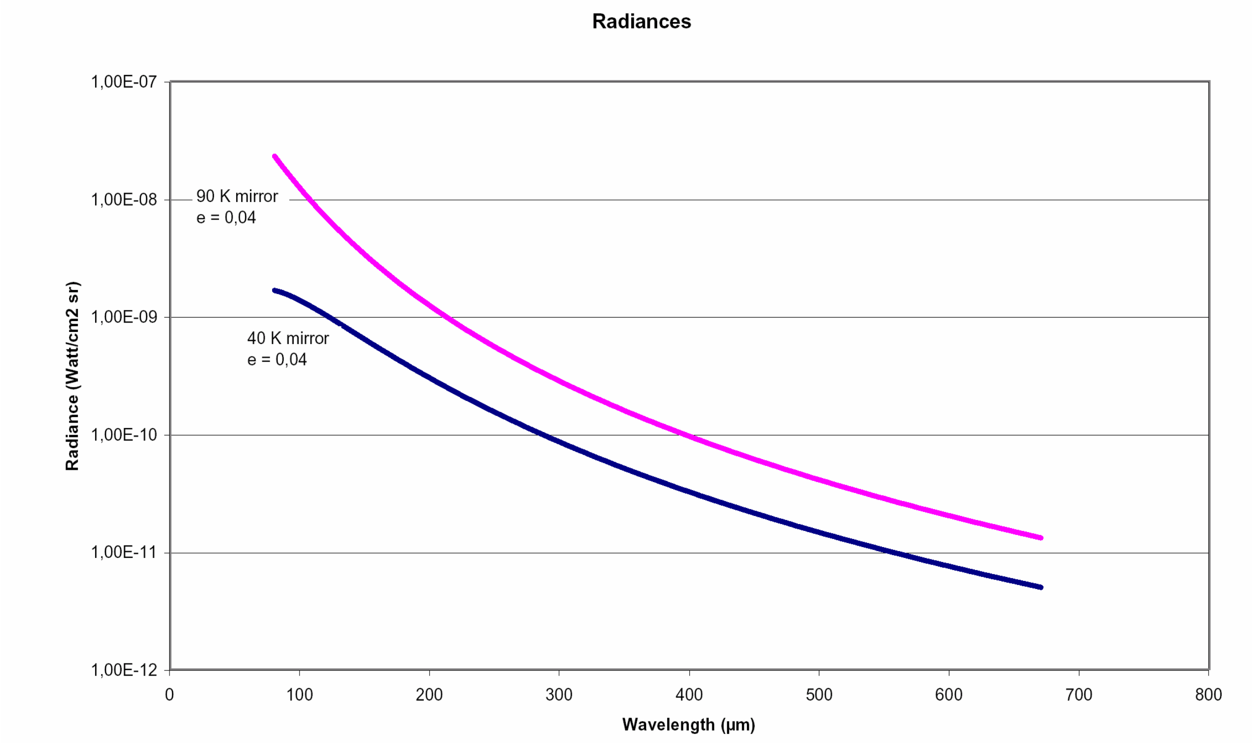
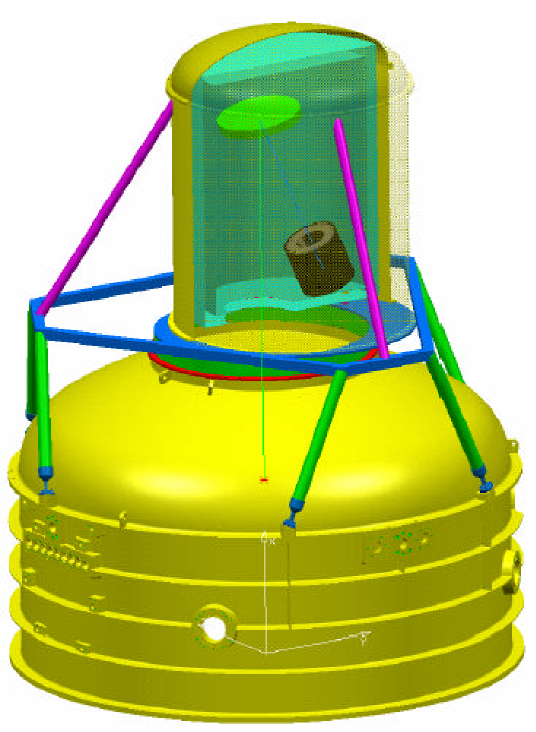


Figure 6-19: Thermal background expected from Herschel telescope

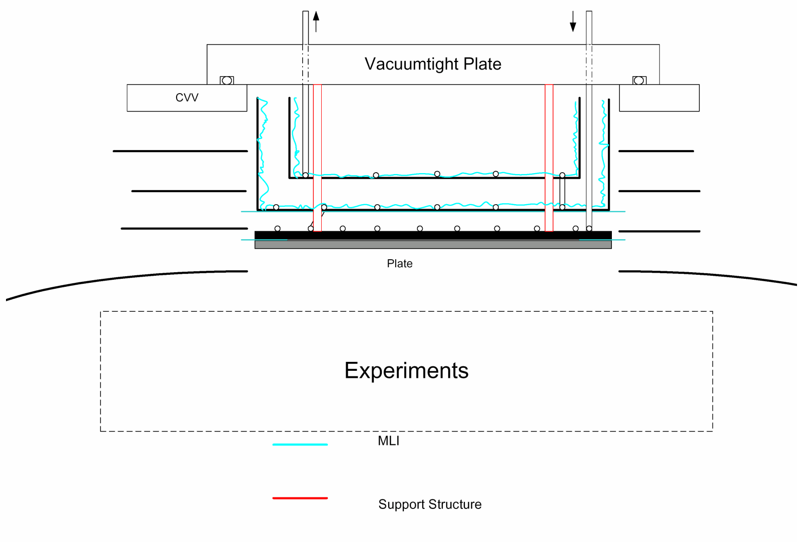
The hardware item used for simulation of the thermal background might be different for EQM and PFM.

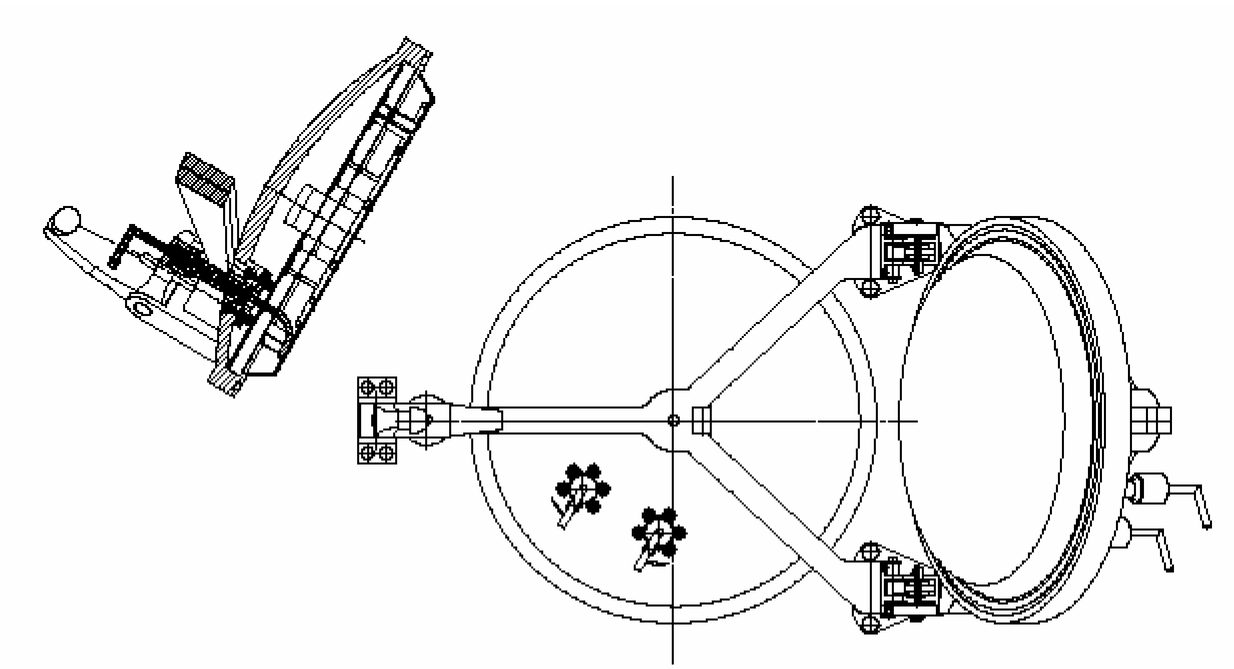
For the simulation of the background different concepts are feasible. A trade has been performed for three feasible concepts, which are shown below.



Off axis telescope

Actively cooled plate





Active flushing of the cover inner shield

Figure 6-20: Different concepts for simulation of the thermal background

The Off Axis Telescope consists of a reflector simulating the Herschel telescope and a black target simulating the thermal background. All of these components are mounted inside a continuous flow LHe-cryostat in order to suppress all disturbing IR radiation The operational temperatures of 40 – 90 K for the reflector and down to 4K for black target and background are reached by 3 independent cooling cycles. The temperatures will be adjusted by flow control of the LHe. Additional heaters allow a quick warm up.

