HERSCHEL / PLANCK

Planck CQM Cryogenic & Thermal test Specification

Product Code : H-P-3-ASP-TS-0645

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ENREGISTREMENT DES EVOLUTIONS / *CHANGE RECORD*

Issue. Revision	DATE	§ : CHANGE RECORD	AUTHOR
1.0	23/07/2004	First Issue	P Rideau
2.0	15/01/2005	Modification of T° criteria for Ph02-008 and Ph02-009 consistently with thermal analyses (19K instead of 18K). Update of Table 5-1 consistently. Update of §5.2.3 tables consistently	E. Gavila
2.0	15/01/2005	Update of §3.2.1.1 : refinement of breakdown (Figure 3-1) and modification of Table 3-6 (number of sensors for groups B&C).	E. Gavila
2.0	15/01/2005	Addition of reference sensors in Table 1-1 for all I/F	E. Gavila
2.0	15/01/2005	Update of sensors position for PC1&2 Sorption Cooler I/F in Table 1-1.	E. Gavila
2.0	15/01/2005	Addition of wires length measurement and precision for CQM ATC cables not used during CQM in §3.1.2.1	E. Gavila
2.0	15/01/2005	Acronyms list added in §2.3	E. Gavila
2.0	15/01/2005	4K and Dilution cooler I/F added to Table 1-1	E. Gavila
2.0	15/01/2005	SC Cooler switch off shifted from phase 05-001 to 05-002 Start criteria for ph05-002 changed to "End of Ph04"	E. Gavila
2.0	15/01/2005	Addition of FPU decontamination heating lines in §3.1.2.1.2 Mention to S/C global warm-up removed from §3.2.1.2. Addition of power lines in PLM EGSE parameters §5.3.1.3 Addition of Table 5-5 for FPU Decontamination lines Addition of Table 3-2 (PLM EGSE lines for FPU decontamination) and Table 4-2. Switch on FPU decontamination lines for Ph05-002. End criteria of 45K to be verified on coldest FPU (HFI) sensor. Pre-cooling loop kept OFF during warm-up Two heater configuration for Decontamination lines (F&G) Decontamination heating power to be adapted (Ph06-001) in order to keep RAA Main Frame @300K(±10K)	E. Gavila
2.0	15/01/2005	Test heaters switched OFF step by step for passive demonstration at all interfaces (Ph01-002, Ph02-002, Ph02-004, Ph02-005). Detection chain switched on at Ph02-005 instead of Ph02-002. Clarification of passive demonstration configurations (§5.2.2.1.3)	E. Gavila
2.0	15/01/2005	Modification of power values to be injected in heaters (Table	E. Gavila

Issue. Revision	DATE	§ : CHANGE RECORD	AUTHOR
		5-5). Injected values correspond exactly to allocations. Nota under table changed consequently.	
2.0	15/01/2005	Addition of power profile for transient (§5.2.2.1.2) Addition of associated predictions	E. Gavila
2.0	15/01/2005	Updated profiles for shrouds cool-down (see Table 5-3) and warm-up (see Ph06-001 and Table 5-4)	E. Gavila
2.0	15/01/2005	§5.1.12.2and §5.1.12.3 updated with latest results	E. Gavila
2.0	15/01/2005	Ph02-003 start criteria updated	E. Gavila
2.0	15/01/2005	Criteria synthesis added in §5.1.11 (Table 5-1)	E. Gavila
2.0	15/01/2005	Transient phase duration (§5.1.7) changed to 15h instead of 10h	E. Gavila
2.0	15/01/2005	Configuration tables updated in §5.2.1, §5.2.2 and §5.2.3.	E. Gavila
2.0	15/01/2005	Sentence removed at end of §1.2 according to ESA comment	E. Gavila
2.0	15/01/2005	Reference to Instrumentation Plan added to §8.1	E. Gavila
2.0	15/01/2005	Addition of stability criteria at PPLM boundaries in §6.1	E. Gavila
2.0	15/01/2005	Cool-down duration updated because of 0.1K stage modelling unreliability. Analyses are performed down to 4K, duration drawn from test results are then added to estimate complete cool-down (0.1K) duration (see Figure 5-1)	E. Gavila
2.0	15/01/2005	PACE GSE switch on @175K (Ph02-003) §5.1.5, §5.2.3, Table 5-1.	E. Gavila
2.0	15/01/2005	Update of §3.1.3.2	L.Ouchet
2.0	15/01/2005	§7 ref RID CDR DAIV-0403 & ESA comments (H-P-ASP-MN-5397/N°27 & 41)	P. Armand
2.0	15/01/2005	S/C configuration §3.1.1 ref RID CDR DAIV-0405 & ESA comment (H-P-ASP-MN-5397/N°9)	P. Armand
2.0	15/01/2005	§1.3 ESA comment (H-P-ASP-MN-5397/N°4)	P. Armand
2.0	15/01/2005	§4.1 ESA comment (H-P-ASP-MN-5397/N°11)	P. Armand
2.0	15/01/2005	§4.2.1 ESA comment (H-P-ASP-MN-5397/N°12)	P. Armand
2.0	15/01/2005	§4.3 ESA comment (H-P-ASP-MN-5397/N°13)	P. Armand
2.0	15/01/2005	§4.4 ESA comments (H-P-ASP-MN-5397/N°14 & 15 & 35)	P. Armand
2.0	15/01/2005	§4.5 ESA comments (H-P-ASP-MN-5397/N°16)	P. Armand
2.0	15/01/2005	ESA comment (H-P-ASP-MN-5397/N°34) §4.7.2 /§5.1.5 / §5.1.1 New step has been added	P. Armand
2.0	15/01/2005	Ph03-004 dedicated to PACE GSE pressure fluctuation	P. Armand
2.0	15/01/2005	Phases duration synthesis added in §5.1.12 (see Table 5-2)	P. Armand
2.0	15/01/2005	§3.2.4 microvibration instrumentation updated: accelerometer type and label	J. COUCHE

Issue. Revision	DATE	§ : CHANGE RECORD	AUTHOR
2.0	15/01/2005	§4.9.3 microvibration instrumentation updated: accelerometer at the square support feet added, including location type and labels	J. COUCHE
2.0	15/01/2005	§5.1.3 Shrouds cooling optimisation in order to evaluate the facility leak	P. Armand
2.0	15/01/2005	Additional test required by HFI included in the baseline (ref. NT-PH260-400499-IAS & NT-PH260-400500-IAS §1.3 & §5.1.6	P. Armand
2.0	15/01/2005	Name of ESA representative	P. Armand
2.0	15/01/2005	Update of Figure 4-7 with EMC & μ-vib EGSE	P. Armand
2.0	15/01/2005	Add of a reference to HFI microsequence §5.2.3	JP Chambelland
2.0	15/01/2005	Update of cryo-chain test objectives §1.3 and 1.4	JP Chambelland
2.0	15/01/2005	Update of cryo-chain testing §5.1.5, §5.1.6	JP Chambelland
2.0	15/01/2005	Update of cryo-chain criteria §6.2 and 6.3	JP Chambelland
2.0	15/01/2005	§1.1 ESA comments	P. Armand
2.0	15/01/2005	§4.3 ESA comments (duplication sentence)	P. Armand
2.0	15/01/2005	§8 ESA comments (clarification of the requested documentation)	P. Armand
3.0	10/06/2005	Update of RAA Main Frame T° objective (24K instead of 20K) §5.1.5 and Table 5-1	E. Gavila
-	-	Addition of TRA heaters activation (§5.1.8)	-
3.0	21/07/05	Removal of the annex 9 (list of HFI TM)	JP Chambelland
3.0	21/07/05	§1.3 three additional objectives	JP Chambelland
3.0	21/07/05	§2.2 reference document list updated	JP Chambelland
3.0	21/07/05	§3.2.2 HFI instrumentation updated	JP Chambelland
3.0	21/07/05	§5.1.1 Phase 0.0 001 : duration of the 0.1K flushing modified 002 : description of the WSFT added & 4K cooler stays ON with stroke set to 0 mm 003 : PACE is now pumped down at the end 004 : HFI stays ON during the pumping	JP Chambelland
3.0	21/07/05	§5.1.2 Phase 0.1 001 : pre-cooling and isotope purging 004 : new criteria on the facility leak check beginning phase 005 : add of functional test. PACE remains in vacuum after 006 : add of success criteria. Precooling loop stays in flusging 007 : remove compressor stop. New criteria	JP Chambelland

Issue. Revision	DATE	§ : CHANGE RECORD	AUTHOR
		008 : detailed paragraph 009 : continuous flushing of 4K cooler	
3.0	21/07/05	§5.1.3 Phase 0.2 003 : set compressor stroke at 0 instead of switch off	JP Chambelland
3.0	21/07/05	§5.1.4 Phase 01 001 : HFI already ON. Continuous flushing of isotope circuit 002 : criteria to observe sucessful opening of clamping mech. 004 : set compressor stroke at 0 instead of switch off	JP Chambelland
3.0	21/07/05	§5.1.5 Phase 02 001 : set compressor stroke at 0 instead of switch off 002 : switch ON HS1 and HS2 in Ph02-005 003 : add of PACE nominal pressures 004 : details on pre-cooling set up 005 : detailed operation for HFI configuration 006 : add of quantified criteria 007 : to perform 4K effort calibration if needed 008 : change the criteria parameter 009 : detailed operations for isotope start up 010 : change the criteria parameter 011 : FPU thermal control tests added 012 : Electrical crosstalk tests added	JP Chambelland
3.0	21/07/05	§5.1.6 Phase 03 001 : performance characterisation completed 002 : EMC tests detailed 003 : PACE pressure fluctuation detailed 004 : 4K cooler frequency test detailed 005 : defrost test and 4K cooler margin detailed 006 : 4K failure to be performed only if Ph03-004 not performed	JP Chambelland
3.0	21/07/05	§5.1.8 Phase 05 001 : restain isotope flow rate to 2 ml/mn 002 : power steps on the TRA added	JP Chambelland
3.0	21/07/05	§5.1.9 Phase 06 001 : change RAA temperature	JP Chambelland

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1. TEST OBJECTIVE

1.1 Introduction

This document is the test specification for the CQM testing of the Planck spacecraft. This test will be done in CSL (Centre Spatial de Liège).

This specification deals in particular with:

- Test specimen definition
- Test objectives
- Requirements towards test facilities
- Success criteria
- Input/output data

The CQM test can be split in the following series of tests:

- Adequacy of the Planck S/C test set-up for the FM acceptance tests (for the PPLM part only).
- PPLM passive test during which the passive thermal control performances of the PPLM are tested.
- Cryo chain testing during which the capability of the cryo chain provided by the instrument to reach 0.1 K on the FPU will be tested.
- Instrument testing in cryogenic environment: for the CQM, this will be limited to tests on HFI, as LFI is not present and replaced by a dummy.
- PPLM transient test during which the transient behaviour of the PPLM will be tested to comfort behaviour w.r.t. straylight requirements.
- In parallel to these tests, microvibration verification will be performed to verify that the levels coming from the facility and from the specimen (4K cooler) generate acceptable microvibration levels at FPU interface.

1.2 PPLM CQM passive performance test objectives

This test main objective is to verify the PPLM passive thermal control performance. Secondary objectives are to functionally test the flight temperatures acquisitions and to verify the mathematical model reliability. Corollary objectives are to maintain test environment parameters within required range as well as to achieve test measurements.

1.2.1 Objectives related to specimen performance

<u>*Passive thermal control performance*</u>

The PPLM passive thermal control is designed to provide Instruments with cold interfaces during operation. These interfaces, along with associated required max temperatures, are recalled in next table.

Operating mode		Max T (K)	Location at which the required temperature must be guaranteed	Reference test sensor for objective verification
LFI WG	VG1	170	on interface shield side	Pt101&Pt141
	VG2	120		Pt201&Pt241
	VG3	60		Di302&Di341
Sorption Cooler	VG1	170	at exchangers and on exchangers side (at exchanger 3C on shield 3)	Pt131 (-Y, on exchanger) Pt151 (+Y, on exchanger)
	VG2	120		Pt231 (-Y, on exchanger) Pt251 (+Y, on exchanger)
	VG3	60		Di2&Di935 (-Y, on exchanger) Di1&Di934 (+Y, on exchanger)
JFET box		60	on PR panel side	Di522&Di524
4K cooler VG3 I/F		60	on shield side	Di302
Dilution cooler VG3 I/F		60	on shield side	Di341&Di342
LFI FPU		65	on PR panel side	Di531&Di532&Di533
Primary reflector		50	on reflector (1)	None (Di536&Di537 for I/F T°)
Secondary reflector		50	on reflector (1)	None (Di501&Di511 for I/F T°)

Table 1-1: Passive performance requirements

(1) No reflector being available for CQM test, temperature is checked at PR&SR Panels interfaces

The passive test shall demonstrate that these interfaces are kept below required max temperatures, in flight EOL conditions, with Instruments interfaces loads as allocated (see next table).

Sorption Cooler I/F Heat Loads	T reference (K)	Allocated load (mW)	Margin	Max load (mW)
Shield 3	58.5/56.3/52.3	1175	10%	1293
Shield 2	108	447	20%	531
Shield 1	158	566	20%	673

Table 1-2: Sorption Cooler I/F heat loads allocations

LFI RAA I/F Heat Loads	T reference (K)	Allocated load (mW)	Margin	Max load (mW)
Shield 3	51.4/57.6	710	20%	852
Shield 2	106	560	20%	672
Shield 1	166	5370	20%	6444

Table 1-3: LFI RAA I/F heat loads allocations

HFI I/F Heat Loads	T reference (K)	Allocated load (mW)	Margin	Max load (mW)
Shield3+telescope	50	620	20%	744
Shield2+struts	110	20	20%	24
Shield 1	165	50	20%	60

Table 1-4: HFI I/F heat loads allocations

Note that no specific heater on VG1&2 being allocated to HFI I/F simulation, the corresponding power will be spread on WG I/F simulation heaters (see Table 5-5).

In order to optimise at best test duration, the here above presented performances will be verified in three steps, two steps being performed in parallel with active cooling. Table 5-6 presents the performances checked during each phase (see §5.1 for phases definition) as well as the simulation heat loads for each step.

This demonstration requires moreover specific SVM dummy thermal control. The SVM Dummy / PLM interfaces are considered as test environment interfaces (see §3.1.4 for requirements synthesis).

Flight temperatures acquisition

Flight sensors (Platinum probes PT2000) acquisition through flight harness shall be verified during test (acquired temperature compared to test probes).

Note that this verification will be limited to probes+PPLM harness level, therefore excluding the flight data acquisition software and hardware.

Thermal mathematical model verification

The test shall confirm, through comparisons between temperature measurements and test predictions, that the flight PPLM TMM is reliable or, in case of major discrepancy, shall provide information allowing to correct the encountered TMM failures. No verification of SVM Dummy TMM shall be performed.

The TMM used for tests prediction is the one used for flight adapted in order to take into account ground CQM test configuration (CQM specimen, test harness, vacuum chamber …).

Note that the uncertainty reduction for flight predictions, though it could result from TMM check, is not an objective of this test.

The TMM verification will be performed in static and/or dynamic condition (see also PPLM Transient Test objective).

Note that the verification of decontamination heating lines functioning and performance (reflectors and FPU) is not part of PPLM CQM test objectives.

1.2.2 Objectives related to test environment performance

Temperatures on specimen successfully acquired and recorded during all phases (see thermal sensors classification in §3.2.1.1)

Power on specimen successfully injected, acquired and recorded

Test environment conditions as specified, including “SVM dummy / PLM” interfaces

1.3 Cryo chain testing objectives

The HFI coolers (0.1K and 4K) have never been tested together neither with the rest of HFI detection chain, that is why **the main objectives of this test is to obtain 0.1K at the bolometer interface**.

The 20K cooler on the CQM is replaced by a set of pipes and hydrogen bottles, therefore this cryo-chain is considered as tool to reach 20K at LFI interface, and not as a qualification. The PACE CQM (QM pipework) will be verified in a fight like environment (Nominal case: massflow & pressure). The Sorption Cooler System would only be qualified on the FM tests.

The 0.1K cryo chain consist in the same cold end, warm and cold pipework assembly, and DCCU as the flight ones, but the He tanks are replaced on the CQM by He bottles located outside the vacuum chamber. This part of the cryo chain would only be qualified on the FM tests.

Apart from the main objective described above, this test may also fulfil secondary objectives :

- validation of the PPLM thermal mathematical model including HFI Instrument. In case of major discrepancies, the test shall provide information to correct the cryo-chain model.
- qualification of the facility for Planck FM tests wrt :
- thermal environment
- EMC environment
- micro-vibration environment
- 4K plate environment
- verification of the impact of micro-vibration on the cryogenic performance from source internal to the satellite (4K compressor)
- HFI cooler troubleshooting validation (defrost and failure of 4K chain)
- HFI 4K cooler cooling power measurement
- crosstalk measurement between different bolometer channels
- test of the PID regulation efficiency at 1,6K and 4K stage
- test of influence of 100 mK PID regulation on the bolometer noise
- 20K Sorption Cooler failure
- Impact of 20K Sorption Cooler temperature fluctuation

1.4 Instrument functional tests objectives

Assuming that the previous main objective is fulfilled (0.1K on the HFI cold end), the verification of HFI detection chain performance under flight-like environment is the second Instrument main objective of this test.

It consist in :

- noise density spectrum criteria
- absolute response to a blackbody criteria

Secondary objectives are :

- HFI EMC susceptibility test (ref. RD[11])
- Validation of the HFI test procedures and GSE, and training of HFI, ASP and CSL teams.

In addition (or in parallel) to this objective, the CQM test will validate the functional behaviour of the HFI Instrument which will be for the first time integrated together for this test. In particular, the following points will be validated :

Cross validation of the electrical chain DPU/REU/DCCU/4KCDE. Verification of the TM/TC interfaces.

Validation of both complete 0.1K and 4K cryo-chains with electronics, pipework and cold ends.

Validation of the command/control interface between the DPU and the CCS, and the gathering of the science data.

1.5 PPLM transient test objective

The PPLM transient test objective is to confirm / refine thermal inputs used for straylight analyses. This objective will be split in two parts :

- The measurements of dynamic response to pre-defined thermal perturbation. This response will be extrapolated to actual fluctuations and then used as input for straylight analyses.
- The verification that the TMM dynamic behaviour is close enough to the actual system, so that TMM based analyses may complete and consolidate the inputs used for straylight analyses.

The second part may lead to TMM updates after test results processing.

1.6 Microvibration test objectives

The microvibration test objectives are:

- To ensure that vibrations at the FPU Interface as all as at the HFI Interface are kept below the instrument specifications during cryogenic operations of the CQM.

To collect data in order to demonstrate that microvibration levels on the FPU will remain below the instrument specified level on the satellite flight model.

Corollary objectives are:

- To assess microvibration sources, including sources caused by the chamber under CSL responsibility.
- To asses microvibration structural transfer paths.