The actively cooled plate is in the instruments FoV and cooled by a continuous flow of LHe. The plate is thermally insulated by radiation shields from its environment. The plate's surface can either be black with operational temperatures between 7,5 and 36 K or reflectively goldized and non-autocollimating for the instruments with temperatures between 40 and 70 K

The active flushing of the cover inner shield is very similar to the active cooled plate, but forms part of the Herschel cover. Accordingly, the shield is flight hardware, whereas off axis telescope and actively cooled plate are considered to be ground support equipment.

A trade off (RD15) has been performed for these concepts with criteria like EQM compatibility, PFM compatibility, temperature range, Planck curve representation, compactness, mass, technical complexity, test complexity, test flexibility, test expense, costs, schedule and contamination risk.

It has been shown that all three concepts are feasible and offer adequate resources for instrument testing.

It is evident that the "actively cooled plate" as well as the "active flushing of cover shield" demonstrate by compactness, test simplicity and simple design some technical and programmatic advantages. The domain of the off axis telescope is its test flexibility.

During the PDR assessment meeting (RD 16) it has been decided, that the "actively cooled plate" is the baseline concept for EQM. Agreement of the Herschel scientists is still pending.

6.3.2 MGSE

Due to the same requirements for MGSE H/W (w.r.t. load, basic dimensions and I/Fs) between ISO/PLM and Herschel PLM, the existing ISO MGSE items will be used for the Herschel AIT phase. For operation of ISO MGSE items during Herschel PLM AIT phase, a requalification of these items is required.

Furthermore, the requalified XMM Multi purpose trolley will be used within the Herschel PLM/AIT sequence.

Herschel PLM MGSE refurbished and requalified comprises the following items:

Item No.	MGSE Item	Quantity	Remark
1	Clean room class 100 integration dolly (Integration dolly)	1	ISO MGSE
2	Multi purpose trolley with EDU	1	XMM MGSE
3	Test dolly No. 1	1	ISO MGSE; stainless steel, without paint
4	Test dolly No. 2	1	ISO MGSE; white painted
5	Test dolly No. 3	1	New item
6	Hoisting Equipment No. 1	1	ISO MGSE
7	Hoisting Equipment No. 2	1	ISO MGSE
8	EQM/SVM Simulator	1	New item

Table 6-8: EQM - MGSE

General MGSE Functional Characteristics

The MGSE shall be designed to provide all mechanical and environmental integration and test support required for ground operations.

The PLM/EQM MGSE shall be designed to handle, protect, transport, assemble, integrate, refurbish and verify the S/C and/or its modules. It shall provide the auxiliary items required for personal access to accommodate ground operations.

Clean room class 100 integration dolly (Integration dolly)

This item is used for the integration of PLM/PFM and PLM/EQM in clean room class 100. Functional and technical details according ISO-VV-ZYYR-SP-0043.

XMM Multi Purpose Trolley and Equipment Drive Unit

This item is used for the integration of PLM/PFM in clean room class 100 000. Functional Requirements according MPT Item Specification XM-IS-APC-0098 and EDU Item Specification XM-IS-APC-0262

Test dolly No. 1

This MGSE is made from stainless steel and can be used for integration and testing of the PLM without EQM/SVM simulator in environment clean class 100 000. Functional and technical details according ISO-VV-ZYYX-SP-0473.

Test dolly No. 2

This MGSE will be used for integration and testing of the PLM without EQM/SVM simulator in environment clean class 100 and clean class 100 000. Functional and technical details according ISO-VV-ZYYX-SP-0473.

Test dolly No. 3

This MGSE will be used for integration and testing of the PLM mounted with EQM/SVM simulator in environment class 100 000.

Hoisting Equipment No. 1

This MGSE is used for hoisting ISO PLM/QM and Herschel PLM completely integrated (with SVM simulator, without telescope, without sunshield, without sunshade) with the tanks full, X-axis in vertical- and X-axis in horizontal position (Y- or Z-axis vertical).

Hoisting Equipment No. 2 (identical with Hoisting Equipment No. 1)

This MGSE is used for hoisting ISO PLM/QM and Herschel PLM completely integrated (with modified SVM, without telescope, without sunshield, without sunshade) with the tanks full, X-axis in vertical- and X-axis in horizontal position (Y- or Z-axis vertical). Functional and technical details according ISO-VV-ZYYY-SP-0048.

EQM/SVM Simulator

This MGSE is used for testing of the EQM/PLM.

6.3.3 CVSE

The Cryo Vacuum Service Equipment (CVSE) shall be used to perform all cryogenic and vacuum operations of the Herschel EQM program.

The CVSE shall comprise the following units:

- High vacuum pumping unit with turbo molecular pumps
- LHe service vacuum pump unit I
- LHe service vacuum pump unit II
- CVSE equipment rack
- LHe transfer lines (He I and He II service)
- LHe flushing lines for cavity cooling (TBD)
- General purpose vacuum pumps
- GHe and vacuum piping in order to connect the Herschel EQM with the pumping units
- Safety unit
- Scaffolding
- Flow meter units
- He leak detector
- Bake out unit
- LHe supply tanks 450 L
- Standard vacuum parts

The CVSE shall allow the basic operations with the Herschel EQM:

- Leak check of cryogenic system
- Evacuation and leak check of the cryostat isolation system
- Cool-down of the auxiliary He I tank (HOT) and the He II tank (HTT) from ambient to LHe temperatures
- Filling of the He I tank and He II tank with LHe in vertical position
- Production of LHe II in the He II tank and refilling of the He II tank with He II
- Production of He II in the He I tank and refilling of the He I tank with LHe II (TBC)
- He II conversion
- Warm up of the He I and He II tanks from LHe temperatures to ambient temperature
- Cooling of the cryostat test cavity by flushing to LHe at T = 4.2 K (TBD)

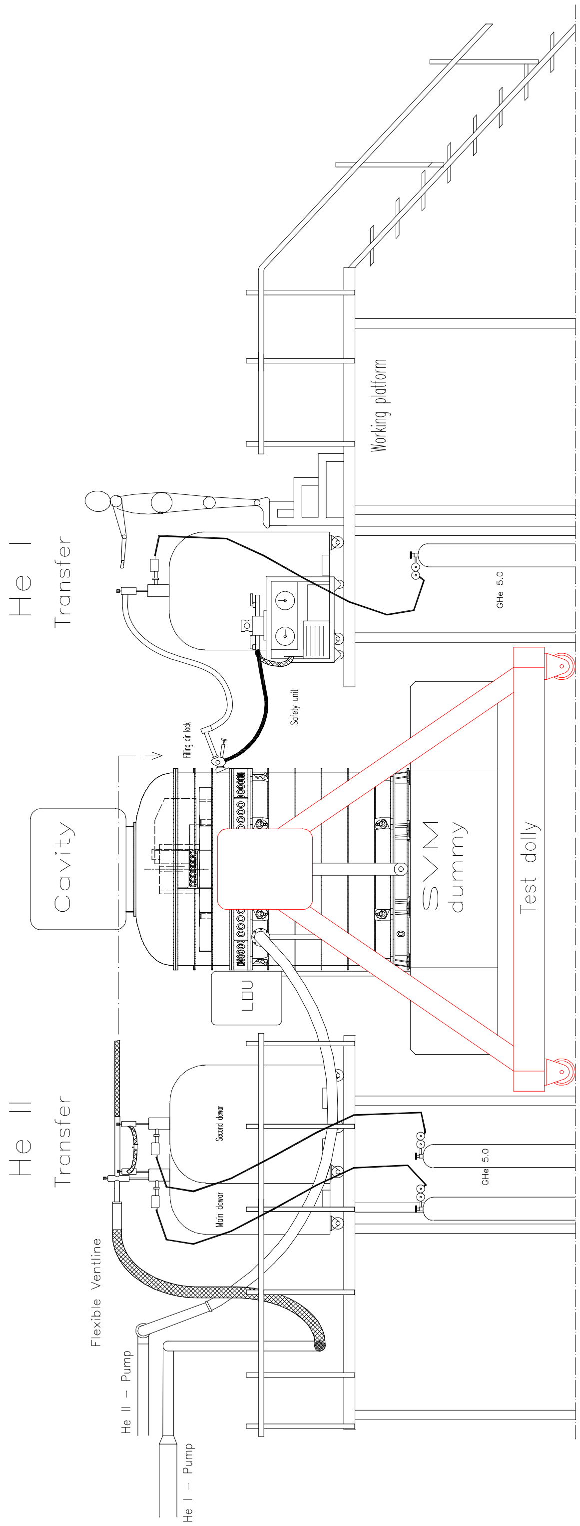


Figure 6-21: Herschel EQM cryo operations (He I and He II operation as example with old / non optimized version of the cooled plate)