1.7 Requirements verified by this test.

IIDB-HFI 3.2 - Ch.7 to 10 [HP-HFI-REQ-1370]

IIDB-HFI 3.2 - Ch.7 to 10 [HP-HFI-REQ-1410]

IIDB-HFI 3.2 - Ch.7 to 10 [HP-HFI-REQ-1420]

IIDB-HFI 3.2 - Ch.7 to 10 [HP-HFI-REQ-1400]

IIDB-HFI 3.2 - Ch.7 to 10 [HP-HFI-REQ-1390]

PPLM-IFAS 3.0 [AD-3 a]

PPLM-IFAS 3.0 [AD-2 a]

SRS 3.3 - Ch.5 [SPER-065 P]

SRS 3.3 - Ch.5 [SFUN-015 P]

SRS 3.3 - Ch.5 [SFUN-010 H]

SRS 3.3 - Ch.5 [SCVE-175 H/P]

SRS 3.3 - Ch.6 [SPLA-025 P]

SRS 3.3 - Ch.6 [SPLA-030 P]

IIDB-HFI 3.2 - Ch.5 [HP-HFI-REQ-0220]

IIDB-HFI 3.2 - Ch.5 [HP-HFI-REQ-0290]

IIDB-HFI 3.2 - Ch.7 to 10 [HP-HFI-REQ-1200]

IIDB-HFI 3.2 - Ch.7 to 10 [HP-HFI-REQ-1210]

IIDB-HFI 3.2 - Ch.7 to 10 [HP-HFI-REQ-1220]

IIDB-HFI 3.2 - Ch.7 to 10 [HP-HFI-REQ-1230]

IIDB-HFI 3.2 - Ch.7 to 10 [HP-HFI-REQ-1430]

IIDB-HFI 3.2 - Ch.7 to 10 [HP-HFI-REQ-1440]

2. DOCUMENTS

2.1 Applicable documents

Ref	Reference of Document	Title
AD01	H-P-1-ASPI-PL-0009	Design and Development Plan
AD02	H-P-3-ASP-PL-0668	Planck CQM AIT Plan
AD03	SCI-PT-IIDA-04624	Instrument Interface Document IID-Part A
AD04	SCI-PT-IIDB-04141	Instrument Interface Document IID-Part B, Instrument HFI
AD05	SCI-PT-IIDB-04142	Instrument Interface Document IID-Part B, Instrument LFI
AD06	H-P-3-ASP-TN-0671	Planck CQM Technical Description
AD07	H-P-1-ASPI-PL-0225	Herschel & Planck VPP
AD08	H-P-3-ASPI-TS-0051 Is 2.0	RS for the Plank Cryogenic Facility
AD09	Draft	HFI CQM cryogenic test at CSL Monitoring sensor list
AD10	Draft (dated 28/06/2004)	HFI Cryogenic test specification
AD11	TP-PHZY-300025-LAL	Sequences of HFI telecommands
AD12	NT-PH260-400499-IAS	Description of HFI addition tests and clarification about the already foreseen
AD13	NT-PH260-400500-IAS	Description of HFI addition tests and clarification about the already foreseen.
AD14	PL-LFI-PST-ID-001	LFI-HFI Instrument Interface

2.2 Reference documents

Ref	Reference of Document	Title
RD1	H-P-3-ASPI-TE-0540	Planck CQM family tree
RD2	RP/CSL/PSPA/03002 Is 3.4	Planck Cryogenic Facility - Test Set-up Design Report
RD3	PL/CSL/PSPA/02009 Is 2.1	Planck Cryogenic Facility – S/C Test Sequence Plan
RD4	H-P-3-ASP-TN-0582 Is 1.0	Planck CSL supporting device micro vibration analysis
RD5	TN/CSL/PSPA/04002 Is 1.0	RTAP &Octopussy fonctionnalités
RD6	H-P-3-ASP-AN-0758	RAA Thermal Dummy thermal design justification
RD7	H-P-3-ASP-TN-0814 (I2R0)	Planck CQM Instrumentation plan
RD8	TN/CSL/PSPA/04003 Is 1.0	Cool down and warm-up description
RD9	ADP-LA-1389	Main frame dummy acceptance data package
RD10	H-P-3-ASP-TN-0640	Request for test – Characterisation of microvibration environment of CSL F5 Chamber
RD11	H-P-3-ASP-RS-TS-0650	Planck CQM EMC Test Requirement Specification

RD12	10203001-A	Planck Sorption Cooler electrical schematic
RD13	10203002-B	Planck Sorption cooler piping Instrumentation drawing
RD14	H-P-3-APCO-ES-0049, Iss 1	Equipment Design Specification, SVM Dummy
RD15	H-P-3-ASP-TN-822	PPLM Lower structure dummy - design description
RD16	H-P-3-AIRL-UM-18 (3)A	PACE GSE User Manual
RD17	H-P-3-ASP-TN-0640	Request for Tests – Characterisation of Microvibration Environment at CSL facility
RD18	PR-PHZY-300024-LAL	HFI EGSE Packing and Unpacking Procedure
RD19	TN-PHZY-300021-IAS	Planck HFI EGSE Quick Start Manual
RD20	UM-PHZY-500027-LAL	EGSE User's Manual
RD21	PL-HFI-IAS-TN-1451 3/01	Data acquisition and CSL User's Manual QLA
RD22	PR-PH740-500581-IAS	Procedure validation ISSS-PGSE
RD23	PR-PH740-500559-IAS	DCCU-SA pipes connections procedure
RD24	PR-PH740-500589-IAS	HFI CQM Warm Short Functional Test Procedure
RD25	PR-PH740-500584-IAS	WARM DC Pneumatic Test
RD26	PR-PHD740-500594-IAS	HFI CQM CSL Cryo-Test macro-sequences
RD27	PR-PH740-500583-IAS	HFI dilution cooler precooling & isotope loop leak reat test procedure
RD28	PR-PH740-500617-IAS	HFI CQM monitoring paramters

2.3 Acronyms

AD	Applicable Document
CFRP	Carbon Fiber Reinforced Plastic
CTE	Coefficient of thermal expansion
BOL	Begin of Life
EOL	End of Life
EP	Entrance Pupil
FPA	Focal Plane Assembly
FOV	Field-of-view
PPLM	Planck Payload Module
HFI	High Frequency Instrument
HL	Heat Load
LFI	Low Frequency Instrument
LOS	Line Of Sight
LSS	Lower Structure Support
MOS	Margin of Safety
N/A	Not applicable
PA	Product Assurance

PLM	Payload Module
PR	Primary Reflector
PtV	Pic to valley
RD	Reference Document
RH	Relative Humidity
RMS	Root Mean Square
S/C	Spacecraft
SR	Secondary Reflector
TA	Telescope Assembly
TBC	To be confirmed
TBD	To be determined
WFE	Wave Front Error
wrt	With Regards To

3. TEST SPECIMEN DEFINITION

3.1 Satellite configuration

3.1.1 Overall configuration

From thermal points of view the CQM is fully representative of the flight model of the PLM (including HFI H/W). The main differences are the following (detailed configuration ref. [AD06]):

- No reflector
- No He tanks of the 0.1K dilution cooler, will be replaced by a dedicated external fluidic PGSE (ISSS-PGSE)
- 20 K cooler lines:

PACE Nominal	Replace by thermal dummies including heaters to simulate the allocated heat loads
Nominal 20K sorption cooler compressor	No
PACE Redundant	CQM H/W
Redundant 20K-sorption cooler compressor	Substituted by an external fluidic PGSE (PACE-GSE) in order to fill the PACE subsystem with the right mass flow & pressure

- The SVM is replaced by mass & thermal dummies (SVM Dummy) which provide the requested thermal behaviour in order to perform the verification of the PPLM passive thermal control.
- Cold units of instruments are mechanically and thermally representative, but only few active bolometers are present on HFI.

3.1.2 PPLM configuration

CQM Cryo-Structure and Telescope definition is flight representative, exception made of active thermal control hardware.

A RAA thermal dummy is moreover implemented for CQM tests in order to replace LFI CQM hardware.

3.1.2.1 Active thermal control hardware

3.1.2.1.1 Temperature acquisition

In order to functionally check flight temperature measurements, some flight representative thermal sensors (PT2000 Rosemount) are mounted on PPLM and are acquired during test. These sensors are identified in Table 3-1. Their location is also displayed with test thermal sensors in [RD7].

Item	Description	Location	ID	Neighbour test sensor
Groove 3	Wave Guides Interface1	On Groove (-Y), between WG and DC I/F	8	Di341&2
Groove 3	Wave Guides Interface1	On Groove (-Y), between WG and DC I/F	108	Di341&2
Groove 3	Wave Guides Interface2	On Groove (+Y), between WG and 4KC I/F	9	Di301&2
PR panel	FPU interface2 (+Y)	Between +Y bipod feet	13	Di533&5
PR panel	FPU interface2 (+Y)	Between +Y bipod feet	113	Di533&5
PR panel	FPU interface3 (-Y)	Between -Y bipod feet	14	Di532&4
Baffle	Baffle 1 (Front face)	On Baffle +Z-Y, close to frame attachment	15	Di602&3
Baffle	Baffle 1 (Front face)	On Baffle +Z-Y, close to frame attachment	115	Di602&3
Baffle	Baffle 2 (Lateral face medium)	On Baffle -Y, above braids attachment	16	Di602&3

Table 3-1: "Flight" sensors mounted on CQM

In order to be flight representative in term of heat leaks through the probes harness, all the wires, including those associated to sensors not mounted on CQM, are implemented on PPLM. The cables design (AWG28 Brass), as well as the corresponding routing on structure, are flight representative.

When not used :

- cables PLM side will be stripped and fixed on PLM structure using Kapton (black or Carbon substrate) or CHOFOIL adhesive (Aluminium surface),

- cables SVM side will be connected as flight to dedicated bracket.

Note that, though the fixation process of all CTA hardware on PPLM is qualified at elementary level, the cables and sensors will be fixed as for flight in order to check, on full scale model, all integration activities as well as behaviour in operational conditions. *The corresponding wires length will be measured after cut-to-fit and noted for each cable.*

3.1.2.1.2 Decontamination heating lines

3.1.2.1.2.1 Reflectors

Though reflectors heating lines are not part of CQM configuration (since there are no reflectors), the associated harness is mounted, in order to be representative of associated heat leaks.

Cables PLM side will be stripped and fixed on PLM structure using adhesive. Cables SVM side will be connected as flight to dedicated bracket.

As for thermal sensors, the harness characteristics (AWG24 Brass) as well as the routing and corresponding fixations are flight representative.

3.1.2.1.2.2 FPU

At the time this report is written, LFI flight definition is not known. Test heating lines are though implemented on RAA Dummy main frame in order to simulate flight decontamination heating. The chosen test definition is :

Number of lines : 2 (each line redunded)

Wires : AWG24 Brass

Installed power (under 28V) : 20W per line

Position of heaters : LFI Main Frame external walls (+-Y for line 1 and +X for line 2)

Cables routing on structure is flight representative.

Heaters are covered by SLI in order to limit radiative leaks. The SLI definition is :

Kapton 50μm (Aluminised 1 side -> External side)

Fixation by CHOFOIL

Approximate dimensions : 4 patches 90*140mm² (cut to fit)

Spare PLM EGSE lines are used to power FPU decontamination lines. Correspondence is given here below :

PLM EGSE	Max power	PLM lines	Installed power under 28V (W)
Sorp Cooler Compressor Nom 1	170W	FPU1 nom	20W
Sorp Cooler Compressor Red 1	170W	FPU1 red	20W
Sorp Cooler Compressor Nom 2	170W	FPU2 nom	20W
Sorp Cooler Compressor Red 2	170W	FPU2 red	20W

Table 3-2: FPU Decontamination lines – Link to PLM EGSE

3.1.2.2 RAA Dummy

RAA thermal Dummy design is fully described in [RD9 &15] and justified in [RD6]. In the absence of LFI CQM, the RAA Dummy shall :

→ Provide adequate thermal interface for PPLM passive performance verification.

Table 3-3 shows how LFI – PPLM Interface different aspects are simulated during the test :

LFI-PPLM thermal I/F : RAA Dummy Lower Structure	Simulation during test
Heat loads to Shields	Heaters on shields
V-Groove effect perturbation	Low emissive Kapton bundle (WGs outer envelope)

Table 3-3: LFI-PPLM I/F simulation

Note that the RAA Dummy lower structure is designed so that the radiative exchange with the PPLM remains low (when compared to simulated heat loads).

→ Allow to create a dummy 20K LFI stage compatible with HFI functioning and performance verification.

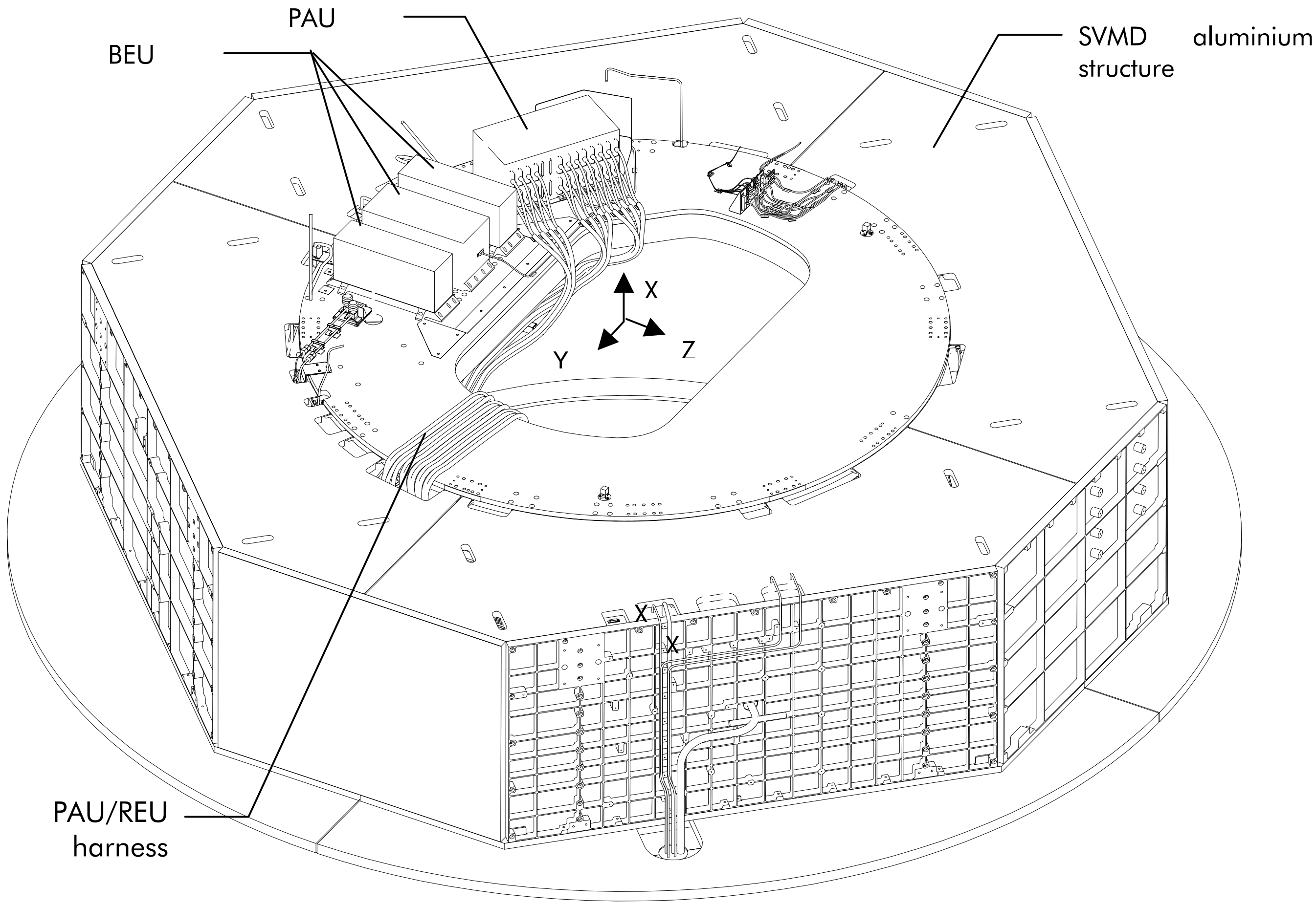
LFI-HFI thermal I/F : RAA Dummy Main Frame	Simulation during test
LFI FPU internal dissipations	Heaters at main source areas
Internal gradients	Flight geometry and material

Table 3-4: LFI-HFI I/F simulation

Note that only representativity on Main Frame internal gradients will be achieved, the gradient induced by the TSA between JPL LVHX and the Main Frame being not reproduced during CQM test. The HFI-LFI interface temperature will therefore be colder during CQM than in flight configuration.

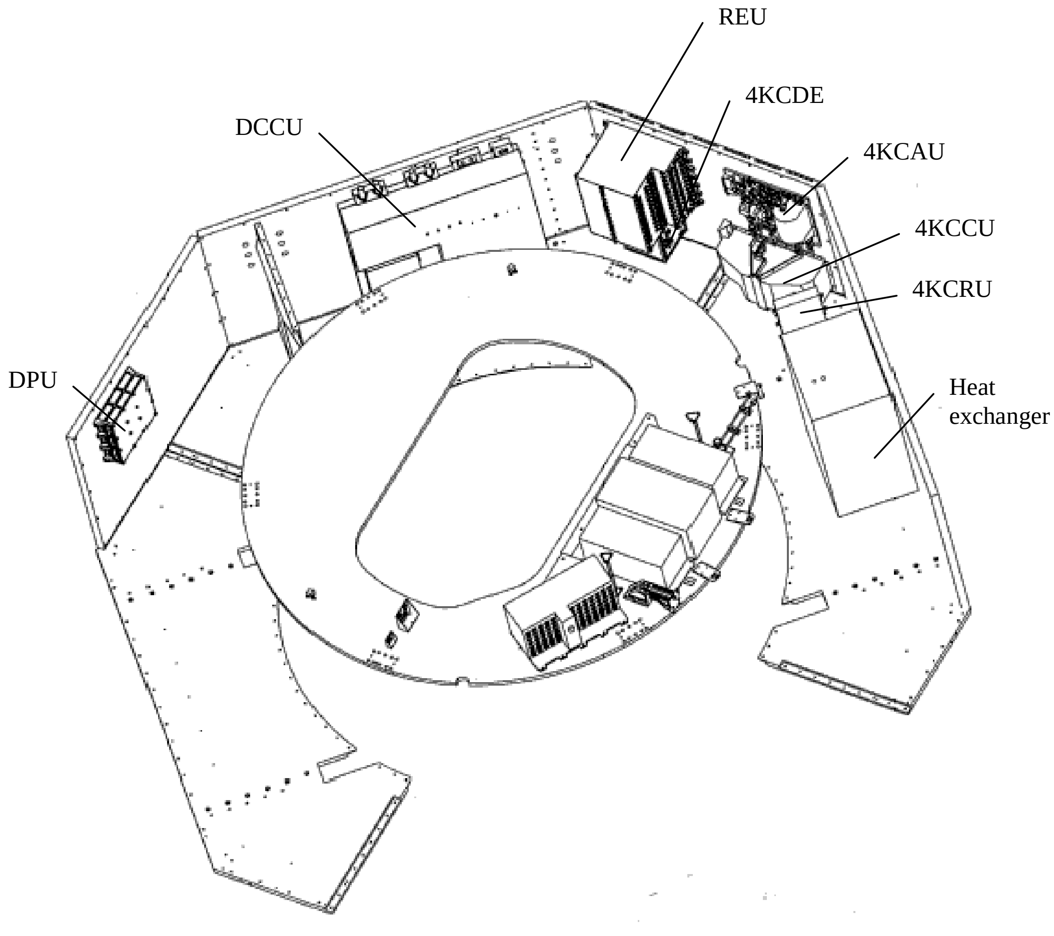
3.1.3 SVM dummy configuration

3.1.3.1 Mechanical configuration



The SVM dummy configuration consists mainly of the:

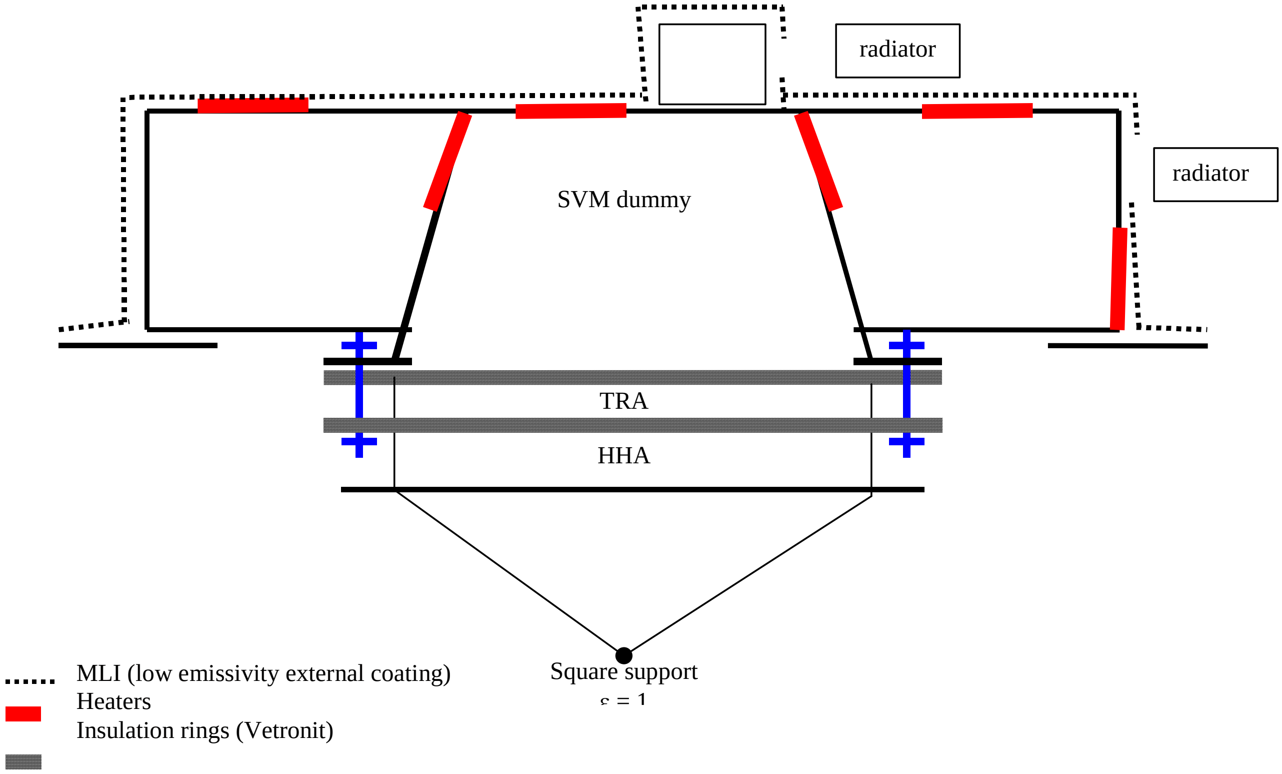
- SVMD itself, an aluminium structure of 950kg
- PAU (13.5kg), BEU (2x8.5kg + 10kg) and PAU/REU harness on the subplatform
- DPU (5.5kg) on the +Z lateral panel
- DDCU (21kg) on the +Y+Z lateral panel
- 4KCCU (18kg), 4KCAU (7kg), 4KCDE (7kg), REU (34kg) on the +Y lateral panel
- 4KCRU on the +Y-Z shear panel
- Heat exchanger (7kg) on the +Y-Z lateral panel and under the lower panel and solar array
- Harness, pipes 0.1K, 4K and 20K, MLI, Active thermal control,….



Details on the mechanical definition of the SVM dummy can be found in document RD14.

3.1.3.2 Thermal configuration

The SVM dummy thermal design in CQM test configuration, can be simplified in the drawing below:



Passive configuration

Five radiators have been implemented (using Z306 black paint) allowing dissipation to be rejected to the test chamber shrouds :

- PACE heat exchanger (+Y-Z)
- 4K WU (+Y)
- DPU (+Z)
- PAU (subplatform)
- BEU MTD (subplatform)

It is to be noticed that DCCU does not require any specific radiator, +Y/+Z panel is totally covered in MLI.

Internal black paint has been applied only on units supporting panels.

The MLI used is of the same type and composition everywhere (20 layers, aluminised on external foil)

All the units are mounted on CHOTHERM filler to improve their contact conductance.

Active configuration

Heating lines	**Location on SVM dummy**	**Address To EGSE**	Number of heaters	Installed power (W)	Maximum intensity (A)	Harness gauge
1	Lateral Panel +Z (DPU)	SVM top (50W)	5	28.6 (50V)	0.57 (50V)	26
2	Lateral Panel +Y+Z (DCCU)	Spare 5 (50W)	5	28.6 (50V)	0.57 (50V)	26
3	Lateral Panel +Y (4K)	Cone/rad (200W)	32	183 (50V)	3.66 (50V)	24
4	Lateral Panel +Y-Z (PACE)	Corner plate (20W)	8	11.5 (50V)	0.91 (50V)	26
5 (N)	Upper closure panel	Spare 1 (60W)	12	69.4 (50V)	1.37 (50V)	26
5 (R)	Upper closure panel	Spare 2 (60W)	12	69.4 (50V)	1.37 (50V)	26
6 (N)	Sub-platform	Cone/rad (200W)	12	69.4 (50V)	1.37 (50V)	26
6 (R)	Sub-platform	Spare 4(60W)	12	69.4 (50V)	1.37 (50V)	26
7	Cone	Cone/rad (200W)	14	80.6 (50V)	1.6 (50V)	26
8	TRA	CSL set up	16	4x68W (28V)	TBD	TBD

Each heating line is made of serie/parallel combination of 15x200mm^2 and 437 Ohms heaters except for TRA.

Heaters installed on lateral panels have been bonded on painted area using film transfer Y966 + corner HYSOL EA 9321 adhesive considering the limited temperature range, the low power density and the limited number of cycles.

For each line, in the event of failure of the main circuit, the redundant circuit can be activated by manual override at EGSE level (double layer heaters, TBC for TRA). Line 5 is supplied by an EGSE line able to provide only 60W (which does not allow to use the maximum power installed 69.4W), For that reason and additionnal power supply line (spare 2) is connected on the redundant circuit of the line 5 to allow more power to be applied.

The same principle has been used on line 6 with the use of the power supply line (spare 4)

In the event of a simultaneous use of both circuits, the maximum power density on heaters could reach 0.38 W/cm^2, whereas standard flight qualification for this type of bonding is 0.16W/cm^2 (this deviation could be accepted considering that EEE 50% derating on non flying hardware is deemed not applicable).

Heating lines are designed with a voltage limited to 50V (although EGSE can supply more on some line). The maximum intensity can reach 1.6 A on gauge 26 (typically limited to 1.5 A) and 3.6 A on gauge 24 (typically limited to 2.5 A). This deviation can be accepted considering that EEE 50% derating on non flying hardware is deemed not applicable.

Line 4 is designed to provide panel interface temperature with PACE exchanger monitored between 260 and 280°K (same as SCC interface specification in flight).

3.1.4 SVM – PLM Interface requirements for passive demonstration

In order to allow PPLM passive performance demonstration, SVM Dummy must provide the PLM adequate thermal interfaces, as recalled here after :

SVM Dummy geometry (areas in view with PLM)

Flight representative. Upper closure panels and subplatform outer sides covered by MLI as for flight.

SVM Dummy MLI outer layer temperature (verified by analyses)

- Upper closure panels and subplatform : 220K
- Solar array : 300K
- BEU & PAU : 235K

PLM struts conductive interface : 310K

Heat loads from electronic boxes (verified by analyses)

Electronic boxes I/F Heat Loads	Required load (mW)
PAU&BEU→Shield1	2760

Table 3-5: Electronic boxes I/F heat loads

3.2 Instrumentation

3.2.1 PPLM and RAA Dummy instrumentation

3.2.1.1 Thermal test sensors

PPLM CQM and RAA dummy will be equipped with 110 thermal test sensors. The chosen thermal sensors are Platinum probes (PT100 S651 Minco) and Silicium diodes (DT470 Lakeshore).

The required sensors distribution over the different elements is schematically presented in Figure 3-1.

Sensors are classified according to their importance wrt test objectives. Table 3-6 presents the groups for sensors classification; 4 groups are defined with corresponding allowable failures.

Sensors classification	Number of probes	Allowable failures
Group A	14	1
Group B	22	2
Group C	68	8
Group D	6	1

Table 3-6: PPLM thermal sensors classification (1/2)

The groups are described here below :

Group A	I/F Sorption Cooler Shield 3
	JFET I/F
	WGs Shield 3 I/F
	Main T° measurements linked to passive demonstration (RAA T° control and heat flux injection)
Group B	Other I/F associated with specification
	Cryo-Chain I/F
	Secondary T° measurements linked to passive demonstration
	Flight sensors control
Group C	Structure T° distribution control
Group D	RAA Main Frame T° control

Table 3-7: PPLM thermal sensors classification (2/2)

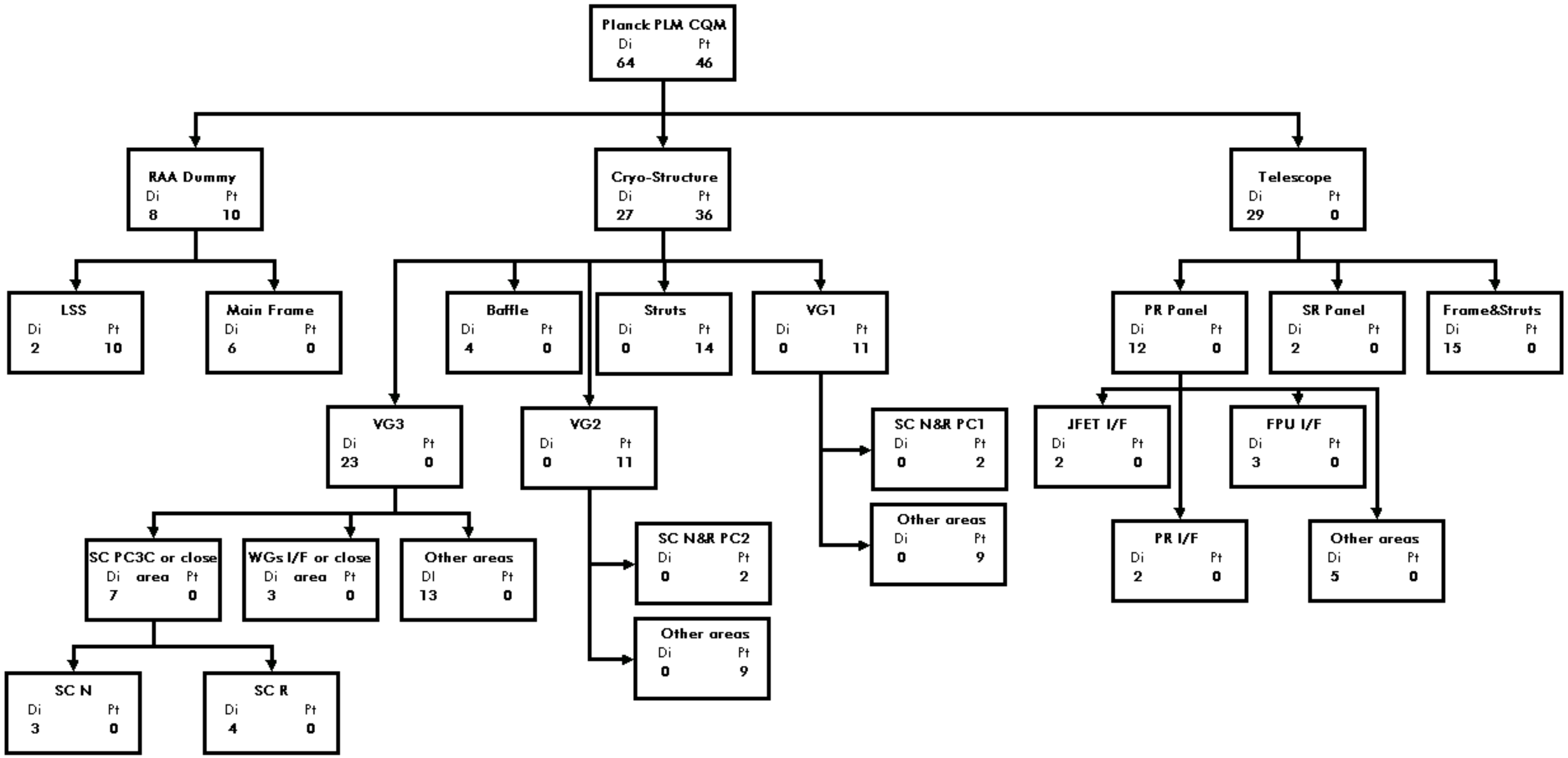


Figure 3-1: PPLM thermal test sensors breakdown

Note that sensors on WG's interface simulating plates are included in RAA Dummy.

The sensors identification, classification and layout are also presented in [RD7].

3.2.1.2 Heating lines

Heating lines functions can be split as follows :

- Allow to simulate LFI RAA thermal interfaces with the PPLM, HFI and JPL
- Inject accurate power at PPLM I/F for passive performance demonstration
- Allow to check PPLM dynamic behaviour

Heating lines are listed in Table 3-8. The heating lines layout is presented in [RD7].

Description	ID	Installed power (W)	Line resistance (Ω)
RAA groove 1	RAAG1_HP	10	178
RAA groove 2	RAAG2_HP	1.5	714
RAA groove 3	RAAG3_HP	1.7	1428
Sorp cool Nom Sh 1	SCNG1_HP	2	1020
Sorp cool Nom Sh 2	SCNG2_HP	2	1020
Sorp cool Red Sh 1	SCRG1_HP	2	1020
Sorp cool Red Sh 2	SCRG2_HP	2	1020
Sorp cool Nom A Sh 3	SCNGA_HP	1	2040
Sorp cool Nom B Sh 3	SCNGB_HP	1	2040
Sorp cool Nom C Sh 3	SCNGC_HP	1	2040
Sorp cool Red A Sh 3	SCRGA_HP	1	2040
Sorp cool Red B Sh 3	SCRGB_HP	1	2040
Sorp cool Red C Sh 3	SCRGC_HP	1	2040
4K cooler	4KCG3_HP	1	1530
JFET	JFETPR_HP	1	2040
Main Frame Area 1	MFR1_HP	0.5	2856
Main Frame Area 2	MFR2_HP	0.4	5712
Main Frame Area 3	MFR3_HP	0.4	5712
Main Frame Area 4	MFR4_HP	0.5	2856
Main Frame Area 5	MFR5_HP	0.5	2856

Table 3-8: PPLM heating lines

Note that all heating lines are redunded.

All lines but one (JFET line) are composed by heaters which are glued on intermediate plates, themselves screwed on the structure to be heated.

Special care is taken for plate screwing (use of elastic washers) in order to guarantee a good thermal contact between the heated plates and the structure. Heater plates are moreover wrapped in aluminised SLI in order to limit radiative losses.

The JFET line is glued on the PR Panel, under the JFET box.

3.2.2 Instruments instrumentation

3.2.2.1 HFI instrumentation

The following temperature sensors need to be adjusted continuously during the cool-down and the warm up in order to avoid saturation : Cryo-HK100mK, Cryo-HK 1.6K, Cryo-HK 4K, Th/Sw 4K/1.6K, Cryo-HK 18K.

These temperature sensor are known under the following acronym by the HPSDB :

- RHC00-TempK (100mK), = Cryo-HK100mK
- RHC01-TempK (1.6K),=Cryo-HK 1.6K
- RHC02-TempK (4K),=Cryo-HK 4K
- RHC09-TempK(1.6K/4K), = Th/Sw 4K/1.6K
- RHC10-TempK (18K)= Cryo-HK 18K

The table which will be used for adjusting these sensors according to their temperature range is in RD26.

3.2.2.2 PACE instrumentation

The accuracy given in this section are the flight ones. All the lines are connected during the test. Nevertheless at PACE-GSE I/F only the nominal lines (heaters/sensors) are connected (Cold redundancy).

3.2.2.2.1 Heaters

The heaters are 2 wires mounting for H33->H25 and 4 wires for H31 & H32. The following table gives their location, resistance, temperature range and control mode required. The corresponding location on the hardware can be found on the Planck Sorption Cooled Electrical schematic [RD11] and Planck Sorption cooler piping Instrumentation drawing [RD13].

Ref	Location	Nominal or Redundant	Resistance* (Ω ± 10 %)	Power range**	Step size	Control mode	Control parameter
H31	LR3	Nominal	480	0 to 2.0	0.01	PID loop	T5
H32	LR3	Redundant of H31	480	0 to 2.0	0.01	PID loop	T5
H33	F9	Nominal	170	4.	N/A	On-Off	User
H36	F9	Redundant of H33	170	4.	N/A	On-Off	User
H34	JT	Nominal	170	4.	N/A	On-Off	User

Ref	Location	Nominal or Redundant	Resistance* (Ω ± 10 %)	Power range**	Step size	Control mode	Control parameter
H35	JT	Redundant of H34	170	4.	N/A	On-Off	User

* : total resistance including associated wiring

** : at nominal voltage /Resistance delivered @ TMU

3.2.2.2.2 Temperature sensors

The temperature sensors are CERNOX Lakeshore CX-1070/CU. The following table gives their location, temperature range and resolution required. The corresponding location on the hardware can be found on the Planck Sorption Cooled Electrical schematic [RD11] and Planck Sorption cooler piping Instrumentation drawing [RD13].

Note: The switch-on of the PACE will be based on ASP test sensors only.

Ref	Location	Nominal or Redundant	Nominal T (K)	Range 1 (K)	Resolution 1 (K)	Range 2 (K)	Resolution 2 (K)
T1	LR1	Nominal	18	16-25	0.01	20-80	1
T2	LR1	Redundant of T1	18	16-25	0.01	20-80	1
T3	LR2	Nominal	20	16-25	0.01	20-80	1
T4	LR2	Redundant of T3	20	16-25	0.01	20-80	1
T5	LR3	Nominal	20	16-25	0.01	20-80	1
T6	LR3	Nominal	20	16-25	0.01	20-80	1
T7	JT	Nominal	20	16-25	0.01	20-80	1
T30	JT	Redundant of T7	20	16-25	0.01	20-80	1
T8	PC3C	Nominal	55	40-80	0.1	80-330	2
T9	PC3B	Nominal	70	40-80	0.1	80-330	2
T10	PC3A	Nominal	80	40-80	0.1	80-330	2
T11	PC2	Nominal	100	80-150	0.1	150-330	2
T12	PC1	Nominal	160	140-190	0.1	190-330	2

3.2.3 SVM dummy instrumentation

The following provision has been made concerning the SVM dummy follow up during the test, detailed location of thermo-couples will be performed when channels allocation is known.

Panel	Monitoring	Thermo-couples provision
DPU (+Z)	Temperature on DPU	3
0.1 K panel (+Y+Z)	Temperature on DCCU	3
4K panel (+Y)	Temperature on REU,CAU,CDE,CCU	10

Shear web (+Y-Z)	Temperature on CRU	3
PACE (+Y-Z)	Temperature on heat exchanger	4
Sub platform	Temperature on PAU/BEU MTD	7
Sub platform / upper closure	Radiative flux to PLM	14
Struts interface point	Conductive flux to PLM	6
Cone	Thermo-elastic behaviour/correlation	6
Solar array back side	Radiative flux to PLM	4
Interface ring/TRA/HHA	Conductive correlation for PFM	10
SVM	Attrition	10
TOTAL		80

3.2.4 Microvibration instrumentation

3.2.4.1 Sensors

Only acceleration measurements shall be conducted. The following accelerometers will be used:

- ENDEVCO 2271 and 7703.
- Filotex CAS 250-20P cables

They are compliant with the following:

- Bandwidth up to à 300 Hz.
- Sensitivity : the sensors shall be able to measure vibration levels down to 10^{-13} g^2/Hz within the above specified frequency band.

All acceleration levels shall be measured **simultaneously.**
All accelerometers shall be mounted on a rigid interface

3.2.4.2 Acquisition System

The acquisition system shall be such that the noise floor be below 10^{-14} g^2/Hz during measurement.

All signals shall be low pass filtered above 300 Hz (max). The analogue filter slope shall be higher than 24 dB/Oct.

Sampling frequency: 2048 Hz

Number of averages: 30 (no overlap)

Acquisition duration: 30s
Windowing: Haning

3.2.4.3 Instrumentation

Accelerometers shall be located as follows (detailed location is provided in [RD7]):

Type	Location	Reference	Co-ordinate Frame
tri-axial accelerometer type 2271	on the PR panel at the FPU Interface (T=40K)	FPU01_X	Local to RDP (see [RD7])
		FPU02_Y	
		FPU03_Z	
tri-axial accelerometer type 2271	on the LFI at the HFI/LFI Interface (T=20K)	FPU11_X	Local to RDP (see [RD7])
		FPU12_Y	
		FPU13_Z	
tri-axial accelerometer type 7703	on the SVM at the PLM/SVM Interface	PLM21_X	Satellite (see [RD7])
		PLM22_Y	
		PLM23_Z	
tri-axial accelerometer type 7703	on the panel at the 4K compressor Interface	P4K31_X	Satellite (see [RD7])
		P4K32_Y	
		P4K33_Z	
tri-axial accelerometer type 7703	on the frame at the SC Interface	SC51_X	Satellite (see [RD7])
		SC52_Y	
		SC53_Z	
		SC61_X	
		SC62_Y	
		SC63_Z	

– CSL shall monitor acceleration at its IF with the test item. 1 tri-axial accelerometers shall be located at each of the 3 interfaces of the bracket with the spacecraft (see Figure 4-11 for accelerometer location).

– ASP does not specifically require to CSL the monitoring of the accelerations at the feet of the supporting bracket. Nevertheless, the ASP data acquisition system used for S/C sensors will be used to master the instrumentation located at theses interfaces (ref § 4.9.3.2).

4. CQM TEST SET-UP

4.1 Main constraints wrt to the facility

Due the unavailability of the sorption cooler compressors there is no constraint wrt to the S/C orientation and horizontality performances for the CQM. Nevertheless, in order to check during the CQM test the FM constraints, the satellite will be oriented with its X-axis horizontal and oriented (around X) so that the dummy radiator of the redundant sorption compressor is horizontal and facing the bottom of the chamber.

4.2 Test configuration

4.2.1 Mechanical configuration:

For the CQM test, the spacecraft is maintained in the chamber by the SVM dummy interface through a specific MGSE:

- Thermal Ring Adapter (TRA ≈ 58 Kg) (Thermal part will be used only to perform the SVM thermal balance; zero flux);
- Horizontal Hosting Adapter (HHA ≈ 380 Kg) will be the interface with the CSL test support by 3 pines.

The general configuration is shown on Figure 4-1.