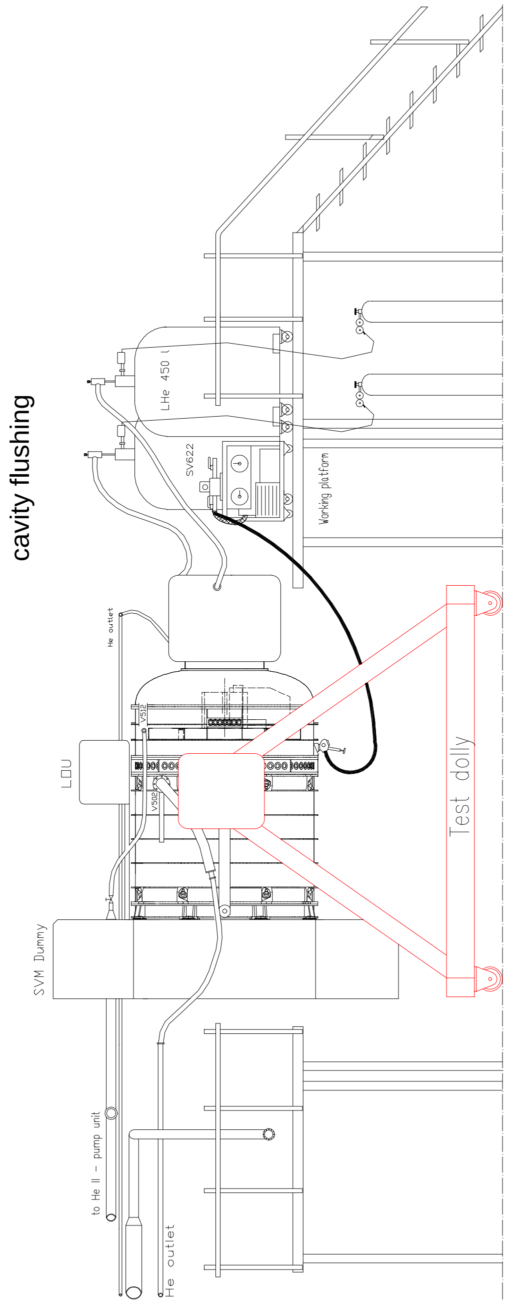


Figure 6-22: Herschel EQM cryo test set-up (Cavity flushing as example with old / non optimized version of the cooled plate)

6.3.4 EGSE

An overview of the required EGSE is given in the following drawing:

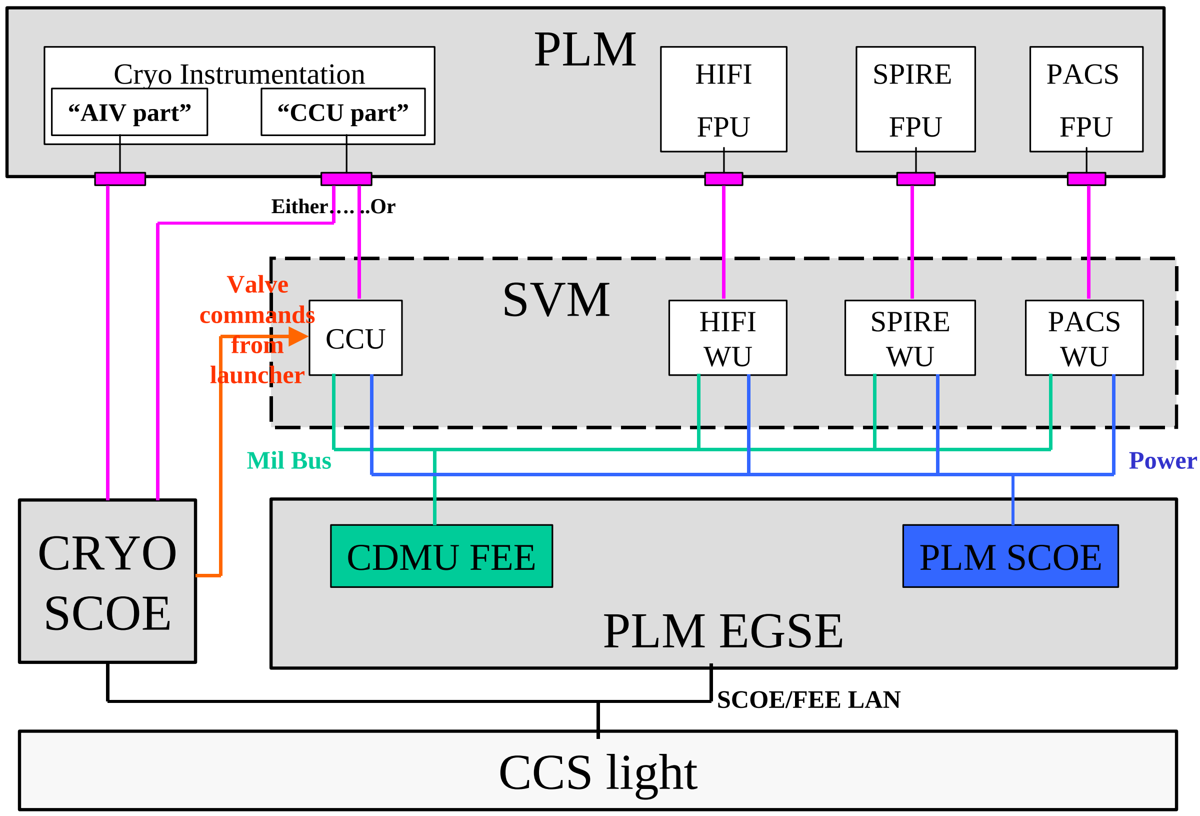


Figure 6-23: EGSE set up for instrument testing

7 EQM AIT PROGRAM

7.1 Integration

7.1.1 Pre- Integration Inspection and H/W release

Before starting the integration, an incoming inspection will be performed on each delivered equipment, to control the quality of the hardware to be integrated.

As a minimum, the following controls/measurements will be performed:

- control of data package according to the shipping list
- visual inspection
- cleanliness inspection
- conformity of identification markings and serial numbers to the configuration status
- fit check (if possible) dimensional check and planarity
- mass
- instrument health check after shipment

Release of hardware for integration will be controlled. Parts required for a particular integration activity will be kited to reflect the requirements of the governing procedure prior to the need date. This kiting operation shall include an inspection according to the system/module assembly drawing and subsystem manufacturing drawings to ensure that all parts / materials are available and that obvious anomalies are found prior to the beginning of integration activities.

7.1.2 Mechanical Integration / Disassembly

Mechanical integration/deintegration will be performed according integration/deintegration procedures in step by step format (RD 3). All activities will be given in correct timely order.

All de-integration and re-integration activities of the EQM cryostat will be performed in cleanroom class 100 environment.

The handling- and integration activities of EQM hardware will be carried out using the ISO refurbished MGSE. It will be done by trained authorised personnel with the necessary experience (ISO heritage).

The deintegration and storage of Herschel relevant H/W from ISO must be performed such that they can be reused for Herschel PLM/EQM (protection of flange I/F’s is mandatory). Generally all parts which shows anomalies (e.g. helicoil inserts, gaskets) have to be replaced. Clear marking of dismounted parts is requested for precise identification during reintegration phase.

The major steps of the disassambly/re-integration is:

- Disassemble non used ISO components
- Integration of new auxiliary tank and L0 cooling straps
- He S/S tubing re-routing/completion
- Re-routing of CCH
- Closure lower part
- Integration of optical bench with pre-integrated thermal foil on lower side
- Connection of optical bench ventline
- Integration of connector ring and instrument harness (up to optical bench)
- Integration of FPUs and connecting of L0 and L1 cooling straps
- Final integration of instrument harness
- Integration of Instrument shields
- Integration of Instrument MLI
- Closure of upper part of CVV including shields & MLI
- Installation of Cooled plate

The re-integration will be completed after closure of the cryostat with a successfully performed leak tightness test. The final integration activities will be continued in cleanroom class 100.000 (e.g. BOLA, LOU integration, external harness integration …).

7.1.3 Hardware ”as built status” List

Through an official record the hardware ”as built status” shall be traced during the AIT activities. The record shall state:

- drawings
- integrated hardware part and serial number
- integration date
- module
- subsystems
- integration location, if applicable
- grounding measurement result

7.1.4 Critical Interfaces

All sensitive interfaces (flange- or optical I/F’s.) must be adequate protected e.g. by foil or protection covers

7.1.5 Electrical Integration/Deintegration

The general approach is a sequential assembling and testing (RD 3). Each unit shall be reasonably functionally tested within existing constraints and as far as possible, before further units are added. The philosophy shall allow the identification of problems as clear and early as possible.

7.1.5.1 Harness and Waveguides

Harness and waveguides will be handled and installed only by adequate and authorised personnel.

All harness interfaces have to be protected by connector savers during integration. Mating/demating during ground handling will be made by separating “non flight” hardware interfaces. Electrical integration of harness will be completed by execution of detailed functional checks/tests. Open ends of the waveguides will be protected by adequate caps.