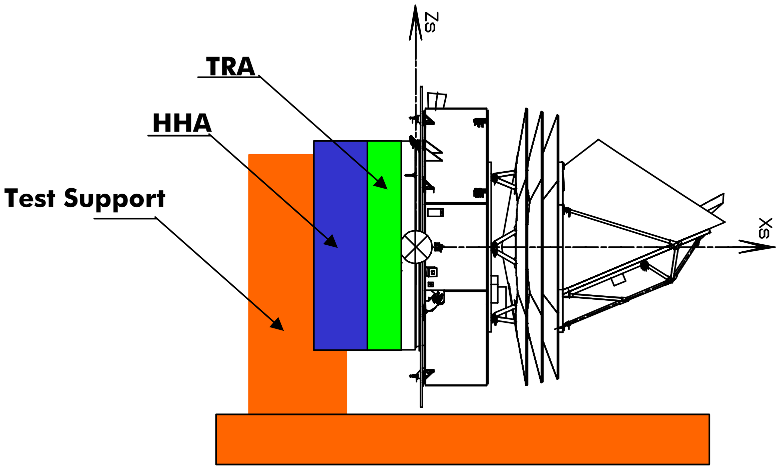


Figure 4-1: Test support and test adapters.

4.2.2 Thermal configuration

To allow the passive cooling of the PLM, a cryogenic shroud at a temperature lower than 20 K will surround the cold part of the spacecraft (above the upper SVM platform).

To allow the thermal control of the SVM, the warm part of the spacecraft will be surrounded by a cryogenic shroud at a temperature lower than 100K.

The shrouds will be covered by black painted open honeycomb in order to absorb S/C radiated flux. Screens will also be implemented in order to cut radiative exchanges between hot SVM and cold PLM parts.

To allow the functional test of the experiments, an optical cryogenic shield < 5K will be placed in front of the FPU horn apertures (see section 4.4).

4.2.3 Spacecraft orientation to test the redundant 20K cooler

To operate the redundant 20K cooler the spacecraft will be oriented with its SVM panel +Y/-Z horizontal and facing the ground. (See Figure 4-2).

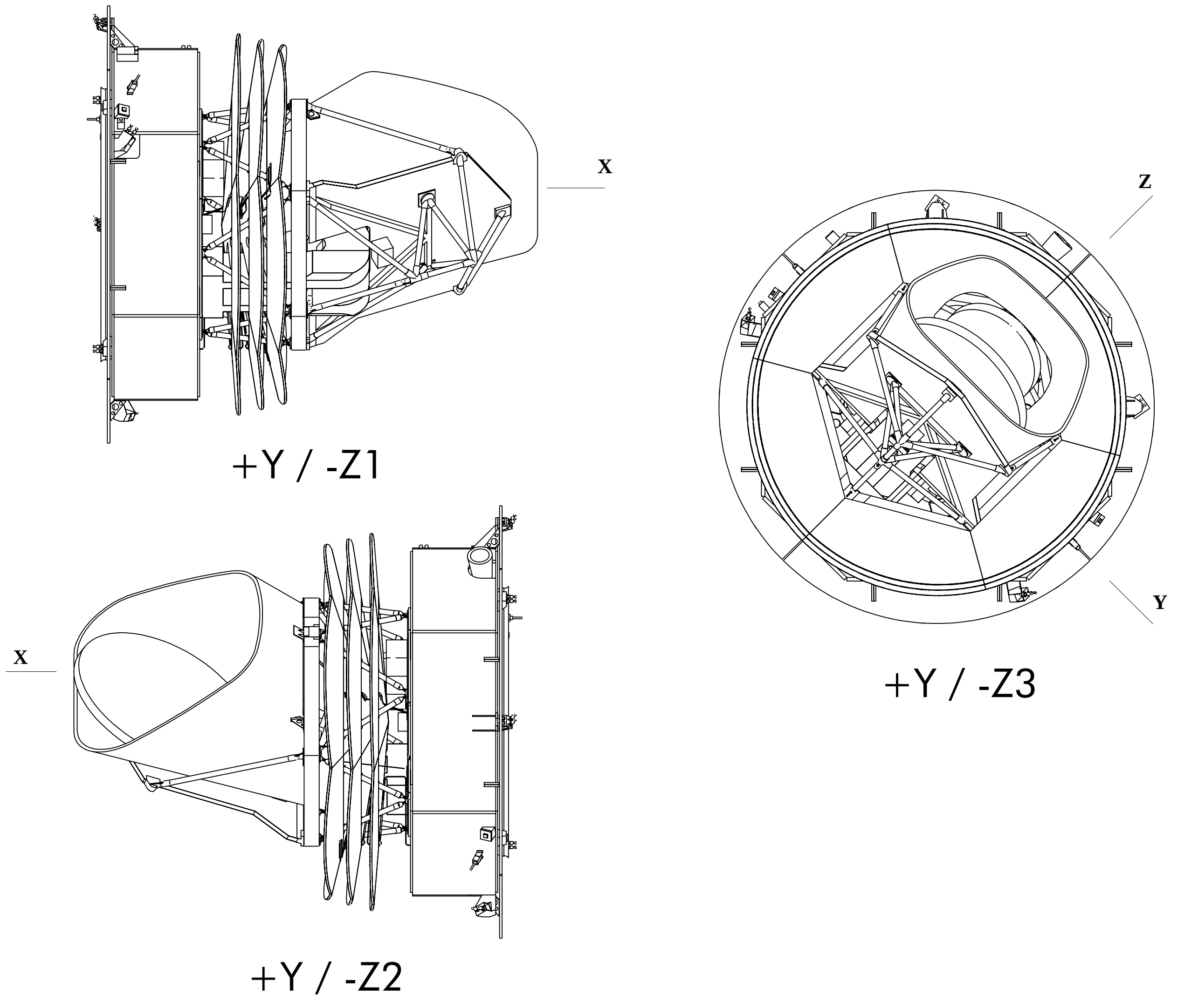


Figure 4-2: S/C orientation to test the redundant 20K cooler.

4.3 Proposed test setting

The proposed test set-up is shown on Figure 4-3 and the shroud configuration is shown on Figure 4-7 (CATIA views). The cold part of the PLM is surrounded by a He shroud cooled at a temperature lower than 20K. The LN2 shroud allows to limit the heat loads on the He shrouds and to simulate the deep space environment for the cooling of the warm part of the spacecraft (SVM dummy for the CQM).

The temperature of the N2 shrouds is adjustable in order to allow the thermal cycling of the SVM during the thermal vacuum test of the PFM satellite

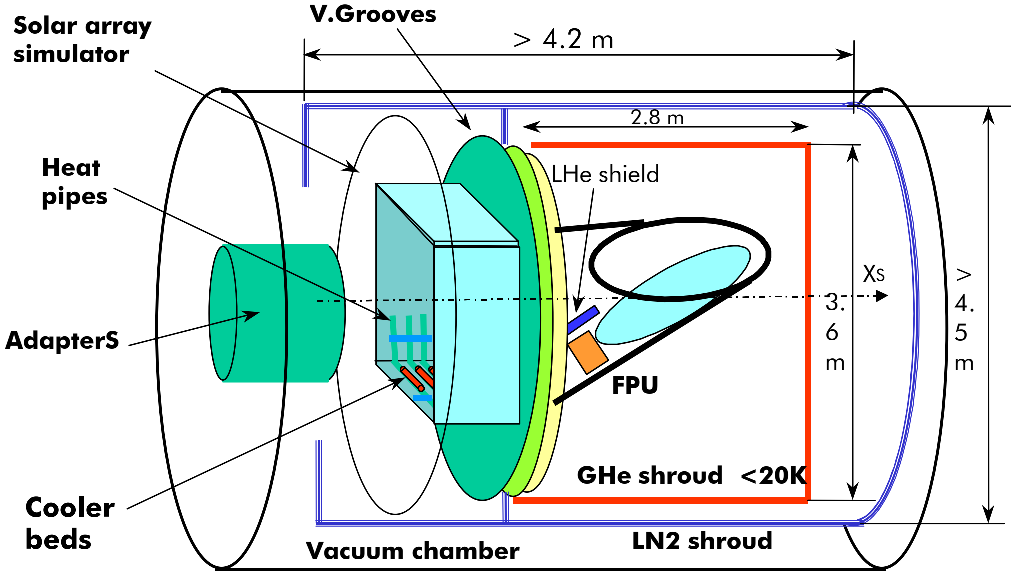


Figure 4-3: Thermal & cryogenic test configuration of Planck

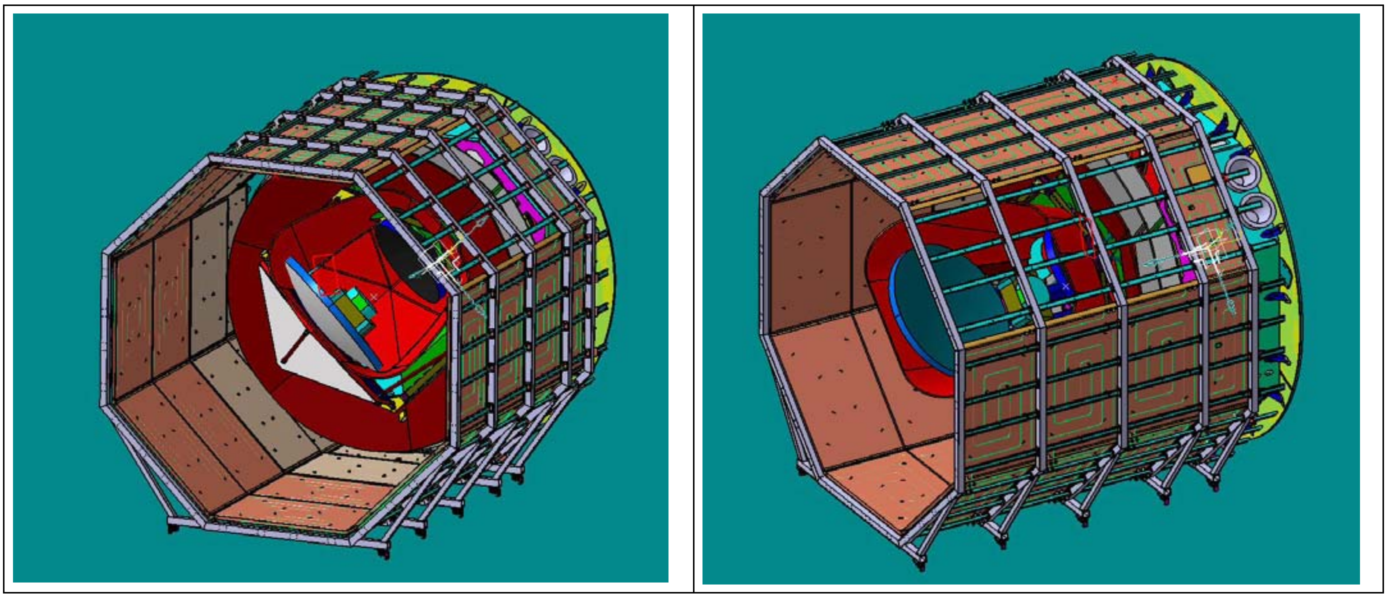


Figure 4-4: Test set-up Shrouds configuration

4.4 The Cold Target

The main objective of the cold target is to avoid the saturation of instrument sensors by reducing the radiated background seen by sensors and to produce a stable target at low temperature (as far as possible compatible with flight like conditions). This "Cold Target" used to perform the Planck instruments functional test is composed of:

- Optical Shield (helium bath).
- ECCOSORB sub-assembly (pyramids of ECCOSORB panels bounded on Pure Aluminium plate) provided by Officine Pasquali.

The figures here after show 3D CATIA views of the optical shield configuration during the test.

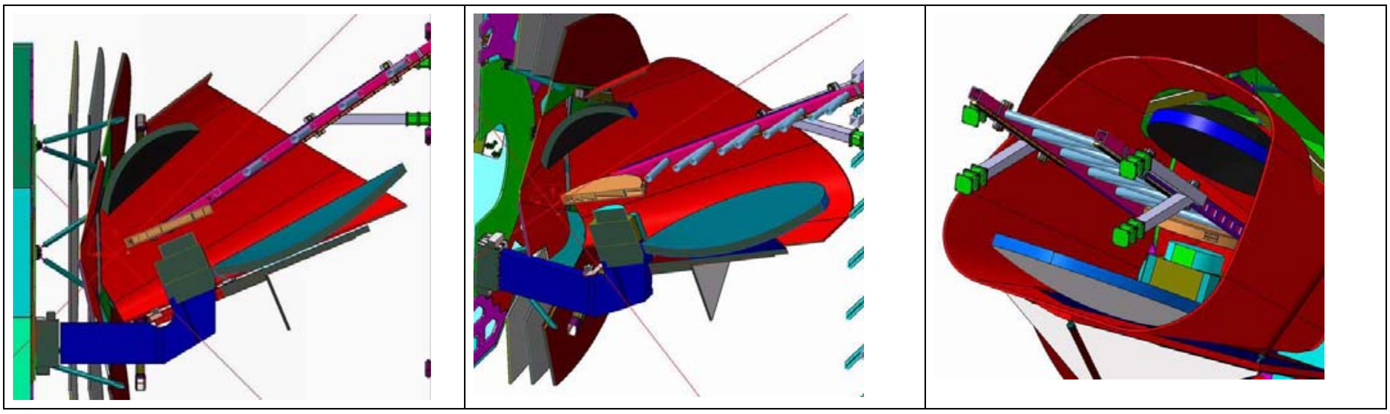


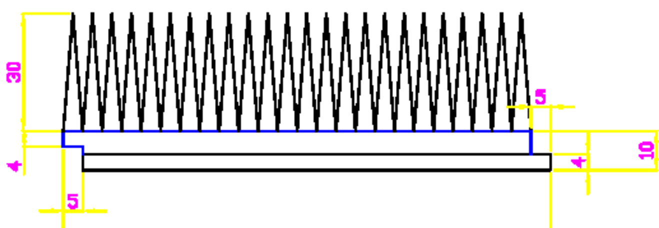
Figure 4-5: Optical shield configuration

ECCOSORB sub-assembly will cover the inner face of the optical shield. This subsystem will be composed of Eccosorb CR1110 pyramid panels fixed by screws on a pure aluminium plate. The instrument team has defined the shape of this material. The layout of the CR1110 pyramid panels onto the pure aluminium plate has been designed in order to cover at least a circle of 600mm of diameter.

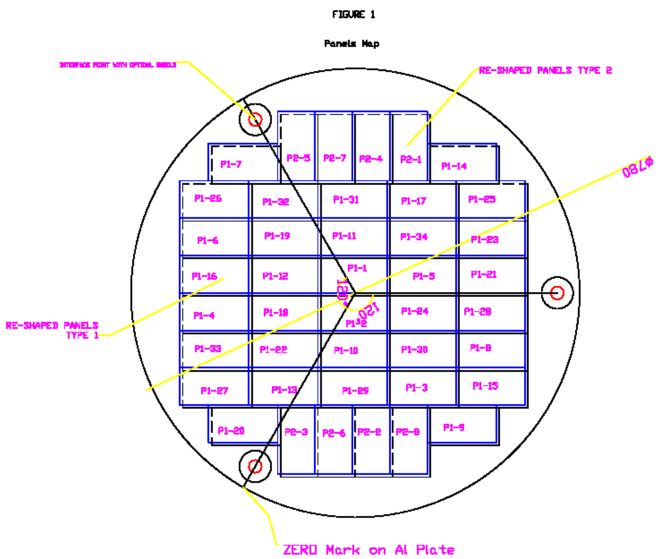
Pyramid side: 5mm

Pyramid height: 30mm

Pyramid load thickness: 10mm



Aluminium Base: 5mm



The design and the installation process are compatible with the allocated volume for the installation of the optical cryogenic shield.

The following requirements will be applied during the instrument measurement period at the CSL helium bathI/F:

- The temperature of the optical shield will be lower than 5K during the measurement period.
- The temperature homogeneity over the optical shield surface will be better than or equal to 0,1K.
- The temperature stability will be better than 1 mK/minute any time during noise measurements.

The introduction of the ECCOSORB sub-assembly will impact the following parameters of the optical shield:

- The temperature of the cooper I/F panel will be increased by around 0,3K but lower than 5K during the measurement period.
- The temperature of the Eccosorb pyramids will be higher than copper I/F panel.

4.5 Mechanical stability and micro-vibrations

The dilution cooler is susceptible to micro-vibrations, which could be created by the pumping system, and by the circulation of the cryogenic fluids and the 4K compressor.

The table here after shows the specified level at FPU I/F. The expected values during the Planck tests (FM & CQM cofiguration) are available in coupled analyses done by Alcatel (ref. RD[04]).

Spec	Bandwith (Hz)	Level I/F FPU (grms) (1)	Axis combination ORDP Axis (2)
1	0-30	2,50E-03	SQRT(x2+y2+z2)
2	30-200	2,00E-03	SQRT(x2+y2+z2)
3	50-70	2,00E-04	SQRT(y2+x2)
4	120-160	2,00E-04	z

Table 4-1: μ-vibration requirement

(1) Instrument specification

(2) Type of axis combination for the specified level

The CSL Facility will only on the following figures given at CSL S/C support I/F points:

- 2.7 10^{-4} grms within bandwidth [10-70]Hz
- 3.8 10^{-4} grms within bandwidth [70-200]Hz

4.6 Cleanliness and cleanliness control

The following cleanliness requirements are deduced from the HERSCHEL / PLANCK cleanliness control plan.

Req N°		Value	Comment
CR-2	Particular contamination	class 10000	During the total duration of the test (including preparation and post vacuum activities)
CR-2	Particular contamination	<145 ppm	From the baffle protective film removal, before the cryo vacuum cycle up to its reinstallation after cryo vacuum cycle.
CR-3	Molecular Contamination	<2 10^{-7} g/cm²	During the total duration of the test (including preparation and post vacuum activities)
CR-4	Molecular Contamination	<4 10^{-8} g/cm²	From the baffle protective film removal, before the cryo vacuum cycle up to its reinstallation after cryo vacuum cycle.

Contamination witnesses and particulate counter will continuously monitor the cleanliness outside the chamber. Contamination witnesses and spectro-analyser will continuously monitor the contamination inside the chamber. This task including witness analysis is fully under the responsibility of the test facility contractor.

In order to limit molecular contamination of the specimen during the transition phases of the cryogenic shrouds, a cold trap will be installed inside the chamber and in the vicinity of the specimen.

To avoid any risk of moisture condensation on the specimen during the pressure recovery sequence, the following steps will be done:

- Fill the vacuum chamber with GN2 until 300 mbar
- Continue with filtered dry air until 1000 mbar with an adapted atmospheric speed recovery.

4.7 CQM Test GSE Configurations and interfaces

4.7.1 EGSE configuration

The Figure 4-6 shows the configuration of EGSE used to operate the spacecraft and for performance testing during the CQM test campaign. These EGSE are grouped to form a spacecraft station. The instrument EGSE interfaces with the spacecraft CCS.

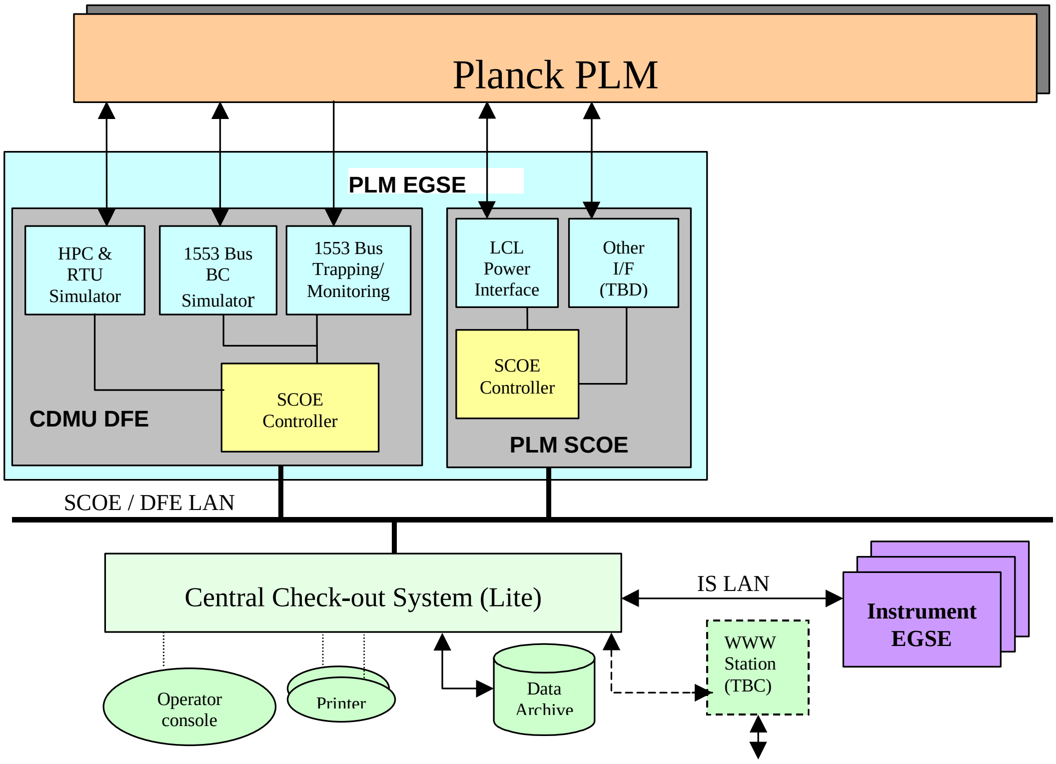


Figure 4-6: S/C Configuration of spacecraft EGSE for CQM

The detailed EGSE configuration for the CQM test is described hereafter.