Integrated ISO harness no longer required for Herschel, it will be preferable to detach a suitable harness I/F before cutting of harness cables.

7.1.5.2 Instrument cold units integration

Grounding and precaution of static discharge requirements will be verified before any activity. Electronic unit/box connectors will be protected by connector savers during integration.

The instrument cold units integration will be supported by short electrical interface checks performed with adequate instrument unit tester.

7.1.5.3 Instrument Warm Units integration

Grounding and precaution of static discharge requirements will be verified before any activity. Electronic unit/box connectors will be protected by connector savers during integration. Mating/demating during ground handling will be made by disconnecting “non flight” hardware interfaces.

Electrical integration of units and subsystems will be completed by execution of detailed functional checks/tests.

The instrument warm-units will be integrated onto the SVM platforms in parallel to the cryostat integration as offline activity in cleanroom class 100.000. The warm-unit integration will be completed by a test sequence debugging, using the FPU simulators and the PLM EGSE together with the Central Check-out System (CCS-light).

These pre-integrated SVM platforms will be finally installed to the cryostat prior to instrument testing.

7.2 Cryo Operations

In order to allow instrument testing in the required thermal environment, the cryostat has to be cooled down and the tanks filled with LHe. Instrument cool down requirements will be respected.

7.2.1 Cooldown & Filling

The cooldown and filling will be performed according procedures based on the verified ISO documents and using the refurbished ISO CVSE.

Cooldown and filling will start after a successfully performed leaktest of the internal Helium S/S to the cryostat isolation vacuum and isolation vacuum to ambient. After filling of the main tank with LHe I, a cold leaktest will be performed.

Similar procedures will be used for filling the auxiliary tank with LHe I.

Cooldown and filling will be performed in vertical position only.

7.2.2 Helium II Production & Top Up

The Helium II production and top up will be performed according procedures based on the verified ISO documents and using the refurbished ISO CVSE.

According to our EQM design concept of the cryostat, the auxiliary tank will be used as He II reservoir for instrument testing, venting through the optical bench directly out of the CVV to the Helium pumping units. It provides the required level 0 temperatures as well as the level 1 and level 2 temperatures, by adjusting the required flight representative massflow of approximately 2.2 mg/s.

These conditions have to be maintained during the complete test sequence. Refilling of the auxiliary tank will start at least at a liquid level of 10 %.

He II production and top up will be performed in vertical position only.

7.2.3 Cooled Pate Operation

To provide a cold background for the instruments in order to perform their instrument testing, the CTA components have to be cooled during test

All testing with the EQM cryostat will be performed with x-axis in horizontal position.

The necessary procedures will be defined after final design of the Cooled plate.

7.2.4 Depletion & Warm-Up

The depletion and warm-up will be performed according to procedures based on the verified ISO documents and using the refurbished ISO CVSE.

It will start after finalising the instrument testing. It will be performed using the internal heaters of the main tank and auxiliary tank.

7.3 EQM Tests

7.3.1 Instrument Tests

Specific tests/verifications with the PLM EQM will be performed according to test procedures (definition of test and documentation of test process). All steps will be given in correct timely order. The release for starting the test will be given by a TRR.

According to the PLM EQM activity flow - see Figure 7-1 - the following instrument specific tests are foreseen : (see also RD 17)

1. Short cold functional tests (SFT) under He I conditions
2. Integrated module test (IMT) with a dark background test under He II condition
3. EMC test under He II condition
4. Validation of alignment procedure
5. Validation of EGSE test software

The SFT will include sequential short tests of the instruments in order to check the instrument health after cooldown and filling. Each instrument will define adequate test sequences to limit testing time.

The IMT will be performed under orbit representative conditions, in order to verify the instrument function in all modes. It will start with a test sequence debugging. The IMT will include

- Functional tests of each instrument separate, in all modes
- Functional tests of PACS and SPIRE in parallel mode
- Check of the instrument sensitivity w.r.t. background conditions, simulated by a Cooled plate

The EMC test will be performed after the IMT. The Cooled plate will be used to reach the required thermal background. It will include CE and CS test.

Some of these tests will be supported by tilting the cryostat around z-axis according instrument or cryostat needs.

A test report will be issued after test.

In detail, the following tests are proposed for each instrument:

HIFI	PACS	SPIRE
Alignment check	Full functional test	Flight operations thermal balance tests
Thermal test	Short performance test	Cooler recycle test
Functional test	AOT tests	Photometer chopper mode
IF properties	PACS/SPIRE parallel mode	Ambient background verification
Receiver tuning	EMC test	Spectrometer mode
Radiometry		EQM EMC Test
EMC test		

Table 7-1: Instrument tests

7.3.2 Alignment Verification

This chapter provides an overview of the Herschel alignment concept. A more detailed description is given RD 18.

Proper function of the three Herschel scientific instruments requires their precise alignment. The instruments have to be aligned to an optical reference system..

During the on-ground alignment two constraints must be taken into account:

- The alignment requirements are valid for in-orbit conditions
- The alignment requirements are specified for operational conditions, whereas the alignment can only be performed at ambient conditions.

The experience gained with the theoretical determination of these offsets and its confirmation during testing with the EQM will be applied for STM and PFM.

With the EQM the alignment procedure shall be verified at an early stage of the AIV programme. The effect on alignment due to pressure change and cool down will also be determined. The effect on alignment due to outer CVV temperature change can only be verified with the STM inside the TV chamber and use of the LOU alignment camera. The test sequence for the EQM (concerning alignment) is as follows:

.....PLM Integration → Alignment → Closing Cryostat → Evacuation → Alignment check → Cooling → Alignment check → Other Tests.....

Only the alignment relevant steps have been shown. The complete test plan is shown in the relevant AIV documentation.

The main tasks are the following:

- Early verification of the alignment as far as possible (no telescope on EQM)
- Verification of pressure and temperature change effects on alignment (with an outer CVV temperature at 300K)
- Lessons learned with the EQM can already be applied for the STM
- Risk reduction for the STM and FM programme

Monitoring the shift and angular deviation of the OB after cryostat evacuation and cool down will be performed using the LOU alignment cameras TBC.

Two alignment cameras are mounted temporarily on the LOU allowing to monitor simultaneously tilt and offsets (two cameras are needed to determine the rotation about the y axis). A distance measurement in y direction is also possible, however, with reduced accuracy TBC. This is no problem for the LOU alignment because the distance requirement w.r.t. this axis is very comfortable (± 15mm for LOU w.r.t. HIFI FPU).

With the actual feature having also a measurement capability in y direction (with improved measurement accuracy) with the LOU alignment camera this camera will also be used to re-adjust the tank support suspension devices after cool down under alignment control.

The advantage to have the LOU alignment camera would be, that it can also be used for the STM programme inside the TV chamber and no additional alignment window is needed.

The LOU alignment camera will be used at the following stages during the whole AIV programme:

1. Alignment of LOU w.r.t. HIFI FPU verification.
2. Re-adjustment of Tank Suspension after cool down.
3. Measurement of CVV shrinkage w.r.t. OB (HIFI) inside TV chamber with the STM and confirmation of the mathematical model.
4. Partial measurement of LOU w.r.t. HIFI stability and confirmation of mathematical model TBC.
5. Alignment check before and after environmental testing and after evacuation and cool down.

Measurement no. 3 and 4 will be performed at nearly in-orbit representative CVV temperatures.