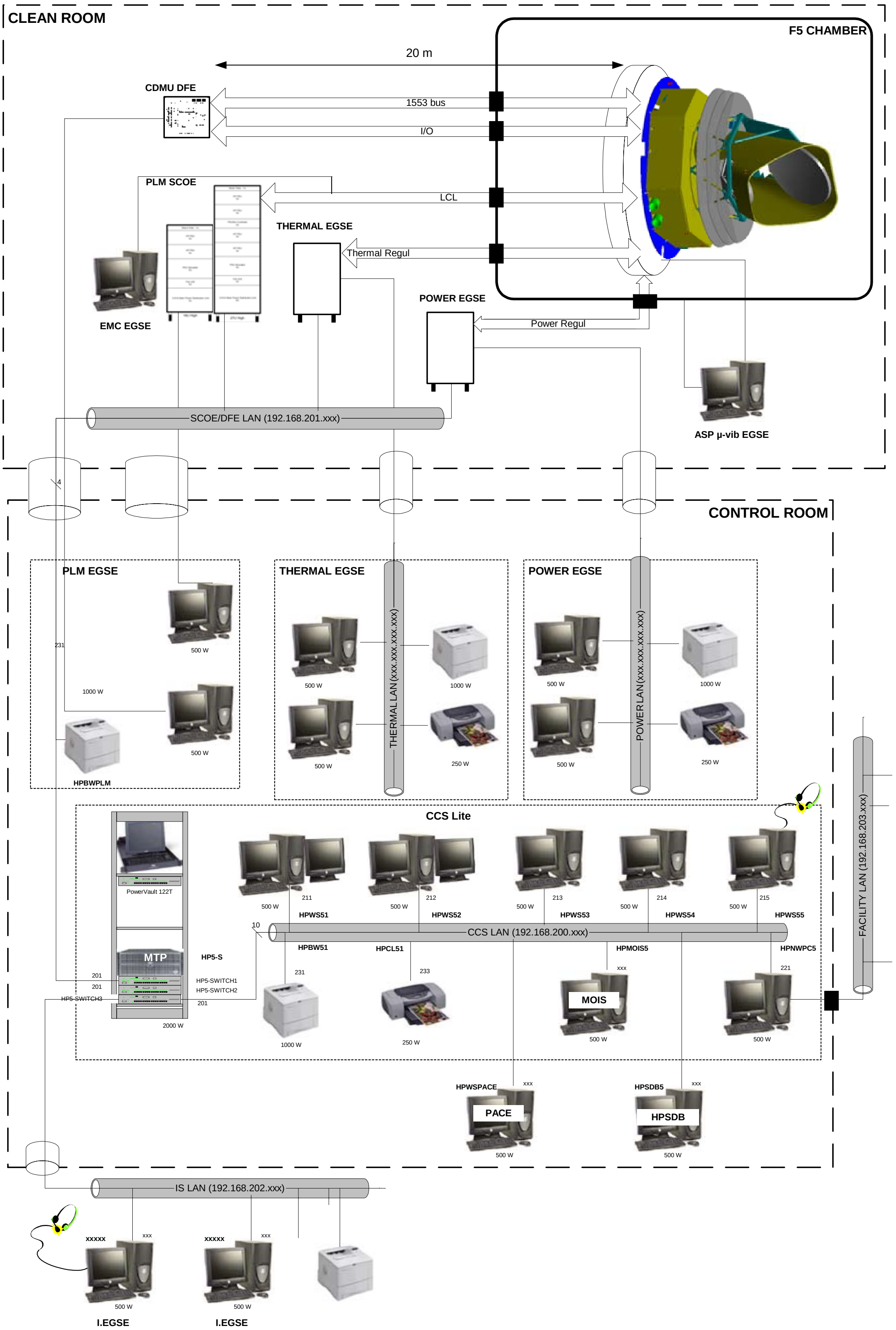


Figure 4-7: Detailed EGSE configuration for the CQM test

4.7.2 PGSE configuration

An "ISotope Supply & Storage Pneumatic Ground Support Equipment" supplied by HFI will be used to:

- Fill the 0.1K Focal Plane to low pressure with required isotopes purity (He_3 and He_4).
- Accelerate the cooling down of the HFI FPU with the Precooling loop (in/out).
- Recover and store the He3/He4 mixture during ground tests.

A "PACE Ground Support Equipment" supplied by Alcatel will be used to:

- Fill the hydrogen Piping Assembly and Cold End (PACE) with the requested flow and pressure.
- Exhaust hydrogen coming from the PACE outside the building.
- Monitor and Power-up the PACE temperature sensors & heaters

The Figure 4-8, extracted from the PACE user manual [RD15], shows the layout of the hydrogen test bench.

A short description of the fluidic equipment of PACE GSE test bench is available hereafter.

We can distinguished 4 main sub-assemblies :

- some equipment installed outside near the H2 cylinder
- some equipment installed inside a gas cabinet in CSL building near the vacuum chamber
- some equipment located inside the ‘FOCAL5’ vacuum chamber
- some equipment (flame arrestor + CV800) located on the roof of the CSL building

The B50 cylinders will be installed outside the CSL buildings within 4 racks of 9 to 12 B50 cylinders each. All the cylinders inside a same rack shall be manifolded together and the manifold shall end by a main isolation valve (V1a & V1b on theFigure 4-8).

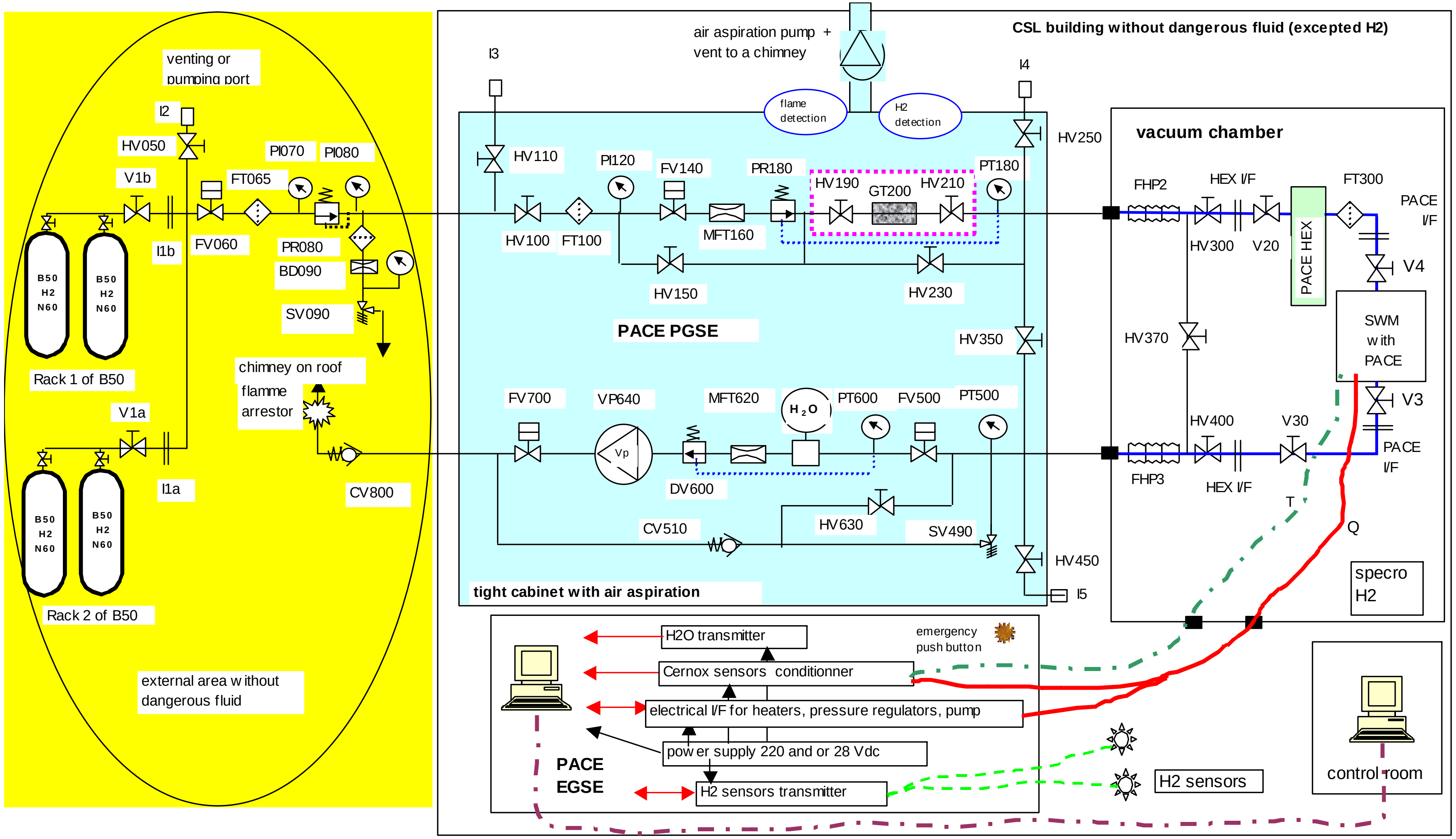


Figure 4-8: PACE GSE Test bench

4.7.3 Thermal & Power EGSE

A "Power regulation EGSE" will be used to inject a regulated power to the test heater lines:

- Simulation of instrument H/W power dissipation onto the PPLM and LFI Main Frame STM.
- Power the MTD.

A "Thermal regulation EGSE" will be used to obtain the requested temperature by injection of power (for programmatic constraints this regulation will be done manually based on measurement done by the facility acquisition system):

- Regulation of SVM dummy parts (cone/radiators)
- Upper plateform
- Cryo structure struts I/F with SVMD

The table hereafter summarised the breakdown of the available lines wrt to the 2 EGSE.

Thermal EGSE		Power EGSE	
Heating lines	Installed power (W)	Heating lines	Installed power (W)
SVMd TOP	50	RAA groove 1	10
Cone/radiator 1	200	RAA groove 2	1.5
Cone/radiator 2	200	RAA groove 3	1.7
Cone/radiator 3	200	Sorp cool Nom Sh 1	2
Corner plate 1	20	Sorp cool Nom Sh 2	2
Corner plate 2	20	Sorp cool Red Sh 1	2
Corner plate 3	20	Sorp cool Red Sh 2	2
Struts	20	Sorp cool Nom A Sh 3	1
Spare 1	60	Sorp cool Nom B Sh 3	1
Spare 2	60	Sorp cool Nom C Sh 3	1
Spare 3	10	Sorp cool Red A Sh 3 1	1
Spare 4	60	Sorp cool Red B Sh 3 1	1
Spare 5	50	Sorp cool Red C Sh 3 1	1
Spare 6	20	0.1K cool Sh 1	1
		0.1K cool Sh 2	1
		0.1K cool Sh 3	1
		4K cooler	1
		JFET	1
		Bellow 1	0.4
		Bellow 2	0.4
		Bellow 3	0.4

Thermal EGSE		Power EGSE	
		Main Frame Area 1	0.5
		Main Frame Area 2	0.4
		Main Frame Area 3	0.4
		Main Frame Area 4	0.5
		Main Frame Area 5	0.5
		PAU MTD	20
		BEU MTD	20
		Spare 2	2

4.7.4 PLM EGSE

A few PLM EGSE power lines are used to feed FPU Decontamination lines.

PLM EGSE	Max current	Operating voltage
Sorp Cooler Compressor Nom 1	6A	28V
Sorp Cooler Compressor Red 1	6A	28V
Sorp Cooler Compressor Nom 2	6A	28V
Sorp Cooler Compressor Red 2	6A	28V

Table 4-2: Used PLM EGSE power lines

4.8 Vacuum Chamber Interfaces

TheFigure 4-9 shows the interface configuration used to operate the spacecraft and for performance testing during the STM/CQM test campaign.

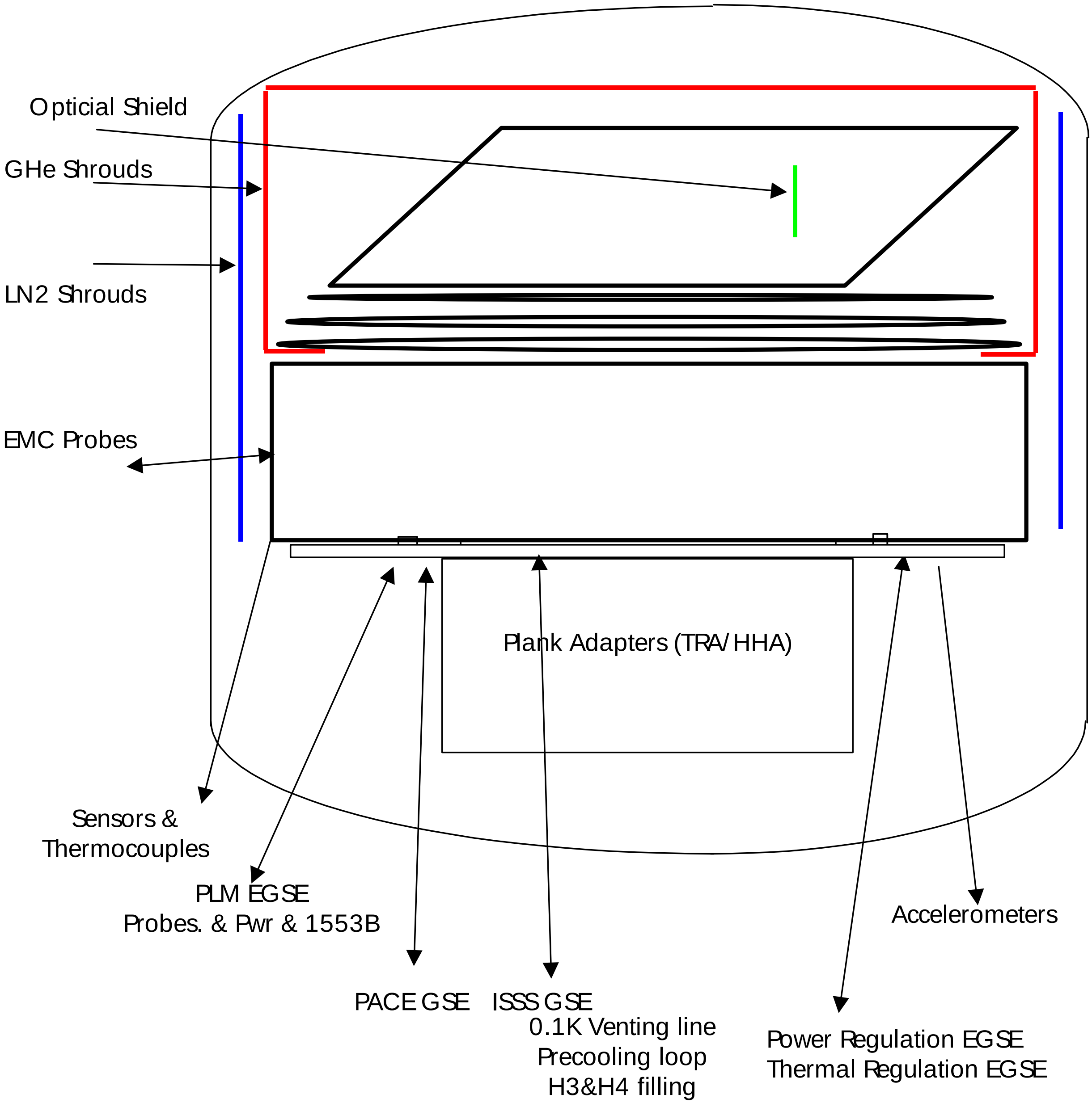


Figure 4-9: CQM Interface configuration

4.9 Facility Instrumentation

Major part of the information presented in this section has been extracted from [RD02].

4.9.1 CSL acquisition system

The figure hereafter presents a general view of the CSL acquisition system.

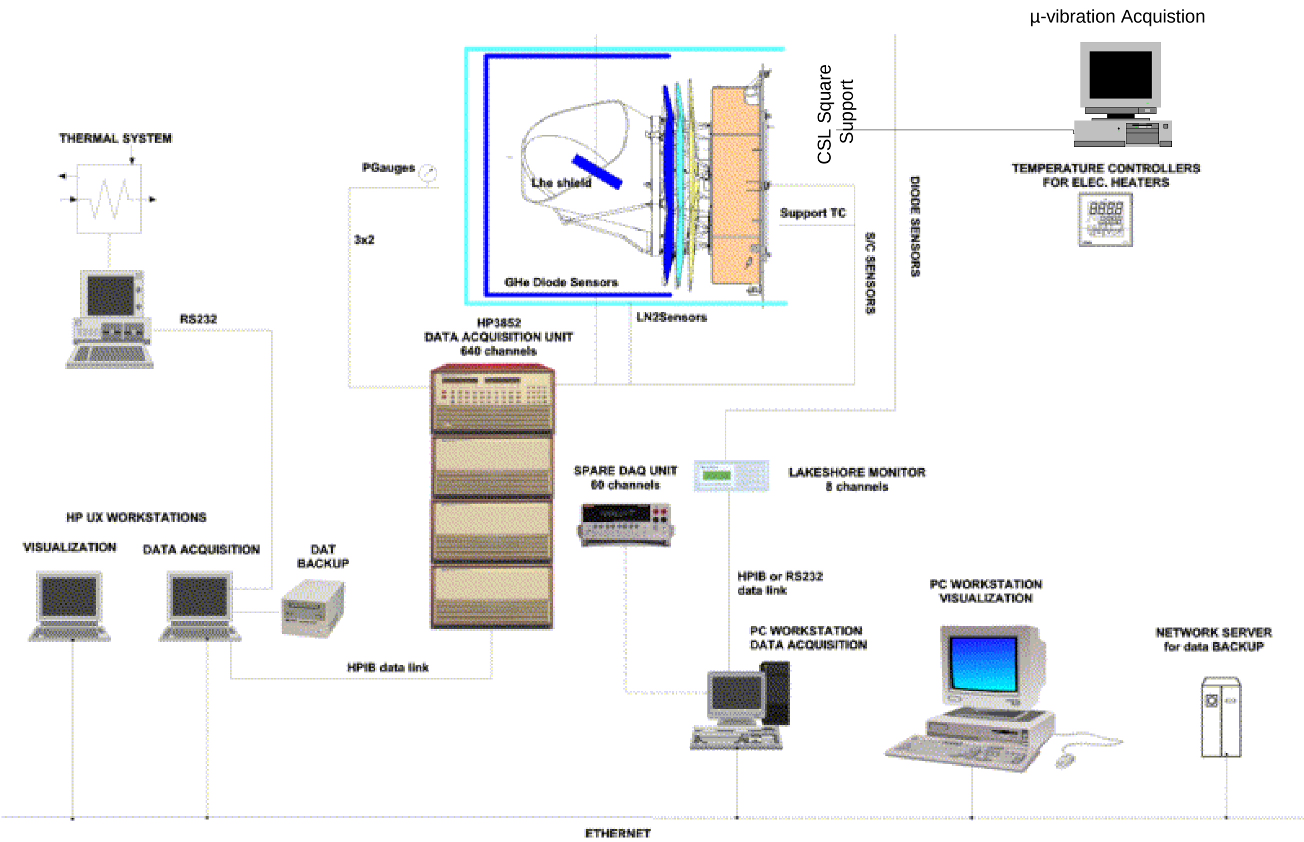


Figure 4-10: CSL acquisition Layout

The data acquisition of Focal 5 is realised by a data logger HP 3852. This data logger is connected, via internal network, to two HP9000 workstations running with industrial standard operating systems and software tools: HP-UX, X-windows, NFS, RTAP.

A second datalogging system for the optical shield is realised by a Lakeshore monitor and a PC. This PC will be equipped with Agilent VEE software and a HPIB link or RS232 connected to the Lakeshore sensors.

Data backup of this PC will be done daily on CSL Servers.

A spare Keithley 2701 datalogger will be added to this system with a smaller capacity (60-80 chnls) to serve as a temporary backup in case of failure of the main datalogger.

RTAP (ref RD[05]) for the real time acquisition

- To be configured before the test
- Acquisition: (1 acq/min)
- Thermocouples T.

- Thermocouples with coefficients (client).
- PT100 4 wires.
- PT500 4 wires.
- Thermistances 2 fils.
- Sensors Cryo.
- Pressure (Membranovac & Combivac).
- Tension.
- Automatic backup on DAT tape every 24h.

Octopussy (ref RD[05]) for the data management

- Can be configured during test
- Maxi 6 graphs per screen (total 48 series).
- Historian online on last 24h (cache) + function 'quasi' real. time
- Historian offline Min.-Max. ou average.
- Zoom.
- For the following data:
  - T° (K et °C).
  - Gradients, averages (t°).
  - Pressure (mBar).
  - Tension (V).