7.4 AIT Logic Flow

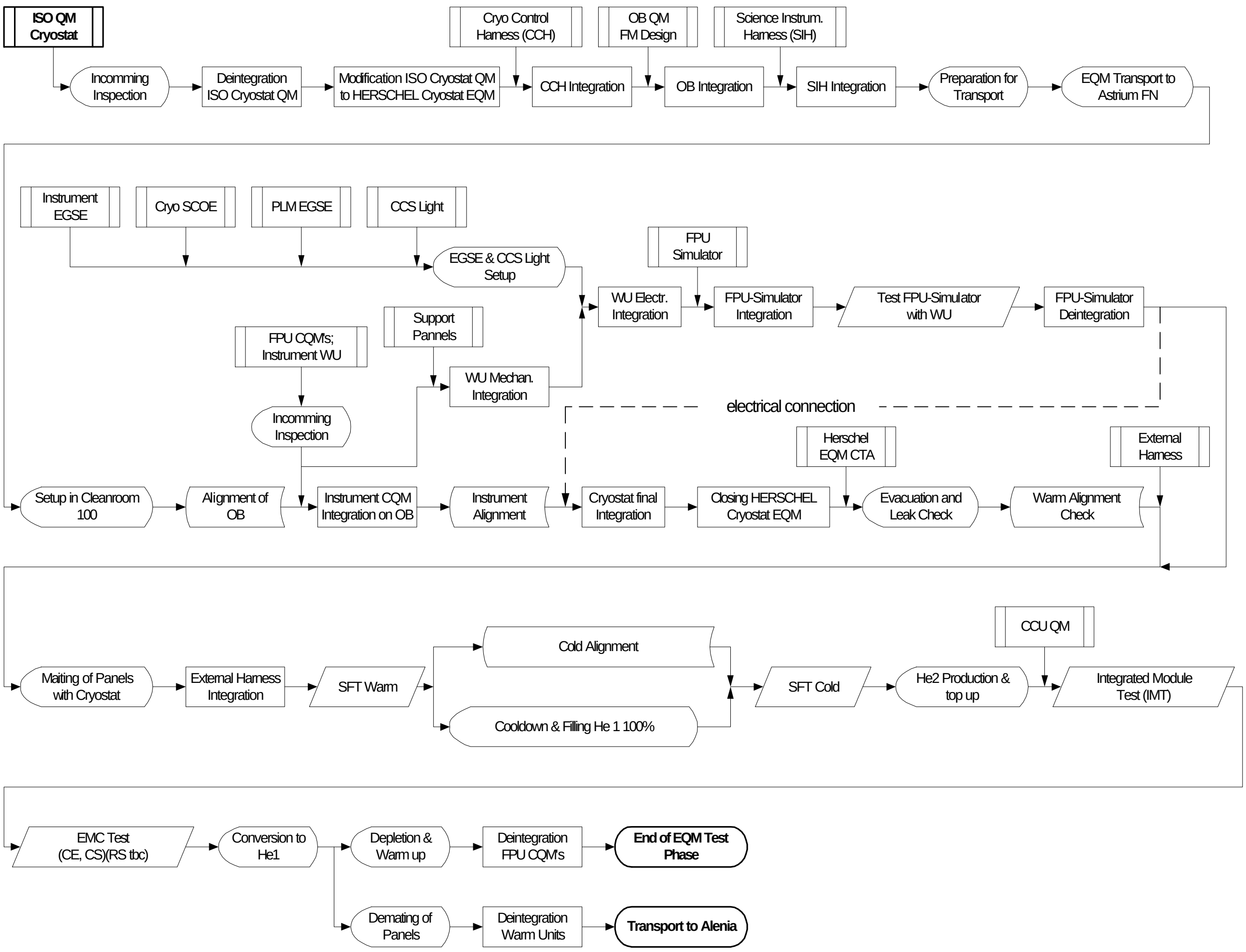


Figure 7-1: Logic flow for Herschel PLM/EQM AIT activities

8 EMC ASPECTS

8.1 General

This EMC design is based on the grounding concept meanwhile best justified in the space businesses: The Distributed Single Point Grounding Concept (DSPG). The quality of the DSPG concept will determine the EMC performance of the equipment, the instruments and HERSCHEL.

Good quality means in general:

- All bonding have to made low resistive and low inductive, considering thermal constraints,
- digital interfaces have to be differential with optimised balanced signals,
- analogue TM/TC and non-differential interfaces must use lines isolated from ground.

8.2 Grounding and Isolation

The proposed grounding scheme comprises a DSPG system for minimum noise pick-up as well as a minimum of emissions. The principle is based on the use of single ended or differential driver interfaces in combination with differential receivers or optically coupled interfaces. As a feature derived from ISO, there is no dedicated ground connection for the cryostat foreseen, i.e.: Grounding of the cryostat will be accomplished by overall shield mesh (TBC) between the cryostat and the SVM, i.e. by cable bundles overall shield and coaxial outer conductors only.

Harness Design

For a good EMC design of the HERSCHEL harness the following two tasks are essential:

1. Minimise emission of- and susceptibility to radiated electromagnetic fields, i.e.
    a) optimise shielding effectiveness (SE) of shield
    b) route of harness as close as possible to structure in order to minimise structure loops
    c) intermediate grounding of the cable shields, where possible
2. Minimise emission of- and susceptibility to conducted noise, i.e.
    a) apply wire twisting
    b) use impedance balanced lines for a wire pair (same cable lengths and type)
    c) minimise cable lengths

For Herschel we can distinguish 3 types of harness, the SVM harness, the CVV external cryo harness and the CVV internal cryo harness. For the EQM the selection of a built standard for each harness type has to consider the rules applicable for electrical and configurational representativity as well as configurational flexibility necessary to perform the different kinds of tests on the EQM PLM together with the avionics models of the SVM.

- The task/parameter 1a, i.e. SE influences the choice of the shield material. Copper or brass harness shields are more advantageous than SST. Therefore, as far as acceptable from thermal aspects, the shield shall be constructed of copper or of a material with similar electrical characteristics, rather than of SST. The material of the harness conductors, however, is without influence on these EMC aspects. Having no thermal constraints in the SVM, the SVM internal harness will be of copper (for both conductors and shields) as usual. Thermal and mission constraints (lifetime) however, are dictating the use of SST for the cryo harness outside the cryostat as well as inside the cryostat.
- It is a common practice to use overall shields, to improve further the shielding effectiveness and consequently the radiated to conducted coupling onto the wire pairs. The shield shall be connected to the structure at least at one end. Thermal constraints may require the grounding at only one point. This has no impact on the shielding effectiveness (with regard to the coupling into DM noise). W.r.t. the Ground Loop Coupling (GLC) mechanisms, the consequence of having only one grounding point instead of two for the shield is rather negligible (ref. e.g. EMC Books from D. White):
- In order to minimise coupling into the CVV due to CM noise on the outer harness, the shield shall not be directly fed through the CVV via pins (or directly). Bonding at the inner side to the CVV and outer side to the CVV at connector location is acceptable. In that case the attenuation of common mode currents entering the CVV might be even less than 20 dB .
- In order to support the objectives above, the harness-conductors and shields should not be interrupted by intermediate connectors and/or connector brackets, unless needed for accessibility during integration and testing. Therefore, presuming that connector brackets are not necessary on the optical bench for the integration, they shall be avoided inside the cryostat.

Details of all the harness design objectives and compromises will be reflected in the relevant HERSCHEL harness design documentation.

a) SVM harness (Copper, flight harness):

Flight harness will be used to interconnect the so called "avionics models" . Thermal constraints do not exist, therefore we use copper harness as usual.

b) CVV external cryo harness (SST test harness, electrically representative):

Although having no major thermal constraints, we will use SST (as in flight) for the construction of this harness type, with the aim to realise nearly the same harness impedance for the test harness as in flight. For this reason the harness lengths is also limited. If necessary, an extension harness of copper can be considered (today not foreseen, TBC), to be implemented in any thermal/electrical/mechanical facility around the cryostat or the "avionics models" that does not allow direct connection of the cryostat via the SST harness.

Using the Cu extension harness (today not foreseen, TBC), the resistance of the complete harness between avionics modules and CVV would not change.

c) CVV Internal Cryo Harness (SST flight harness):

Thermal and mission constraints (lifetime) dictate the use of SST for the cryo harness outside the cryostat as well as inside the cryostat.

9 STRAYLIGHT ASPECTS

Compared to the situation in orbit, we have the following differences, which, in total, should be as small as feasible.

- Thermal Straylight from CVV, Cavity and Thermal Shields

  This is affected by the temperature of these items, which in the test is around 290 K for the CVV + Cavity, and therefore is much higher compared to the CVV and Cavity during mission

  (around 70 K). At least this CVV and Cavity radiation therefore shall be shielded, not only towards the instruments but also towards the mirror. The temperature of this shielding best should be about 80 K. It can be much lower, but not higher, if this part of straylight is considered not important to simulate.

  On the other hand, we have no thermal radiation from the Primary Mirror rear side, which in flight also will be a significant contributor to thermal straylight.

- Thermal straylight from the Cooled Plate

  In orbit, we have two mirrors adding their thermal straylight. In the test the Cooled Plate is mounted in front of the instruments simulating the thermal self emission of the Herschel telescope. Additional straylight from the Cooled plate depends on the selected design and has to be assessed.

10 PA ASPECTS

10.1 Overview

In order to ensure the usefulness of the obtained qualification results as explained in Para. 4 in relation to the Herschel E- PLM the following PA- tasks will be implemented during the Herschel EQM programme:

Remark: It has been decided, that no structural qualification is performed with the Herschel EQM. Therefore only structural design and test requirements as applicable for pressure-, vacuum vessels, ground test equipment and cryogenic liquids (He-I and -II) will be implemented. No requirements as applicable for flight hardware with respect to static- and vibration- loads will be respected.

10.2 Product Assurance

10.2.1 Product Assurance Organisation

In order to ensure effective product assurance management a Product Assurance Organisation has been established as mentioned in Para.2.1 of the Document: HP-2-ASED-PL-0007; Product Assurance Plan for Herschel E-PLM & S/C AIT.

The Herschel Product Assurance Manager is René Stritter ED 61.