4.9.2 Temperature Sensors breakdown

The table here after presents the thermal instrumentation of the CSL set-up

localisation	Type	Sensor qty	Datalogger chnl
Square support monitoring	TC-T	6	6
LN2 shrouds around PLM	TC-T	24	24
LN2 shrouds cover	TC-T	8	8
Square support regulation	PT100	2	0
LN2 shrouds around SVM monitoring	PT100	16	32
LN2 shrouds around SVM regulation	PT100	16	0
LN2 shrouds closure active shrouds	PT100	8	16
Harnesses (regulation)	PT100	4	0
piping at interface (regulation)	PT100	6	0
cold panel	PT100	2	4
Helium piping	DI	4	8
Cryopump	DI	2	4

localisation	Type	Sensor qty	Datalogger chnl
GHe shrouds around PLM	DI	24	48
GHe shrouds around PLM gradient	DI	4	8
GHe shrouds cover	DI	8	16
LHe optical shield	DI	5	5
TOTAL		139	179

SUBTOTAL per sensor type	TC-T	38	
	PT100	54	
	DI	47	
		139	

TheFigure 4-13 presents the thermal sensors localisation on He shrouds.

The Figure 4-14 presents the thermal sensors localisation on Liquid Nitrogen shrouds.

4.9.3 Facility Micro Vibration Sensors localisation

4.9.3.1 CSL IF With Test Specimen

The CSL square support will be equipped by 3 tri-axes mounted close to the HHA I/F points. The figures here after show the localisation of these sensors.

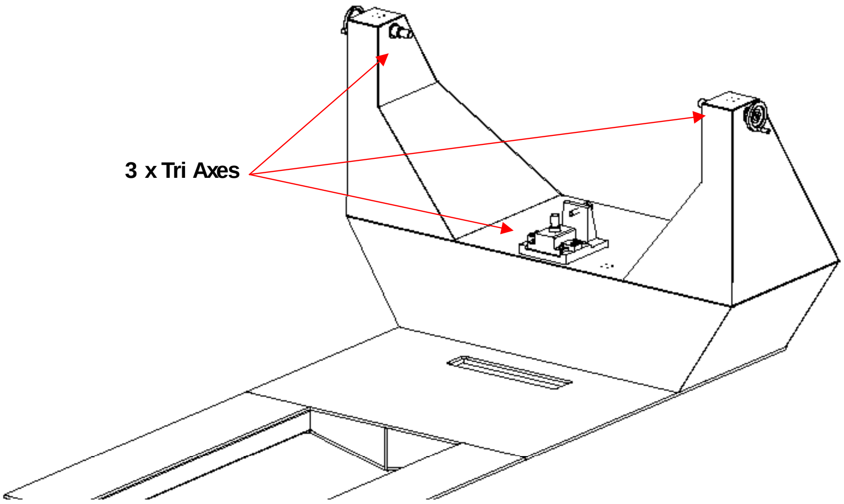


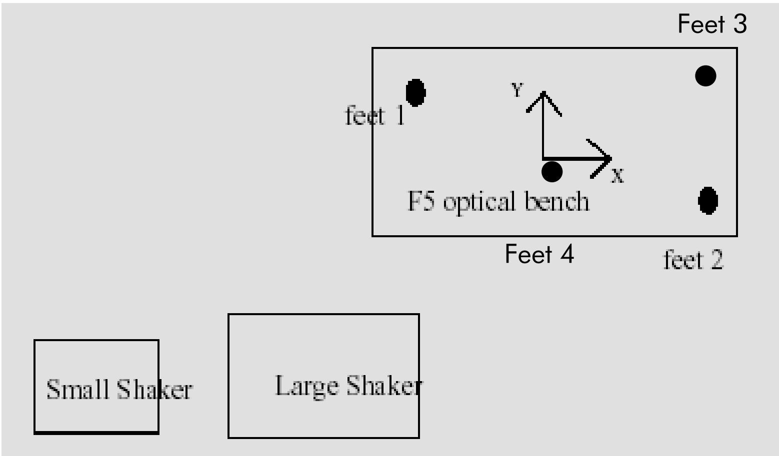
Figure 4-11: : Micro Vibration Sensors localisation

4.9.3.2 Square Support feet IF

Tri-axial sensors shall be located at the base of the square bracket feet (see Figure 4-12). A total of 2 shall be located at feet 1and 2. They shall be oriented in order to meet the X, Y and Z direction.

Uni-axial accelerometers shall be located at the base of the feet (see Figure 4-12). A total of 3 shall be available. 1 shall be located at feet 3 in Z direction. 1 shall be located at feet 4 in Y direction. 1 shall be located at feet 4 in Z direction.

The location shall be coherent with the location specified within [RD 17].



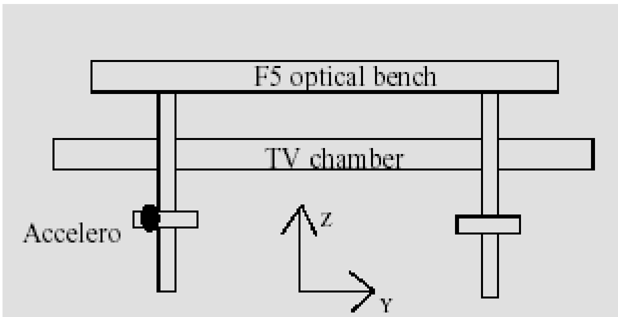


Figure 4-12: General View of Accelerometer locations

The table below provides accelerometer type and labelling

Type	Location	Reference	Co-ordinate Frame
tri-axial accelerometer type 7703	Square Support Feet 1	Feet171_X	Chamber (see [RD7])
		Feet172_Y	
		Feet173_Z	
tri-axial accelerometer type 7703	Square Support Feet 2	Feet281_X	Chamber (see [RD7])
		Feet282_Y	
		Feet283_Z	
Uni-axial accelerometer type 7703	Square Support Feet 3	Feet393_Z	Chamber (see [RD7])
Uni-axial accelerometer type 7703	Square Support Feet 4	Feet4102_Y	Chamber (see [RD7])
		Feet4103_Z	

For sensor type and acquisition system see section 3.2.4.

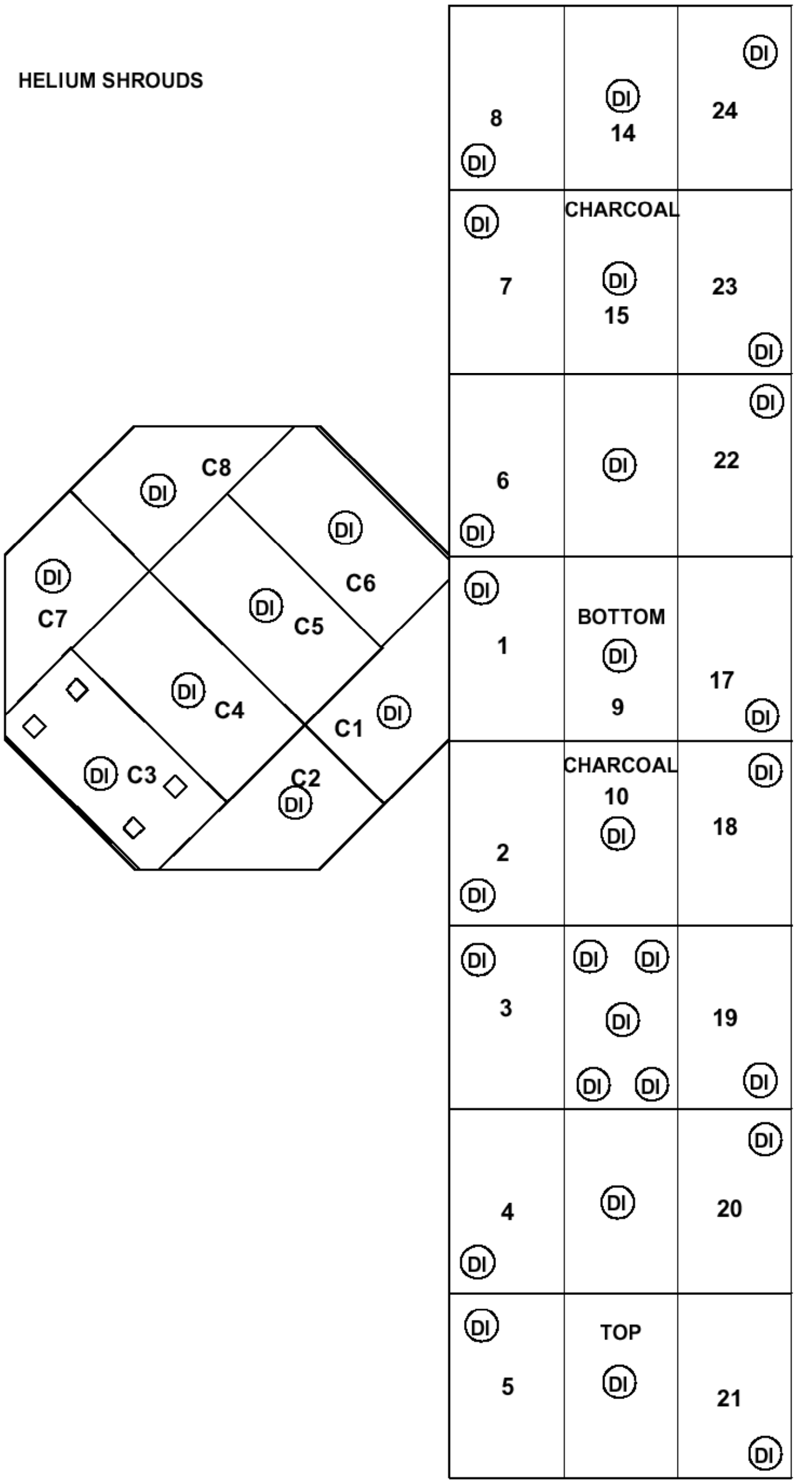


Figure 4-13: Thermal sensor localisation on He shrouds

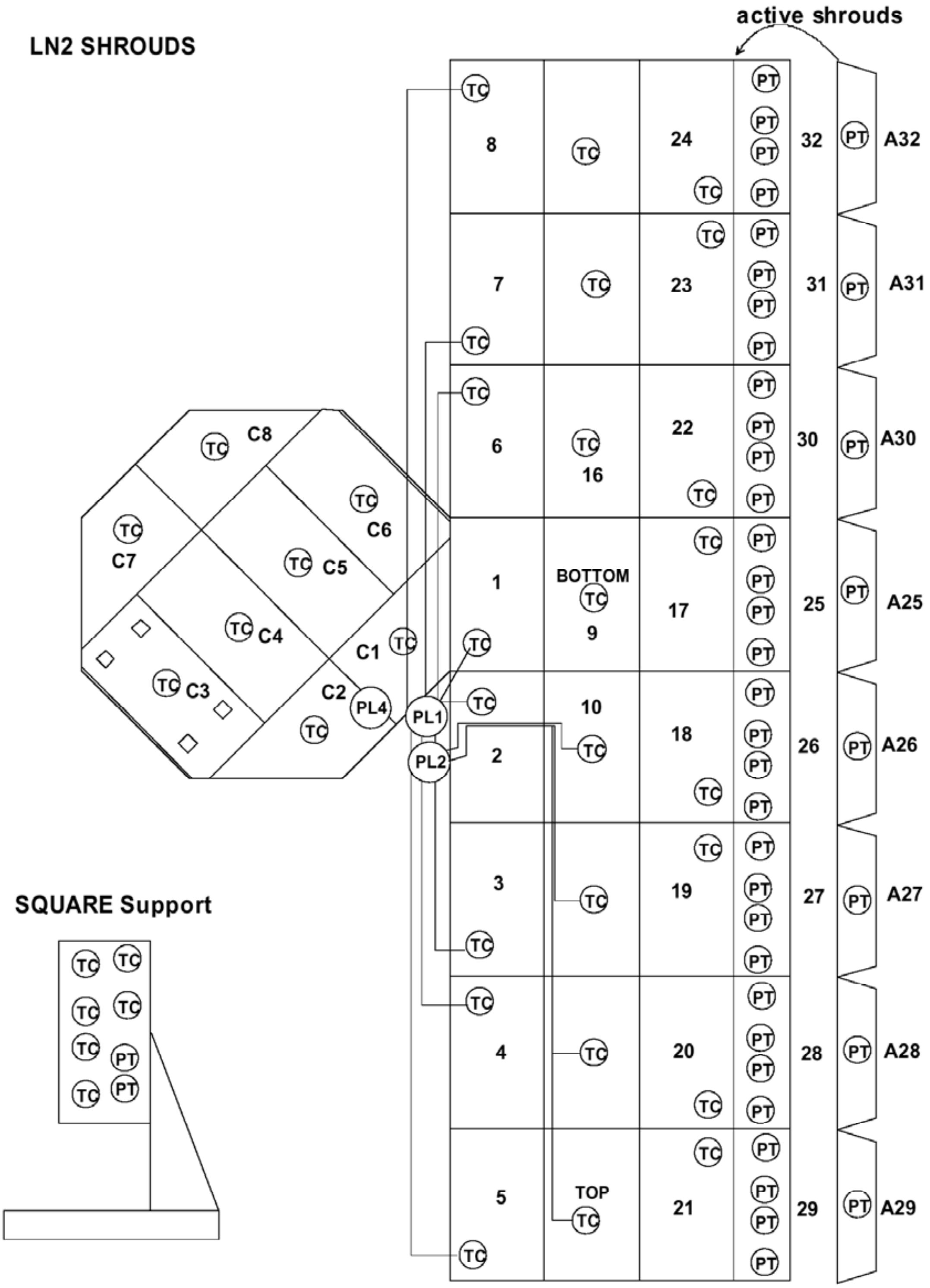


Figure 4-14: Thermal sensor localisation on Liquid Nitrogen shrouds.

5. TEST DEFINITION

5.1 Chronology

The following sections give the overall chronology of the test.

For all HFI activities, the detailed macrosequence is available in RD26.

5.1.1 Phase 0.0 (Final check before chamber closure)

Ph0.0-001	**Title** Facility Check		Duration -
	Start Criteria -	**End Criteria** Activities completed	
	Activity Final connections and associated checks. **HFI activity** : SA-ISSS PGSE pipes connection and verification as per procedure PR-PH740-500582-IAS (Procedure includes 4He flushing in the pre cooling loop until Ph0.1-001)		

Ph0.0-002	**Title** S/C Short Functional check		Duration -
	Start Criteria After Ph0.0-001	**End Criteria** Activities completed	
	Activity HFI Warm Short Functional Test + HFI Warm DC Pneumatic test (Check of μ-vibration during the 4K compressor test). Test includes : • HFI switch ON (including REU-A) • HFI general configuration • CryoHK adjustement • 4K compressor test at 3mm and microvibration check • HFI remains in configuration mode with REU-A OFF at the end PACE CQM: Check of heaters and thermal sensors lines Check of flight sensors line Check of S/C test heaters & thermal sensors lines ISSS-PGSE functional test. Due to the anomaly on the 4K (NC8719 & PMIS 1196) 4K compressor remains in nominal mode with 0 mm range for the following phases based on procedure stated in the anomaly disposition).		

Ph0.0-003	**Title** PACE GSE leak check		Duration -
	Start Criteria - After Ph0.0-002	**End Criteria** Activities completed	
	Activity Perform the PACE GSE switch-on procedure and associated leak check. The PACE is pumped down at the end.		

Ph0.0-004	**Title** Final check before pumping		Duration -
	Start Criteria - After Ph0.0-003	**End Criteria** Activities completed	
	Activity Facility Activity ref. RD[03] §4.1.2 – Check that all air inlet are closed		

The duration of this phase is estimated at 3 days.

5.1.2 Phase 0.1 (PUMP DOWN)

Ph0.1-001	**Title** Pumping phase up-to 5 10^{-5}mb		Duration 3 days
	Start Criteria Beg. Of Phase 0.0	End Criteria <5 10^{-5}mb	
	Activity Switch-on the facility procedure to go down to <5 10^{-5}mb with associated leak check. **HFI Activity** : pre-cooling and isotope purging (see RD27 §3) TC are given in RD26		

Ph0.1-002	**Title** Microvibration check during pump-down		Duration -
	Start Criteria Beg. Of Phase 0.0	**End Criteria** End of Phase 0.1	
	Activity Acquisition of microvibration accelerometers measurements at Facility & S/C levels. The check shall be done after each items switch-on/off. This check can be done on request during the phase.		

Ph0.1-003	**Title** De-sorption of CFRP		Duration 2 days
	Start Criteria End of Phase 0.1-001	End Criteria 2 days	
	Activity 1/ De-sorption of the CFRP under vacuum at ambient temperature		

Ph0.1-004	**Title** Facility Leak under vacuum		Duration -
	Start Criteria P<1.10^{-4} mb	End Criteria End of Ph0.1-001	
	Activity LN2 shrouds, He shrouds, optical shield charcoal panel leaks checks.		

Ph0.1-005	**Title** PACE GSE Leak check		**Duration** -
	Start Criteria End of Phase 0.1-004	**End Criteria** Activities completed	
	Activity Switch-on the PACE GSE at max operational pressure of 53 bars (He) to check the leak. Perform a functional test at nominal pressure (48 bars) with Hydrogen. At the end Switch he PACE GSE in Stand-By. The PACE remains at 1-10^{-3} mbars after the test. If the pressure inside the PACE raise up to 5-10^{-3} mbars, pump down the PACE back to 1-10^{-3} until Ph02.003		

Ph0.1-006	**Title** Pre-cooling loop leak check		Duration 30 min
	Start Criteria End of Phase 0.1-005	**End Criteria** Activities completed	
	Activity Leak check of the pre-cooling loop Leak rate to be performed before filling the shrouds to be able to distinguish between pre-cooling loop leak and shrouds leak. Success criteria is 1.10-5 mbar.l/s (see RD27 §4.1) TC are given in RD26 The pre-cooling loop remains at 2ml/mn from this phase until Ph02-004 for flushing purpose.		

Ph0.1-007	**Title** 4K cooler leak check		Duration -
	Start Criteria After Ph0.1-006	**End Criteria** Activities completed	
	Activity Leak rate to be performed before filling the shrouds to be able to distinguish between pre-cooling loop leak and shrouds leak (see RD26 for the macrosequence) 4K cooler functional test: leak check: criterion 4KC temperature and pressure (leak measurement duration > 0.5 h and stroke 3 mm). After 30 mn, set the stroke range to 0 (see RD26 & FY 8719 & PMIS 1196) <u>Success Criteria:</u> Leak check success criteria: average slope of leak rate measured during 5 minutes over a period of 30 minutes shall not increase. This success criterion will be definitively confirmed after the last leak verification of the FOCAL-5 facility, which is planned before moving the S/C inside FOCAL-5		

Ph0.1-008	**Title** Dilution cooler isotope leak check		Duration 1h15
	Start Criteria After Ph0.1-007	**End Criteria** End of test	
	Activity Leak check of the isotope (3He & 4He) pipes Leak rate to be performed before filling the shrouds to be able to distinguish between isotope leak and shrouds leak. Success criteria is 1.10-5 mbar.l/s (see RD27 §4.2). TC are given in RD26 Close valve FV301 – macro-sequence 67-9b Close valve HPLV101 – macro-sequence 67-1b Close valve FV201 – macro-sequence 67-2b After leak rate has been performed, valves are open using related TC in RD26 TC commands are: Open valve FV301 – macro-sequence 67-9a Open valve HPLV101 – macro-sequence 67-1a Open valve FV201 – macro-sequence 67-2a After completion leak test of the Dilution Cooler circuits, the DC circuits are pumped down till HFI gives agreement for end of pump down. The estimated time for pump down is less than one day. This pump down can be performed in parallel with next activities. At the end of the pump down, PGSE valves are closed (see RD27), however, DCCU valves are left open. HFI remains in configuration mode.		

Ph0.1-009	**Title** 4K cooler Switch-On –Flushing of 4K Pipes		Duration -
	Start Criteria After Ph0.1-008	**End Criteria** Activities completed	
	<u>HFI Activity</u>: Switch on compressors and getter in order to flush continuously the 4K pipes during cool-down phase at CSL. The estimated operating temperature of the getter is 315deg C and the maximal temperature of the getter will never exceed 412.5deg C. Set Compressor stroke at 2mm and switch on Getter **(**See RD26). Run 4K cooler		

5.1.3 Phase 0.2 (SHROUDS cooling)

Ph0.2-001	**Title** Cold shrouds filling		**Duration** -
	Start Criteria end of Phase 0.1	**End Criteria** He shrouds < 20K	
	Activity Shrouds filling with Nitrogen and Helium.. Perform a facility leak check when the shrouds are at Operational temperature		

Ph0.2-002	**Title** Optical shield & Charcoal Panel Filling		Duration
	Start Criteria End of Phase 0.2-001	**End Criteria** Optical shield < 5K & Cryo Panel at <5K	
	Activity filling Optical shield & Charcoal Panel with Liquid Helium.		