10.2.2 Key and Mandatory Inspection Points

In order to minimise risks during integration and tests, Key and Major Inspection Points will be defined in the manufacturing, assembly and test flow at critical points and will be performed according to Para. 10.5.2

10.2.3 Product Assurance Reporting

Reporting on the progress and status for the PA programme will be performed
as defined in Para. 3.4 of RD [06]

10.2.4 PA Procedures

The PA- team will support the establishing of procedures as mentioned in Para. 3.5 of RD [11]

10.2.5 Configuration control

Configuration control will be carried out by the project configuration management in accordance with the configuration management plan as mentioned in Para 3.7 of RD [11]. The procedures utilised by configuration management will be checked by PA to ensure that the as built status is recorded and conforms to the applicable as designed referenced baseline

10.2.6 Qualification Status Reporting

Astrium will prepare a qualification status list (QSL) for the Herschel EPLM which gives also reference to the qualification results reached with the Herschel EQM tests as mentioned in Para. 3.9 of RD [11]

10.3 Safety Assurance

A Safety Assurance Programme as mentioned in Para. 5 of RD [11] will be established in order to initiate safety provisions and to demonstrate that an appropriate safety programme is implemented in accordance with the ECSS-Q-40A. The Safety precautions to be attended for the Herschel EQM are mentioned in the Herschel PLM EQM AIT Plan. RD [03]

The following activities will be performed:

- Safety Testing will be performed if necessary for FM
- Training of personnel for hazardous operations will be implemented if necessary for Herschel EQM
- NCRs established at ISO STM/ QM will be reviewed about impact to safety hazards & items.

10.4 Components Quality and Procurement Control

In general, requirements as defined in Par. 6 of RD [11] will be respected. Due to availability reasons and due to the fact that components & parts developed from ISO STM/ QM will be used, also parts with Non Hi-Rel. Standard shall be used for the Herschel EQM. This shall be evaluated by review of the related ISO ADPs and complete components and parts list for the Herschel EQM and treated via summary RfW.

(See matrix overview to major components used for EQM mentioned under Para.10.6)

10.4.1 Mechanical Parts, Material and Process (PMP) Control

The PMP Programme will be implemented in such a way that the requirements of ECSS-Q-70A/ PSS-01-700 will be taken into account as mentioned in Para 7 of RD [11]

10.5 Quality assurance

10.5.1 Design and Drawing reviews

Design and drawing review control will be established as mentioned in Para 8.2 of RD [11] i. e. the following activities will be performed

- Review and approval of design specifications carried out by PA engineers and participation on the Change Control Board (CCB) activities in the frame of EQM
- All units and assemblies used in qualification and flight hardware will be described by drawings, all drawings will be reviewed by QA for compliance with the QA requirements.

10.5.2 KIP / MIP

KIP and MIP as explained in Para 3.3 of RD [11] will be performed

- KIP: Key inspection points, to be carried out on contractor level only
- MIP: Mandatory inspection points, to be carried out by contractor with the attendance of higher level contractor and / or ESA

The planned KIPs / MIPs for the EQM are defined in the Document Herschel AIT Plan for EQM, RD [03]

10.5.3 Assembly, Integration and Test (AIT) Control

The assembly, integration and Test Control will be established as described in Para. 8.7, RD [11] i.e. the following activities will be performed:

- An AIT Plan has been established see RD [03]
- Test procedures will be established and applied
- Test Facilities/ Test equipment required to conduct the test programme has been specified in the EQM-AIT plan
- Test Readiness Reviews (TRR) and Post Test Reviews (PTR) will be held
- Historical Records (Logbook) will be established for all operations and tests
- Test reports will be provided for each performed test

10.5.4 Cleanliness and Contamination Control

Cleanliness and contamination control activities will be defined and performed in order to ensure proper function of the Helium Subsystem, reaching the required vacuum level and in order to ensure the required contamination level for the Herschel Instruments which shall be integrated into the EQM hardware.

PA will be responsible for the cleanliness monitoring and control through Herschel EQM AIT phases.

All control and monitoring activities are defined and explained in the Contamination Control Plan RD12

10.5.5 Non- conformance Control

Non conformance system as applicable & mentioned in Para 8.9 of RD [11] will be applied for the Herschel EQM.

NCRs established during the ISO STM/ QM Program will be reviewed for an impact to the quality of components which shall be used again for the Herschel EQM and about Safety Critical Items for attention to the Herschel EQM test program.

10.6 Overview of major components to be used for the Herschel EQM

Major Hardware components	Hardware Definition (equal to/ only)	Taken from ISO (STM/ QM/ FS)	Visual inspection 1)	cleaning 2)	calibration	leaktest	NDI	Refurbishm. to be performed	Acceptance (test) to be perfomed	Hi- Rel part 3)	Non Hi- Rel 4)	RfW tbd 5)	Remarks
Cryostat Vacuum Vessel						x							leaktest with integrated components, 6)
Cryostat Upper Bulkhead	**H** (E-PLM)								x				(NDI + leaktest included)
Intermediate Ring	**H** (EQM)								x				(NDI + leaktest included)
Cryostat Cylinder	**I**	**STM/QM**	x										
Cryostat Lower Bulkhead	**I**	**STM/QM**	x										
Cryostat Insulation						x							(on assy. Level)
1st/ 2nd/ 3rd Rad. Upper Bulkhead Thermal Shields	**H** (E-PLM)								x				
1st/ 2nd/ 3rd Rad. Interm. Cylinder Thermal Shields	**H** (EQM)								x				
1st/ 2nd/ 3rd Rad. Cylinder Thermal Shields	**I+**	**STM/QM**	x	x		x	x						NDI on new weld. Seams
1st/ 2nd/ 3rd Rad. Lower Bulkhead Thermal Shields	**I**	**STM/QM**	x										
Optical Bench Shield	**H** (E-PLM)								x				
Cryostat MLI													
1st/ 2nd/ 3rd Rad. Shield Upper Bulkhead MLI	**H** (E-PLM)								x				
1st/ 2nd/ 3rd Rad. Interm. Cylindrical Shield MLI	**H** (EQM)								x				
1st/ 2nd/ 3rd Rad. Cylindrical Shield MLI	**I**	**STM/QM**	x										
1st/ 2nd/ 3rd Rad. Shield Lower Bulkhead MLI	**I**	**STM/QM**	x										
He I tank MLI *(ISO-HeII-tank- MLI)*	**I**	**STM/QM**	x										
Optical Bench Shield MLI	**H** (E-PLM)								x				
Auxiliary Tank MLI *(He II- tank)*	**H** (EQM)								x				
QM Delta MLI	**H** (EQM)								x				
Upper Lower Tank Support Frame													
Upper& lower Spatial Framework	**I**	**STM/QM**	x										
Upper& lower Tank Support	**I**	**STM/QM**	x										
Upper& lower Chains	**I**	**STM/QM**	x										
Strap Pretension Devices 15 piece	**I**	**STM/QM**	x			x							
Strap Pretension Devices 1 piece	**I**	**FS**	x			x							(replacement due to leak)
Instrument Optical Bench													
EQM Optical Bench Shield	**H** (E-PLM)								x				
Optical Bench Structure	**H** (E-PLM)								x				
Interface Brackets to SFW Fasteners	**H** (E-PLM)								x				
Instrument Thermal Connectors (cooling straps)	**H** (E-PLM)								x				
Instruments													
PACS													
PACS-CQM	**H** (E-PLM)								x				Cust. Furn. item
PACS-Interface-Solid to OB (screws, etc)	**H** (E-PLM)								x				
PACS-Cryo-Interface (cooling straps)	**H** (E-PLM)								x				
PACS-Harness	**H** (E-PLM)								x				Cust. Furn. item
PACS-Alignment References	**H** (E-PLM)								x				

Major Hardware components	Hardware Definition (equal to/ only)	Taken from ISO (STM/ QM/ FS)	Visual inspection 1)	cleaning 2)	calibration	leaktest	NDI	Refurbishm. to be performed	Acceptance (test) to be perfomed	Hi- Rel part 3)	Non Hi- Rel 4)	RfW tbd 5)	Remarks
HIFI													
HIFI-CQM	**H** (E-PLM)								x				Cust. Furn. item
HIFI-Interface-Solid to OB (screws, etc)	**H** (E-PLM)								x				
HIFI-Cryo-Interface (cooling straps)	**H** (E-PLM)								x				
HIFI-Harness	**H** (E-PLM)								x				Cust. Furn. item
HIFI-Alignment References	**H** (E-PLM)								x				
SPIRE													
SPIRE-CQM	**H** (E-PLM)								x				Cust. Furn. item
SPIRE-Interface-Solid to OB (screws, etc)	**H** (E-PLM)								x				
SPIRE-Cryo-Interface (cooling straps)	**H** (E-PLM)								x				
SPIRE-Harness	**H** (E-PLM)								x				Cust. Furn. item
SPIRE-Alignment References	**H** (E-PLM)								x				
Cryostat Helium Subsystem													
Main tank (He- I)*(ISO-HeII-tank)*	I	**STM/QM**	x			x							leaktest with integr. Components & piping
Plug mounted instead PPS 111	**H** (EQM)								x				No PPS 111 necessary
Direct Liquid Control Measurement Device 1/ H101-I/ T101	I	**STM/QM**	x										mounted without function
Direct Liquid Control Measurement Device 2/ H102-I/ T102	I	**STM/QM**	x										mounted without function
Helium Level Probe L101-I	I	**STM/QM**	x										defective (actions tbd)
Helium Level Probe L102-I	I	**STM/QM**	x										defective (actions tbd)
Tank Heaters H103-I/ H104-I	I	**STM/QM**	x						x				cont. Test tbp
Helium Rupture Disk RD124	I	**STM/QM**	x										6.)
He 2 Safety Valve SV123	I	**STM/QM**	x										
He 2 Valve SV123 spare	I	**FS**	x										
Helium Gas Adsorber Foils	I	**STM/QM**	x					x					
Helium Filling Port SV 121	**H** (E-PLM)								x				
Oscillation damper S101	I	**STM/QM**	x	x									
Internal Liquid Helium Valve V102-I/ V104-I/ V105-I/ V701-I/ V702-I	I	**STM/QM**	x										funcional check to be perf.
Valve heater VH102-E/ VH104-E/ VH103-E/ VH702-E (valve heater foil 90 Ohm)	I+	**STM/QM**									x	x	
Valve temp. Sensor VT102-E/ VT104-E/ VT105-E	I+	**STM/QM**			x						x	x	
Valve V502	I	**STM/QM**	x			x							6.)
Filter S 501	I	**FS**	x										
Temperature sensor T502-I	I	**STM/QM**	x		x								
Pressure gauge P101 (BHL 4201-01)	**H** (E-PLM)								x				
Pressure gauge P701-E (tbd)	**H** (E-PLM)								x				
Pressure gauge P901-I (penning gauge)	I	**STM/QM**	x		x								functional check tbp, 6.)
Pressure gauge P902-I (penning gauge)	I	**STM/QM**	x		x								functional check tbp, 6.)

Major Hardware components	**Hardware Definition** (equal to/ only)	**Taken from ISO (STM/ QM/ FS)**	**Visual inspection 1)**	**cleaning 2)**	**calibration**	**leaktest**	**NDI**	**Refurbishm. to be performed**	**Acceptance (test) to be perfomed**	**Hi- Rel part 3)**	**Non Hi- Rel 4)**	**RfW tbd 5)**	**Remarks**
Safety valve CVV SV921	**I**	**STM/QM**	**x**			**x**		**x**					functional check tbp, 6)
Safety valve CVV SV922	**I**	**STM/QM**	**x**			**x**		**x**					functional check tbp, 6)
Auxiliary Tank (He- II) *(ISO-HeI-tank)*	**H(EQM)**								**x**				(NDI + leaktest included)
Auxiliary Tank Support (ISO Baffle Tabs)	**I+**	**STM/QM**						**x**	**x**				
Aux. Tank Level probe L701-I	**H(EQM)**								**x**				
Aux. Tank Level probe L702-I	**H(EQM)**								**x**				
Aux. Tank Helium Rupture Disk RD7XX	**I**	**FS**	**x**			**x**							
Helium System Tubing													
He- I Tank Tubing (ISO- He II- tank)	**I +**	**STM/QM**		**x**		**x**	**x**		**x**				NDI on new weld. Seams
Additional Ventline Tubing	**H(EQM)**			**x**					**x**				(NDI + leaktest included)
Auxiliary Tank Tubing (He- II tank)	**H(EQM)**			**x**					**x**				(NDI + leaktest included)
Shields Tubing	**I +**	**STM/QM**		**x**		**x**	**x**		**x**				NDI on new weld. Seams
External Tubing Ventline	**H(EQM)**			**x**					**x**				(NDI + leaktest included)
QM Delta Tubing	**H(EQM)**			**x**					**x**				(NDI + leaktest included)
Optical Bench He Ventline	**H(EQM)**			**x**					**x**				(NDI + leaktest included)
Cryostat Control Instrumentation													
Vacuum feed trough Connectors with cables connected to sensorsT106-I/ T801-I/ T802-I/ T803-I/ T804-I/T101-I/ T102-I/ T104-I/ T105-I	**I**	**STM/QM**	**x**			**x**					**x**	**x**	continuity test and insulation test (low voltage)to be perf.
Vacuum feed trough Electrical Connectors for new instrumentation harness	**H** (E-PLM)					**x**			**x**	**x**			
Electrical Connectors for new scientific harness	**H** (E-PLM)								**x**	**x**			
Cryo Control Harness	**H** (EQM)								**x**				
Scientific Instrument Harnesses	**H** (E-PLM)								**x**				
External harness	**H** (EQM)								**x**				
Aux. Tank Heater H701-E/ H702-E	**I**	**STM/QM**									**x**	**x**	
Surface Thermometer *(C10)* T106-I/ T801-I/ T802-I/ T803-I/ T804-I	**I**	**STM/QM**	**x**								**x**	**x**	continuity test and insulation test (low voltage)to be perf.
Surface Thermometer *(C 100* , Allen bradley carbon resistor) T104-I/ T105-I	**I**	**STM/QM**	**x**								**x**	**x**	continuity test and insulation test (low voltage)to be perf.
Surface Thermometer *(C 100* , Allen bradley carbon resistor) T202-H/ T204-H/ T206-H/ T208-H/ T212-H/ T213-H/ T221-H/ T222-H/ T223-H/ T224-H/ T225-H/ T226-H/ T227-H/ T228-H/ T221-T/ T222-T/ T223-T/ T224-T/ T225-T/ T226-T/ T227-T/ T228-T/ T232-H/ T233-H/ T234-H/ T235-H/ T236-H/ T237-H/ T242-H/ T244-H/ T246-H/ T248-H/ T250-H/ T252-H/ T254-H/ T256-H/ T258-H/ T702-E/ T703-E/ T705-E/ T706-E/ T862-H/ T961-E/ T962-E/ T971-E/ T972-E/ T981-E/ T982-E/ T983-E/ T232-T/ T233-T/ T234-T/ T235-T/ T236-T/ T237-T/ T238-T/ T239-T/ T261-T/ T262-T/ T271-T/ T272-T/ T273-T/ T274-T/ T274-T/ T275-T/ T281-T/ T282-T/ T285-T/	**H** (E-PLM)				**x**				**x**		**x**	**x**	continuity test and insulation test (low voltage)to be perf.
Surface Thermometer *(PT 500)* T103-I/ T422-I/ T423-I/ T424-I/ T442-I/ T443-I/ T444-I/ T462-I/ T463-I/ T464-I/ T501-I/ T805-I/ T806-I/ T807-I/ T808-I/ T851-I/ T852-I/ T853-I/ T854-I/ T855-I/ T856-I/ T857-I/ T858-I/ T851-I	**I**	**STM/QM**	**x**								**x**	**x**	continuity test and insulation test (low voltage)to be perf.

Major Hardware components	Hardware Definition (equal to/ only)	Taken from ISO (STM/ QM/ FS)	Visual inspection 1)	cleaning 2)	calibration	leaktest	NDI	Refurbishm. to be performed	Acceptance (test) to be perfomed	Hi- Rel part 3)	Non Hi- Rel 4)	RfW tbd 5)	Remarks
Surface Thermometer *(PT 1000)* T102-E/ T104-E/ T105-E/ T211-H/ T231-H/ T241-H/ T243-H/ T245-H/ T247-H/ T249-H/ T251-H/ T253-H/ T255-H/ T257-H/ T423-H/ T424-H/ T443-H/ T444-H/ T463-H/ T464-H/ T701-E/ T702-E/ VT704-E/ T861-H/ T901-E/ T902-E/ T921-H/ T922-H/ T931-H/ T932-H/ T933-H/ T934-H/ T935-H/ T963-E/ T964-E/ T973-E/ T974-E/ T984-E/ T991-E/ T992-E/ T993-E/ T994-E	**H** (E-PLM)				x				x		x	x	continuity test and insulation test (low voltage)to be perf.
Heater (tbd) H961-E/ H962-E/ H971-E/ H972-E/ H981-E/ H984-E/ H991-E	**H** (E-PLM)								x		x	x	
Cryostat Electrical Subsystem													
Cryostat Control Electronic	**H** (E-PLM)								x				
PLM external components													
Optical Windows and Filters Support Frames	**H** (E-PLM)								x				
BOLA Support Structure	**H** (E-PLM)								x				
LOU Support Structure	**H** (E-PLM)								x				
LOU Waveguide Mounting Devices	**H** (E-PLM)								x				
LOU-Beam Feed Baffle FPU-CVV	**H** (E-PLM)								x				
Warm Unit Support Structure	**H** (E-PLM)								x				
Instrument Secondary Structure (SVM Dummy)	**H** (E-PLM)								x				
Cryostat Test Adapter													

Column Hardware Def:

I = identical to ISO (STM/ QM/ FS taken from ISO)
I+= ISO design + modification
H= new design (EQM design only for EQM)
H= new design (E-PLM design identical to E-PLM)
NDI= Non destruct. Inspect. (x-ray, penetr. Inspection)

1) Depending of accessibility, further actions on behalf of NCR
2) Additional cleaning to the stand. cleaning during AIT flow
3) Procured with PAD sheet acc. ECSS
4) Commercial Standard, design equal to Hi-Rel
5) RfW to be established (Not compliant to required quality level)
6) Viton Sealing rings to be replaced by new one´s

Table 10-1: Major Hardware Components

11 SUMMARY

The described EQM is an efficient way of supporting all engineering activities for HERSCHEL . The re-use of ISO components is possible by the basic commonality in size of the cryostat for both systems. In addition, ISO technologies are used again and allow the improvement of items like:

- the LHe valves
- thermal isolation techniques
- generation of HeII
- separation of LHe from gas
- temperature and pressure measurement
- the general cleaning and filling procedures.