Ph0.2-003	**Title** Microvibration check during shrouds cooling		Duration -
	Start Criteria Beg. Of Phase 0.2	**End Criteria** End of Phase 0.2	
	Activity Acquisition of microvibration accelerometers measurements at Facility & S/C levels. The check shall be done after each items switch-on filling. This check can be done on request during the phase. HFI Prerequisite: Set the stroke range to 0 (ref. NC 8719 & PMIS 1196) during microvibration measurement sequence (RD26) at least 5mn before starting microvibration measurements. It is noted that the getter does not need to be switched off. At the end of sequence, restart 4K compressor: Set back the Compressor stroke at 2mm (See RD26).		

5.1.4 Phase 1 (PPLM passive performance)

Ph01-001	**Title** Switch ON specimen		Duration -
	Start Criteria End of Phase 0.1	**End Criteria** Specimen units are ON	
	Activity Switch ON test heaters in Heater A configuration (PPLM, RAA lower structure, JFET). For PPLM heaters: heaters at redundant SCC interfaces are ON, heaters at nominal SCC interfaces are OFF Switch ON BEU MTD Switch ON SVM heaters (to maintain switched-OFF warm units within non operating temperature and switched ON warm units within operating temperature) HFI is kept in Configuration mode for the next phases (See RD26). He3 and He4 isotope circuit are flushed at 2ml/mn starting from this phase up to Ph2-009		

Ph01-002	**Title** PPLM cool down (+Y)		**Duration** see §5.1.12.2
	Start Criteria Beg of Phase 0.2	**End Criteria** (PC3C<60K,PC2<120K,PC1<170K) &(WGs I/F VG1<170K, WGs I/F VG2<120K) in redundant (+Y) configuration	
	Activity Passive PPLM cool-down – Performance on +Y side Clamping mechanism opening at 220 K with success criterion on Cryo HK 100 mK (change in slope observed on QLA) –IAS to confirm the opening of the clamping mechanism		

Ph01-003	**Title** PPLM cool down (-Y)		Duration 5h
	Start Criteria End of Phase 1-002	**End Criteria** (PC3C<60K,PC2<120K,PC1<170K) &(WGs I/F VG1<170K, WGs I/F VG2<120K) in nominal (-Y) configuration and duration achieved	
	Activity Passive PPLM cool-down – Performance on –Y side Switch test heaters on Heater B configuration		

Ph01-004	**Title** Microvibration check during PPLM thermal passive performance		Duration -
	Start Criteria Beg. Of Phase 1	**End Criteria** End of Phase 1	
	Activity Acquisition of microvibration accelerometers measurements at Facility & S/C levels. The check shall be done before Ph01-001 and after Ph01-003 This check can be done on request during the phase. <u>HFI Prerequisite</u>: Set the stroke range to 0 during microvibration measurement sequence (RD26) at least 5mn before starting microvibration measurements. It is noted that the getter does not need to be switched off. At the end of sequence, restart 4K compressor: Set back the Compressor stroke at 2mm (See RD26).		

5.1.5 Phase 2 (CRYO CHAIN TESTING)

Ph02-001	**Title** Microvibration check during cryo chain testing		Duration -
	Start Criteria Beg. Of Phase 2	**End Criteria** End of Phase 2	
	Activity Acquisition of microvibration accelerometers measurements at Facility & S/C levels. The check shall be done before & after each sub phases. This check can be done on request during the phase. <u>Note</u>: During phase 2, whenever a microvibration check is run, the 4K cooler will not be stopped		

Ph02-002	**Title** Specimen configuration		Duration -
	Start Criteria End of Phase 1	**End Criteria** All units are ON	
	Activity Switch PPLM test heaters to B' configuration SVMD thermal control adaptation		

Ph02-003	**Title** Switch ON PACE GSE		**Duration** see §5.1.12.2
	Start Criteria LVHX2 < 175 K and end of phase 1	**End Criteria** Activities completed	
	Activity LVHX2 temperature is given by T3 & T4 temperature sensors on the PACE GSE (see 3.2.2.2.2) Switch ON PACE + PACE GSE at the nominal flow : p on high pressure side = 48 bars of Hydrogen. Pressure on low pressure side shall be 0.4 bars.		

Ph02-004	**Title** Switch ON Pre-cooling loop		**Duration** see §5.1.12.2
	Start Criteria End of Ph02-003 and Instruments I/F with VG3<60K	**End Criteria** Activities completed	
	Activity Switch test heaters to B'' configuration Precooling loop flow rate adjustment: 1200 ml/mn (ISSS-PGSE manual operation). It is, however, agreed that the mass-flow could be continuously adjusted during the whole pre-cooling duration in order to optimise the efficiency of the Dilution Cooler pre-cooling.		

Ph02-005	**Title** Switch ON HFI detection chain		Duration see §5.1.12.2
	Start Criteria End of Ph02-004 and JFET&FPU I/F < 60K and reflectors I/F < 50K	**End Criteria** Activities completed	
	Activity Switch test heaters on Heater C configuration • Switch OFF HFI • Switch ON HFI in standby mode • Switch ON REU-A, dummy belts and PID-JFET (See RD26) : nominal dissipation on REU, PAU & JFET • Switch ON HS2 • J-FET thermal regulation ON • Switch ON 4K compressor at 2 mm stroke • Switch to Observation Mode (see RD26) • Observe bolometer noise on QLA : uccess criteria: bolometer noise verified on QLA that is < 12nV/√Hz over a frequency range of 16mHz to 100Hz. • Return to Configuration Mode (see RD26) • Switch ON HS1 • Optimisation • IVC • I CryoHK adjustment SVM thermal control adaptation		

Ph02-006	**Title** Switch ON heaters of RAA FPU		**Duration** see §5.1.12.2
	Start Criteria LVHX2 temperature/ slope	End Criteria	
	Activity To be done when LVHX2 temperature variation is lower than 0.1K/hour and LVHX2 temperature is lower than 24K. LVHX2 temperature is given by T3 & T4 temperature sensors on the PACE GSE (see 3.2.2.2.2) Switch test heaters to configuration D		

Ph02-007	**Title** Set 4K cooler at nominal stroke		**Duration** see §5.1.12.2
	Start Criteria RHC02-TempK (4K)< 30 K	**End Criteria** Activities completed	
	Activity Run 4K cooler at nominal stroke • 4K Compressor stroke is set at 3.9mm • wait for 20 minutes • If averages of any modulus of imbalances over a period of 30 minutes are > 40mN, then run auto-calibration sequence of 4K cooler (see RD26). HFI will gives his go-ahead to proceed with Ph2-007Microvibration check		

Ph02-008	**Title** Switch OFF HS2		**Duration** see §5.1.12.2
	Start Criteria RHC02-TempK (4K)< 19 K	End Criteria	
	Activity : switch OFF HS2		

Ph02-009	**Title** Start 0.1 K cooler		**Duration** see §5.1.12.2
	Start Criteria RHC00-TempK (100mK)< 19 K	**End Criteria** Activities completed	
	Activity • Stop pre-cooling flow rate • Begin the pumping of precooling loop (24 hours) – see ISSS-PGSE manual operation • Start isotopes (He3 and He4) (manual commands from ISSS-PGSE) – mass flow are 25 micromole/s 4He and 8 micromole/s 3He.). Isotopes Flow rates adjustment from ISSS-PGSE (manual operation: 3He = 15 ml/mn, 4He = 60 ml/mn (As per §7.4 and 7.5 from proc: verification electrique fonctionnelle of procedure PR-PH740-500548). Open valve HPLV101, FV201, FV102, FV103, FV203 and FV204 (see RD26 macro-sequence 67). This flow rate will be sufficient to feed the 3He PPLM line with 11ml/mn and the 4He PPLM line with 33 ml/mn. <u>Note</u>: Valves HPLV101, FV201 and FV301 are already open (see Ph01-008).		

Ph02-010	**Title** Switch OFF HS1		**Duration** see §5.1.12.2
	Start Criteria RHC01-TempK (1.6K)< 6 K	End Criteria : activities completed	
	Activity : switch OFF HS1		

Ph02-011	**Title** HFI FPU thermal control		**Duration** see §5.1.12.2
	Start Criteria End of Ph02-010 and Ther_PID4R < 5.5 K (on QLA)	End Criteria : activities completed	
	Activity : Note: from this point EXT will be performed . The duration of this activity is 35 mn and is quoted 40 mn in RD3 to give some margin. • EXT1 (global) duration 35 mn • optimisation • FPU PIDs switch ON		

Ph02-011a	**Title** 4K stage thermal control		**Duration** see §5.1.12.2
	Start Criteria End of Ph02-011	End Criteria : activities completed	

Activity :

- Configuration of Cernox for Temperature Fluctuation measurement at 4K level

Adjustment of the faster Cernox sample frequency at 4K level (REU) CryoHK_4K = RHC02-TempK (4K) (measurement of the 4K temperature fluctuations HSK1 packet)

- Re-Configuration of all Cernox

In the next sequence, a temperature target using the Heater 4K PID is injected.. The objective of the test is to measure the noise of the 4K thermometers and the 100mK fine thermometers when applying a power step.

- On PID 4K T reg = Ther_PID4R + 0.02K manually adjusted with QLA
- Switch to Observation Mode
- Select one 4K thermometer channel (Belt11 channel4 / Ther_PID4R)
- Noise observation of selected 4K thermometer (Belt11 channel4 / Ther_PID4R) using QLA during 30mn
- Switch to Configuration Mode
- Noise observation of all relevant fine thermometers using QLA during 30mn

Same activity with a step of 0.04K instead of 0.02K

- On PID 4K T reg = Ther_PID4R + 0.04K manually adjusted with QLA
- Switch to Observation Mode
- Select one 4K thermometer channel (Belt11 channel4 / Ther_PID4R)
- Noise observation of selected 4K thermometer (Belt11 channel4 / Ther_PID4R) using QLA during 30mn
- Switch to Configuration Mode
- Noise observation of all relevant fine thermometers using QLA during 30mn

Return to nominal configuration Treg=Ta4K on PID 4K

Ph02-011b	**Title** 1.6K stage thermal control		**Duration** see §5.1.12.2
	Start Criteria End of Ph02-011a and Ther_PID1.6R < 1.45 K or Ther_PID1.6R asymptotic (on QLA)	End Criteria : activities completed	
	Activity : The following sequence is to inject a step of power on the Heater 1.6K PID.. The objective of the test is to measure the bolometer noise when applying this power step. • On PID 1.6K: T reg = Ther_PID1.6R + 0.05K manually adjusted with QLA • Switch to Observation Mode • Select one 1.6K thermometer channel (Belt9 channel2 / Ther_PID1.6R) • Noise observation of selected 1.6K thermometer using QLA during 30mn • Switch to Configuration Mode • Noise observation of all relevant fine thermometers using QLA during 30mn • On PID 1.6K: T reg = Ther_PID1.6R + 0.1K manually adjusted with QLA • Switch to Observation Mode • Select one 1.6K thermometer channel (Belt9 channel2 / Ther_PID1.6R) • Noise observation of selected 1.6K thermometer using QLA during 30mn • Switch to Configuration Mode • Noise observation of all relevant fine thermometers using QLA during 30mn Return to nominal configuration Treg=Ta1.6K on PID 1.6K		

Ph02-012	**Title** Electrical crosstalk		**Duration** see §5.1.12.2
	Start Criteria End of Ph02-011b and (Ther_0.1K1) < 500 mK (on QLA)	End Criteria : activities completed	
	Activity : • VI configuration (duration 60mn) • Run electrical crosstalk EXT2 (duration 35 mn) • Run electrical crosstalk EXT3 (duration 35 mn) • Optimisation • Wait until Ther_0.1K1 < 300 mK (on QLA) • Microvibration check • VI configuration (duration 60mn) • Run electrical crosstalk EXT4 (duration 35 mn) • Run electrical crosstalk EXT5 (duration 35 mn) • Optimisation		

End of Phase criteria

- 4K Stage: Ther_PID4R < 5.5K on QLA
- 1.6K Stage: Ther_PID1.6R < 1.45K on QLA
- Dilution Cooler stage: Ther_0.1K1 < 105mK on QLA
- RAA Main frame average Di841, Di842, Di843 & Di844 < 24K

See §5.1.11 for thermal criteria synthesis and reference sensors for verification.

5.1.6 Phase 3 (INSTRUMENT FUNCTIONAL TESTING)

Start Phase: end of Phase 2

Ph03-001	**Title** Characterisation of HFI Performance at Nominal Operating Temperature	**Duration** 36 h	
	Start Criteria End of Phase 2	**End Criteria** Tests completed	
	Activity **A Key Point Meeting will confirm the decision to start the phase Ph03-001** **This 03-001phase is subdivided in 4 sub-phases:** **Phase 03-001a: Regulation of 100mK Cold End with PID1** **Phase 03-001b: Regulation of 100mK Bolometer Plate with PID2** **Phase 03-001c: Performance Characterisation with Temperature Regulation ON** **Phase 03-001d: Performance Characterisation without Temperature Regulation** Reminder: at the beginning of this phase, HFI FPU thermal control PID 4K and 1.6K are still ON and PIDs 100mK are still OFF. Definition of main activities performed during the sub-phases: • Opt: Optimisation • IVC: I,V curve ; Bolometers and thermometers bias determination • NOI: Bolometers noise, response measurements (on the cold target temp variation into the specs). FFT monitoring on QLA • EFF: optical efficiency; Step function on 1.6K and 4K • TSS: thermal stage sensitivity; Step function on 1.6K and 4K • EXT: electrical cross-talk		

Ph03-001a	**Title** : Regulation of 100mK Cold End with PID1		**Duration** : 1 h
	Start Criteria End of Ph02	**End Criteria** Tests completed	
	Activity Microvibration check Switch On PID1N on 100mK cold end Switch to Observation mode Noise measurement on 100 mK thermometers cold end. FFT monitoring on QLA (duration 40mn) Switch to configuration mode		

Ph03-001b	**Title** : Regulation of 100mK bolometer plate with PID2		**Duration** : 4.5 h
	Start Criteria End of Ph03-001a	**End Criteria** Tests completed	
	Activity • Switch ON PID2N • IVC (duration 60mn) • Optimisation except active PID thermometers (duration 20mn). Current resulting from previous IVC for each Channel) • NOI: Noise measurements over 1 hours of data for Iopt/3, Iopt and 3*Iopt (duration 180mn) • Observation with Iopt/3 done with FFT QLA (60 mn) • Observation with Iopt done with FFT QLA (60 mn) • Observation with 3*Iopt done with FFT QLA (60 mn) Total Duration of sub-phase 03-001b is 260mn		

Ph03-001c	**Title** : Performance characterisation with temperature regulation ON		**Duration** : 17 h
	Start Criteria End of Ph03-001b	**End Criteria** Tests completed	
	Activity • IVC (duration 60mn) • EXT3(duration 35 mn) • Optimisation except active PID thermometers (duration 20mn). Current resulting from previous IVC for each Channel) • NOI: Noise measurements over 1 hours of data for Iopt/3, Iopt and 3*Iopt (duration 3h) • Observation with Iopt/3 done with FFT QLA (60mn) • Observation with Iopt done with FFT QLA (60mn) • Observation with 3*Iopt done with FFT QLA (60mn) • Crosstalk test EXT4 (duration 35 mn) • Channel global config with Iopt • EFF+TSS with step on 4K: + 0.04K manually adjusted with QLA (duration 30mn) • EFF+TSS with a step on 1.6K: +0.1K manually adjusted with QLA (duration 30mn) • Return to the 4KTreg • IVC (duration 60mn) • EXT5 (duration 35 mn) • Optimisation except active PID thermometers (duration 20mn). Current resulting from previous IVC for each Channel) • Mode configuration n° 100. All channels (31 = 12 bolometers + 17 fine thermometers + R + C) are red successively during 5 minutes in raw signal data (Estimated duration : 160 mn) • EFF+TSS with step on 4K: + 0.04K manually adjusted with QLA (duration 30mn) • EFF+TSS with a step on 1.6K: +0.1K manually adjusted with QLA (duration 30mn • Return to T4Kreg • IVC (duration 60mn) • EXT5 (duration 35 mn) • Optimisation except active PID thermometers (duration 20mn). Current resulting from previous IVC for each Channel) • Mode configuration n° 100. All channels (31 = 12 bolometers + 17 fine thermometers + R + C) are red successively during 5 minutes in raw signal data (Estimated duration : 160 mn) • EFF+TSS with step on 4K: + 0.04K manually adjusted with QLA (duration 30mn) • EFF+TSS with a step on 1.6K: +0.1K manually adjusted with QLA (duration 30mn • Return to T4Kreg Total Duration of sub-phase 03-001c is 1040 mn		

Ph03-001d	**Title** : Performance Characterisation without Temperature Regulation	**Duration** : 12h
	Start Criteria End of Ph03-001c	**End Criteria** Tests completed

Activity

Objective of this sub-phase: to go down the lowest Temperature

- Switch OFF 100 mK PID1 & PID2
- Crosstalk test EXT4 (duration 35 mn)
- IVC (duration 60mn)
- Optimisation except active PID thermometers (duration 20mn). Current resulting from previous IVC for each Channel)
- NOI: Noise measurements over 1 hours of data for Iopt/3, Iopt and 3*Iopt (duration 3h)
- Observation with Iopt/3 done with FFT QLA (60mn)
- Observation with Iopt done with FFT QLA (60mn)
- Observation with 3*Iopt done with FFT QLA (60mn)
- Global conf Iopt
- EFF+TSS with step on 4K: + 0.04K manually adjusted with QLA (duration 30mn)
- EFF+TSS with a step on 1.6K: +0.1K manually adjusted with QLA (duration 30mn)
- Return to T4Kreg
- Crosstalk test EXT5 (duration 35 mn)
- IVC (duration 60mn)
- Optimisation except active PID thermometers (duration 20mn). Current resulting from previous IVC for each Channel)
- NOI: Noise measurements over 1 hours of data for Iopt/3, Iopt and 3*Iopt (duration 3h)
- Observation with Iopt/3 done with FFT QLA (60mn)
- Observation with Iopt done with FFT QLA (60mn)
- Observation with 3*Iopt done with FFT QLA(60mn)
- Global conf Iopt
- EFF+TSS with step on 4K: + 0.04K manually adjusted with QLA (duration 30mn)
- EFF+TSS with a step on 1.6K: +0.1K manually adjusted with QLA (duration 30mn)
- Return to T4Kreg

Total Duration of sub-phase 03-001d is 710 mn

Ph03-002	**Title** HFI EMI-EMC test		**Duration** 24 h
	Start Criteria End of Ph03-001	**End Criteria** Tests completed	
	Activity Conducted Susceptibility on the 4 feeding lines (ref. RD[11] with HFI agreement This test is performed with acquisition of SC and correlation is done in real time in between the EM source and the displayed signals of the fine thermometers and bolometers. Conducted Emission Susceptibility Injection on feeding lines of: DPU, DCCU, REU-A & REU-P Test Duration 24 h (duration to be confirmed) Activity Conducted Susceptibility with HFI agreement – see details of related in TC PR-PHD740-500594-IAS for switching ON and OFF units. See document RD11 for Injection Profile and Success Criteria. <u>Activities</u> : • switch OFF 1.6K and 4K stage PID • select one single channel of raw data on the QLA in order to maximise the volume of data resulrs • switch to observation mode • proceed with EMC tests and observe the results on the QLA • switch to Configuration mode		

Ph03-003	**Title** PACE GSE pressure fluctuation		Duration 10 h
	Start Criteria End of Ph03-002	**End Criteria** Tests completed	
	Activity A/ PACE-GSE outlet square profile (100 s, 0,11 bar) during 1200s (12 periods) (4K PID OFF) Note: 4K PID is OFF from Ph03-002. Monitor on QLA the real-time evolutions of temperatures of FPU stage 4K, 1.6K, 100mK and monitor evolutions of 20K stage temperatures of PACE on PACE-EGSE Wait HFI Gohead B/ PACE-GSE outlet square profile (100 s, 0,11 bar) during 1200s (12 periods) (4K PID ON) Switch ON 4K PID. Monitor on QLA the real-time evolutions of temperatures of FPU stage 4K, 1.6K, 100mK and monitor evolutions of 20K stage temperatures of PACE on PACE-EGSE Wait HFI Gohead C/ PACE-GSE outlet square profile (667s, 0.11 bar) during 4000s (6 periods) (4K PID OFF) Switch OFF 4K PID. Monitor on QLA the real-time evolutions of temperatures of FPU stage 4K, 1.6K, 100mK and monitor evolutions of 20K stage temperatures of PACE on PACE-EGSE Wait HFI Gohead D/ PACE-GSE outlet square profile (667s, 0.11 bar) during 4000s (6 periods) (4K PID ON) Switch ON 4K PID. Monitor on QLA the real-time evolutions of temperatures of FPU stage 4K, 1.6K, 100mK and monitor evolutions of 20K stage temperatures of PACE on PACE-EGSE Wait for 10 minutes and step “E” is a remake of Pace fluctuation of step “D”. E/ PACE-GSE outlet square profile (667s, 0.11 bar) during 4000s (6 periods) (4K PID ON) 4K PID ON from previous step. Monitor on QLA the real-time evolutions of temperatures of FPU stage 4K, 1.6K, 100mK and monitor evolutions of 20K stage temperatures of PACE on PACE-EGSE Wait HFI Gohead F/ PACE-GSE outlet square profile (4000s, 0.11 bar) during 3 hrs Monitor on QLA the real-time evolutions of temperatures of FPU stage 4K, 1.6K, 100mK and monitor evolutions of 20K stage temperatures of PACE on PACE-EGSE Total operation duration: 7 hours Note : ASP does not commit to the exact shape of the profiles.		