The basic differences between Herschel and ISO, however, limit the representativity of this EQM. Herschel Instruments have a by far longer wavelength range and are more centered on gathering spectral data than the imaging tasks performed with ISO. These result in a profoundly different arrangement of optical instruments. While ISO required a cold telescope mirror at He temperatures and at nm precision, Herschel can live with a moderately cold telescope mirror at several µm precision.

Accordingly, the ISO main mirror was buried deep inside the cryostat and forced the design of a toroidal LHe tank, whereas Herschel can live with an external main telescope mirror and a bulk LHe tank, allowing more space for an internal Optical Bench. This difference in tank geometry is overcome by the AXT, the 'Auxiliary Tank', which functionally represents the main cooling source for the EQM Optical Bench. The resulting EQM design now has two LHe tanks. This adds an additional parameter to all thermal tests, the shield temperatures can be adjusted independently (within limits) from the optical bench temperatures . This feature is not available on the PFM but can be used to simulate on orbit conditions with a wide variation in temperature parameters. The different and more complex tubing of the EQM may lead to increased heat loads onto the tanks and prevent direct lifetime measurements applicable to the PFM, though the thermal analysis tools may profit.

The details of the geometries surrounding the optical bench will also differ, like tank mounting, tubing and valves as well as MLIs. Accordingly, EMC measurements which depend also on the peripherial geometry - consider 30 GHz (wavelength of 1 cm!) radiated susceptibility - may only provide confidence of the PFM performance, without accurate numerical coincidence with the PFM. All efforts will be undertaken to have a flight representative harness. This should enable the determination of transmission quality up to moderate frequencies, with good comparability to the PFM.

This Herschel EQM is a natural successor in the line of cryostat developments for space experiments. Though never intended to be orbited, it has all potentials to provide the necessary hardware oriented engineering insights for a successful design of the Herschel PFM.

Fig. 11-1 shows the actual Herschel EQM status at the date this report was written.

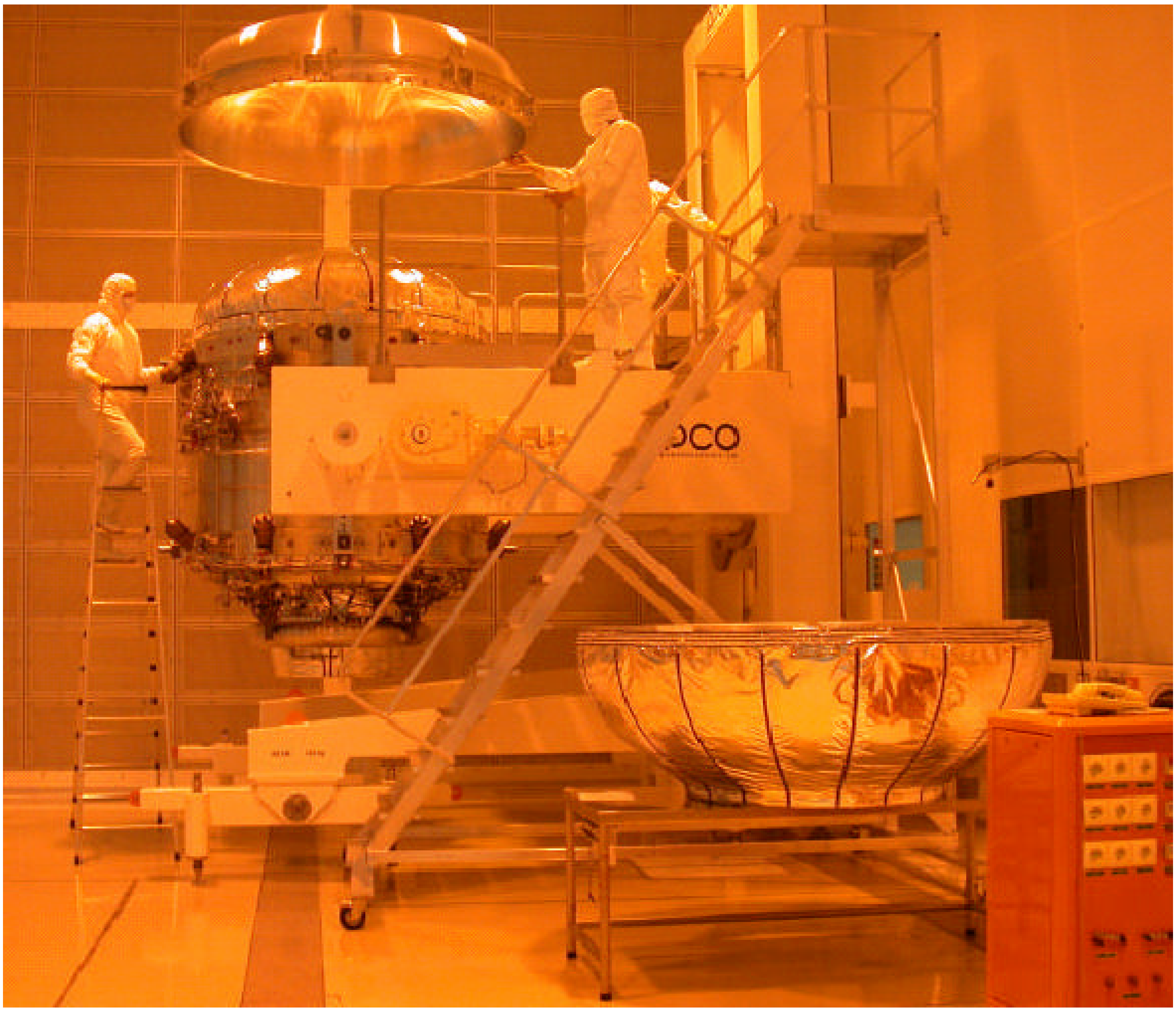


Figure 11-1: Herschel EQM in the class 100 cleanroom at ASTRIUM Ottobrunn, 5.6.02

END OF DOCUMENT

Quantity	Name	Dep./Comp.	Quantity	Name	Dep./Comp.
	Alberti von Mathias Dr.	ED 544		Runge Axel	OTN/TN 94
	Barlage Bernhard	ED 62		Sachsse Bernt	EC 34
	Bayer Thomas	ED 532		Sagner Udo	OTN/TN 64
	Faas Horst	ED 516		Schäffler Johannes	OTN/TN 64
	Grasl Andreas	OTN/TN 64		Schink Dietmar	ED 522
	Grasshoff Brigitte	ED 511		Schlosser Christian	OTN/TN 64
	Hartmann Hans Dr.	ED 172		Schwabbauer Paul Dr.	OTN/ED 17
	Hauser Armin	ED 541		Schweickert Gunn	ED 544
	Hinger Jürgen	ED 541		Steininger Eric	ED 522
	Hohn Rüdiger	ED 531		Stritter Rene	ED 61
	Hölzle Edgar	ED 171		Tenhaeff Dieter	ED 544
	Huber Johann	ED 532		Thörmer Klaus-Horst Dr.	OTN/ED 37
	Hund Walter	ED 556		Wagner Adalbert	OTN/IP 35
	Idler Siegmund	ED 521		Wagner Klaus	ED 541
	Ivády von András	EC 32		Wietbrock, Walter	ED 511
	Jahn Gerd Dr.	ED 541		Wilz Eberhard	OTN/ED 37
	Kalde Clemens	ED 513		Wöhler Hans	ED 544
	Kameter Rudolf	OTN/TN 64		Ziegler Fred	OTN/ED 522
	Knoblauch August	ED 51		Zipf Ludwig	EC 32
	Koelle Markus	ED 533			
	Kroeker Jürgen	ED 515			
	Lamprecht Ernst	OTN/TN 72			
	Lang Jürgen	ED 556			
	Langfermann Michael	ED 531			
	Mack Paul	OTN/TN 64		Pastorino Michel	ASPI Resid.
	Maier Hans-Ulrich	ED 61			
	Mauch Alfred	ED 544		Alcatel (on FTP-Server)	
	Moritz Konrad Dr.	ED 37		ESTEC (on FTP-Server)	
	Müller Lutz	OTN/TN 64			
	Muhl Eckhard	OTN/TN 64			
	Peitzker Helmut	ED 37		APCO	
	Peltz Heinz-Willi	ED 515		MPGE	
	Peters, Gerhard	ED 533		RALA	
	Pietroboni Karin	ED 37		SRON	
	Puttlitz Joachim	OTN/ED 37			
	Raupp Helmut	ED 543			
	Rebholz Reinhold	ED 531			
	Reuß Friedhelm	ED 7			
	Rühe Wolfgang	ED 3			