Ph03-004	**Title** 4K cooler frequency influence on Dilution Cooler and bolometers	**Duration** 15 h
	Start Criteria End of Ph03-003	**End Criteria** Tests completed

Activity

- Restart all PIDs : Note 4K PID is on from previous sequence Ph03-003 (PACE Fluctuations)
- Switch to observation mode
- Noise observation on QLA during 2 hours
- Switch to configuration mode

1. Save the REU parameters. Stop Cooler and switch OFF HFI. Switch ON HFI and restore the REU parameters
2. Change to Fi Frequency (F1=35.07, then F2=37.69, then F3=44.69)
3. Run the Vibration Cancellation System Calibration. Switch OFF HFI. Switch ON HFI. Restore REU parameters. Run the compressor at 3.9 mm.
4. Change to observation mode, and observe NOI on the QLA during 75 mn.
5. Adjust PID set point according to 4K temperature and wait for stabilisation (around 30 mn). Wait the go ahead from HFI QLA analysis to proceed.
6. Mode configuration n° 100. All bolometer channels (12 bolometers) are red successively during 5 minutes in raw signal data
7. Go back to 1. for the next frequency

- Save the REU parameters. Stop Cooler and switch OFF HFI. Switch ON HFI and restore the REU parameters
- Change to 40.08 Hz Frequency
- Run the Vibration Cancellation System Calibration. Switch OFF HFI. Switch ON HFI. Restore REU parameters. Run the compressor at 3.9 mm
- Change to observation mode, and observe NOI on the QLA during 75 mn

Ph03-005	**Title** HFI coolers recovery systems test and 4K cooler margin		**Duration** 8 h
	Start Criteria End of Ph03-004	**End Criteria** Tests completed	
	Activity (ref. to [AD12] & [AD13]) HFI activities are in sub-phases Ph03-005-a, Ph03-005-b, Ph03-005-c.		

Ph03-005 a	**Title** 4K Cooler heat lift margin		**Duration**
	Start Criteria End of Ph03-004	**End Criteria** Tests completed	
	Activity • Switch ON Dilution Cooler defrost system at 4K, at power, 25 mW (100% on one heater) • Wait for the 4K JT temperature (Ther_4KL1 – Belt9 – Channel5 or 4Tt03-4Kstage both on QLA) increases by 1K and then switch off power and wait that 4K JT (Ther_4KL1 – Belt9 – Channel5 or 4Tt03-4Kstage) comes back to its previous temperature (maximal duration is 0.5 hours) • Switch the power to 7.5mW (30% of one heater). Wait for the behaviour of the 4K cold end Temperature (Ther_4KL1 – Belt9 – Channel5 or 4Tt03-4Kstage both on QLA). • If temperature of 4K JT (Ther_4KL1 – Belt9 – Channel5 or 4Tt03-4Kstage) increases, reduce power to 5mW (10% on each heater) until 4K JT (Ther_4KL1 – Belt9 – Channel5 or 4Tt03-4Kstage) comes back to its previous temperature. • If temperature of 4K JT (Ther_4KL1 – Belt9 – Channel5 or 4Tt03-4Kstage) increases, reduce power to 2.5mW (10% on one heater) until 4K JT (Ther_4KL1 – Belt9 – Channel5 or 4Tt03-4Kstage) comes back to its previous temperature. (maximal duration is 0.5 hours)		

Ph03-005 b	**Title** Dilution cooler defrost system test		**Duration**
	Start Criteria End of Ph03-005a	**End Criteria** Tests completed	
	Activity • Switch ON Dilution Cooler defrost system at 50K, at: 200 mW (10% of maximal power) • Verify temperature increase of DTt105-50K4HeIIt and monitoring of associated thermometers (Duration 10mn) • Switch ON Dilution Cooler defrost system at 18K at: 15 mW (10% of maximal power) • Verify temperature increase of DTt106-18K4HeIIt and monitoring of associated thermometers (Duration 10mn)		

Ph03-005 c	**Title** 4K cooler defrost system test		**Duration**
	Start Criteria End of Ph03-005b	**End Criteria** Tests completed	
	• Activity • Switch ON 4K defrost • Monitor temperature increase of 4K J-T. on QLA. Success criteria: watch 4K JT temperature (Ther_4KL1 – Belt9 – Channel5) increase. If slope is positive during at least 5mn, then test is successful. If not, wait 20mn for temperature increase.. Max. duration: 20 minutes TBC • Switch OFF 4K cooler defrost • Wait 1 hour (TBC) to return to nominal stabilised temperature on the 4K cold end.. Success criterion is 4K J-T (Ther_4KL1 – Belt9 – Channel5) back at nominal temperature (+ margin of 0.05K)		

Ph03-006	**Title** Coolers Failure test phase		**Duration** 4 h
	Start Criteria End of Ph03-005	**End Criteria** Tests completed	
	Activity HFI activities are: • HFI 4K cooler failure test (in Ph03-006a) • PACE cooler failure test (in Ph03-006b)		

Ph03-006a	**Title** HFI 4K cooler failure test		**Duration** 4 h
	Start Criteria End of Ph03-005	**End Criteria** Tests completed	
	Activity This test will only be performed if Ph03.004 has not been successfully performed. HFI will give the go-ahead for performing or not this phase • Save REU parameters. Switch OFF HFI. • Monitor all HFI/FPU temperatures with QLA. • Switch ON HFI. Restore REU parameters. Set the compressor range to 3.9 mm. • Monitor all HFI/FPU temperatures with QLA (1h) Warning: No need to return to nominal temperatures		

Ph03-006b	**Title** PACE cooler failure test		**Duration**
	Start Criteria End of Ph03-006a	**End Criteria** Tests completed	
	Activity • PGSE PACE OFF (1 h) (only on the pressure inlet, the outlet will stay at nominal pressure). • Monitor all HFI/FPU temperatures with QLA • PGSE PACE ON (1 h) • Monitor all HFI/FPU temperatures with QLA Warning: No need to return to nominal temperatures		

Ph03-007	**Title** Microvibration check during Instrument Functional test		Duration
	Start Criteria Beg. Of Phase 2	**End Criteria** End of Phase 3	
	Activity Acquisition of microvibration accelerometers measurements at Facility & S/C levels. The check shall be done after each items switch-on/off. This check can be done on request during the phase.		

End of Phase criteria

All instrument test successfully performed

5.1.7 Phase 4 (PPLM transient)

Start Phase: end of Phase 3

Ph04-001	**Title** PPLM transient	Duration 15h
	Start Criteria End of Phase 3	**End Criteria** PPLM test heaters switched OFF
	Activity Inject power profile in PPLM test heaters (configuration heater E) Measure temperature transient Note: this phase can be performed in parallel to beginning of phase 5	

5.1.8 Phase 5 (FPU warm up)

Start Phase: end of Phase 3

Ph05-001	**Title** Stop coolers	**Duration** see §5.1.12.3
	Start Criteria End of Phase 3	**End Criteria** Coolers stopped
	Activity • Stop Dilution Cooler isotope flow (restrain the nominal flow rate to 2 ml/mn) • Stop 4 K cooler • Stop getter • SVM thermal control adaptation • Switch ON HS1 and HS2	

Ph05-002	**Title** Warm-up	**Duration** see §5.1.12.3
	Start Criteria End of Ph04	**End Criteria** :RHC00-TempK (0.1K) > 45 K
	Activity Stop PACE cooler Switch ON FPU decontamination lines (configuration F) Power steps to be injected in TRA heating line (50W during 5h and then 100W during 5h)	

5.1.9 PHASE 6 (PPLM WARM UP)

Start Phase: end of Phase 5

Ph06-001	**Title** PPLM Warm Up	**Duration** see §5.1.12.3
	Start Criteria End of Phase 5	**End Criteria** Specimen at ambient temperature
	Activity ASP activity: Switch ON PPLM decontamination lines (configuration G) At the end of warm-up, adapt FPU heating power to keep RAA main frame @ 290K(±10K) Clamping mechanism closing at 220 K with success criterion on Cryo HK 100 mK (change in slope observed on QLA) –IAS to confirm the opening of the clamping mechanism Facility Activities Ref. [RD8] § 4.3 Warm up of shrouds Timing for shrouds warm-up (see §5.1.12.1) Optical shield He shrouds N2 shrouds HFI activity Return HFI in standby mode Switch OFF HFI (at beginning of phase)	

5.1.10 PHASE 7 (PRESSURE RECOVERY)

Start Phase: end of phase 6

Ph07-001	**Title** Pressure recovery	Duration 10 hrs
	Start Criteria S/C at ambient temperature	**End Criteria** Atmosphere pressure
	Activity Facility Activities Ref. [RD8] § 4.4 Pressure recovery with GN2 until 300mb with a slope of 2mb/min Perform an stabilisation at 300 mb during 2hrs (TBC) to checks all items inside the chamber Pressure recovery with dry air until 1000 mb with a slope of 5mb/min Opening of the chamber Collecting of the contamination witnesses inside the vacuum chamber Spacecraft inspection by ASP and CSL	

5.1.11 Thermal criteria and associated verification synthesis

Phase (1)	Criteria description	Criteria ID	Value	Sensors
Ph0.2-001 (E)	He Shrouds T°	TC0.1	≤20K	Max(Di on Ghe shrouds) (2)
Ph01-002 (E)	Sorption Cooler VG3 I/F T° (+Y)	TC1.1	≤60K	Di1
-	Sorption Cooler VG2 I/F T° (+Y)	TC1.2	≤120K	Pt251
-	Sorption Cooler VG1 I/F T° (+Y)	TC1.3	≤170K	Pt151
-	Wave Guides VG2 I/F T°	TC1.4	≤120K	mean(Pt201;Pt241)
-	Wave Guides VG1 I/F T°	TC1.5	≤170K	mean(Pt101;Pt141)
Ph01-003 (E)	Sorption Cooler VG3 I/F T° (-Y)	TC1.6	≤60K	Di2
-	Sorption Cooler VG2 I/F T° (-Y)	TC1.7	≤120K	Pt231
-	Sorption Cooler VG1 I/F T° (-Y)	TC1.8	≤170K	Pt131
-	Wave Guides VG2 I/F T°	TC1.4	≤120K	mean(Pt201;Pt241)
-	Wave Guides VG1 I/F T°	TC1.5	≤170K	mean(Pt101;Pt141)
Ph02-003 (S)	LVHX2 T°	TC2.1	≤175K	JPL(T3 & T4) or Di841
Ph02-004 (S)	Instruments I/F with VG3	TC2.2	≤60K	Max(Di302;Di341;Di342)
Ph02-005 (S)	Telescope Instruments I/F T°	TC2.3	≤60K	Max(mean(Di522;Di524);mean(Di531;Di532;Di533))
-	Reflectors I/F T°	TC2.4	≤50K	Max(mean(Di536;Di537);mean(501;511))
Ph02-006 (S)	LVHX2 T°	TC2.5	Asymptotic	JPL(T3 & T4)
Ph02-007 (S)	4K stage T°	TC2.6	≤30K	RHC02-TempK (4K)
Ph02-008 (S)	4K stage T°	TC2.7	≤19K	RHC02-TempK (4K)
Ph02-009 (S)	0.1K stage T°	TC2.8	≤19K	RHC00-TempK (100mK)
Ph02-010 (S)	1.6K stage T°	TC2.9	≤6K	RHC01-TempK (1,6K)
Ph02-011 (S)	4K stage T°		<5.5 K	Ther_PID4R (QLA)
Ph02-012 (E)	0.1K stage T°	TC2.10	≤0.105K	Ther_0.1K1 (QLA)
Ph02-012 (E)	1.6K stage T°	TC2.11	≤2.1K	Ther_PID1.6R (QLA)
Ph02-012 (E)	4K stage T°	TC2.12	≤5.5	Ther_PID4R (QLA)
Ph02-012 (E)	JFET T°	TC2.13	120K±10K	JFET Box therm
Ph02-012 (E)	20K stage T°	TC2.14	≤24K	Mean(Di841;Di842;Di843;Di844)

Table 5-1: Thermal criteria synthesis

Notes :

(1) E for End of phase (criteria), S for Start of phase.

(2) See RD[7] for sensors position.

5.1.12 Preliminary thermal predictions

Predictions are performed with assumptions consistent with here above chronology description. In particular, **Pre-Cooling loop mass flow** has been set to **1 10^{-3} mol/s** and **Dilution Cooler mass flow** has been set to **1.5×"nominal mass flow".**

Only cool-down and warm-up phases (phases 0, 1, 2, 5 and 6) are analysed and presented in §5.1.12.2 and §5.1.12.3. Phases 3 and 4 duration is considered as fixed.

Global duration of vacuum phases is equal to 45 days (see Table 5-2).

Note that these analyses will be updated in prediction analyses document.

Phase description	Duration (days)	Duration issued from simulation
Pump down (from Ph0.1-001 to Ph0.1-008)	5	NO
Shrouds & PPLM passive cool-down (from Ph0.2-001 to Ph01-004)	7.3	YES
Active cooling (from Ph02-001 to Ph02-010)	18	YES (1)
Instruments test (from Ph03-001 to Ph03-007)	5,1	NO
Transient (Ph04-001)	0.6	NO
Warm-up (from Ph05-001 to Ph06-001)	7.0	YES
Pressure recovery (Ph07-001)	2	NO
Total	**45**	

Table 5-2: Vacuum phases duration synthesis

(1) Cool-down is analysed with cryo-chain TMM down to 4K (approximately end of Ph02-009). 5d are then added in order to take into account further cool-down to 0.1K. These 5d are drawn from FPS CQM test results.

5.1.12.1 Shrouds temperature profiles

Assumptions about shrouds temperature transitions are extracted from [RD8] and are recalled hereafter :

Cool down shrouds profiles	t (h)	T LN2 shrouds (K)	T GHe shrouds (K)	T Optical Shield (K)
	t	300	300	300
	t+12	80	80	Linear
	t+84	80	20	220K (passive) (1)
	t+108	80	20	5 (1)

Table 5-3: Shrouds T° profile (cool down)

Note : Optical Shield is not fed with He during shrouds Cool-Down in order to allow He leak checks in cold conditions (end of Ph0.2-001). It will nevertheless passively cool down following its environment. Conservative assumption is made that it will passively slowly cool down to 220K by the time He shrouds are cold.

Warm-up shrouds profiles	t (h)	T LN2 shrouds (K)	T GHe shrouds (K)	T Optical Shield (K)
	t	80	20	5
	t + 48	80	100	5
	t + 60	80	linear	linear
	t + 72	linear	200	linear
	t + 84	200	linear	linear
	t + 120	300	300	200
	t + 144	300	300	280

Table 5-4: Shrouds T° profile (warm-up)

5.1.12.2 Cool down phases (phases 0, 1 and 2)

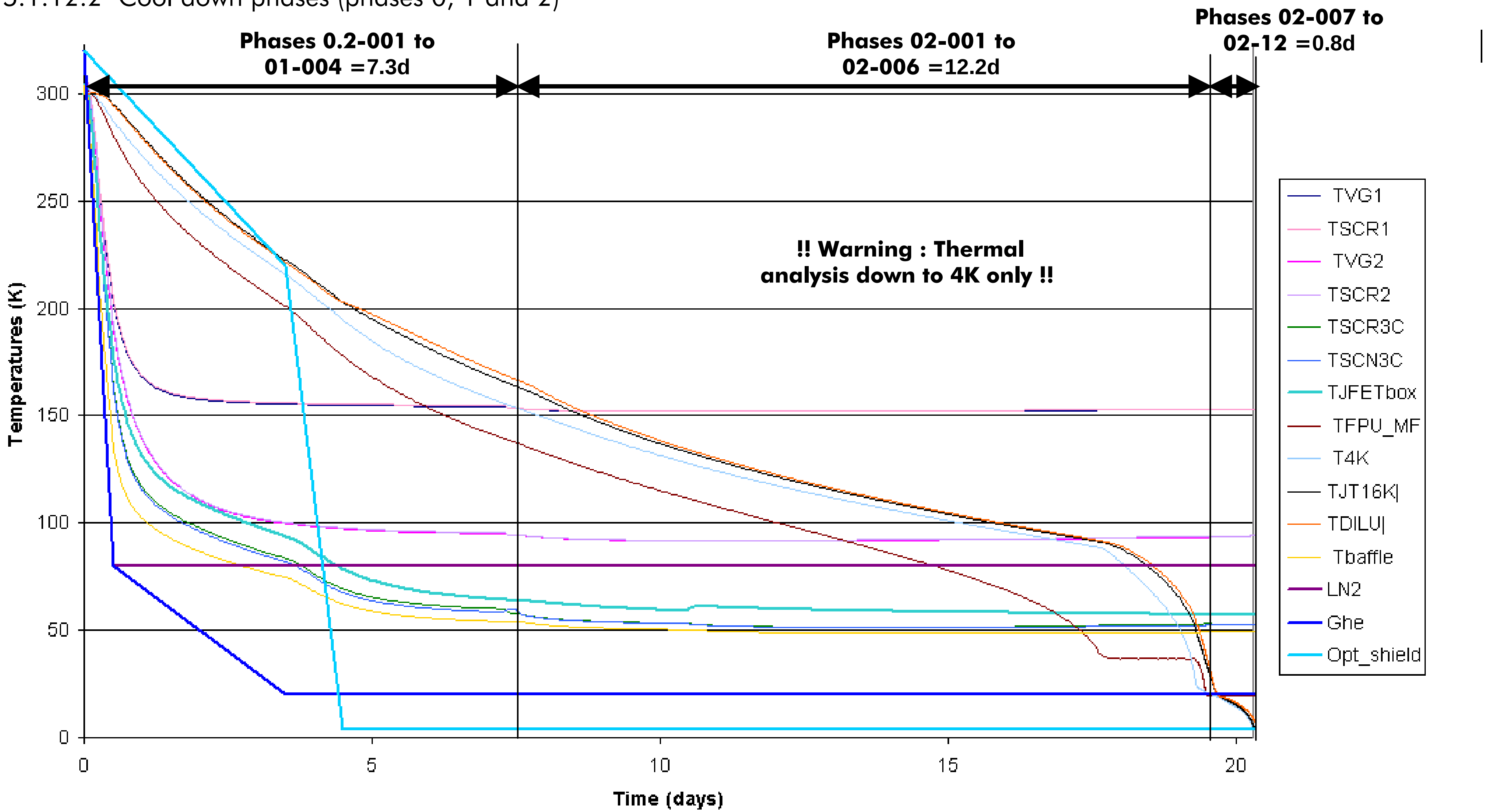


Figure 5-1: S/C cool down

Comments :

- ✓ The influence of the slow optical shield cool-down (before He shrouds stabilisation) can be noticed on graph. The achievement of passive performance is delayed, with no significant impact on global cooling.
- ✓ The three-step passive demonstration are noted on graph. The PACE GSE, started when first step is achieved (7.3d), speeds up 20K stage cool-down.
- ✓ Cool-down is analysed down to 4K (corresponds approximately to end of Ph02-009). A duration of 5d is added to take into account further cool-down to 0.1K (CQM FPS test results). Global cool-down duration is then estimated at 25.3d.

5.1.12.3 Warm-up phases (phases 5 and 6)

Results are presented in Figure 5-2.

Comments on results:

- SCR3C temperature decreasing at t0 is explained by the fact that initial temperatures are those at the end of previous "Transient" test (when power profile is injected in shield 3).
- In accordance with CSL facility possibilities, shrouds warm-up profiles have been adjusted so that :
    - o PPLM structure temperatures are kept within Ghe and LN2 shrouds temperatures (an exception can be noticed around 2.5d but on a short period)
    - o HFI FPU coldest areas are kept hotter than the Optical Shield. End of warm-up (around 7d) can be adjusted in order to avoid inversion with no significant impact on sequence duration.
- Change of slope for FPU main frame T (between Ph05-002 and Ph06-001) is due to change of injected power (20W for Ph05-002 and 40W for Ph06-001)

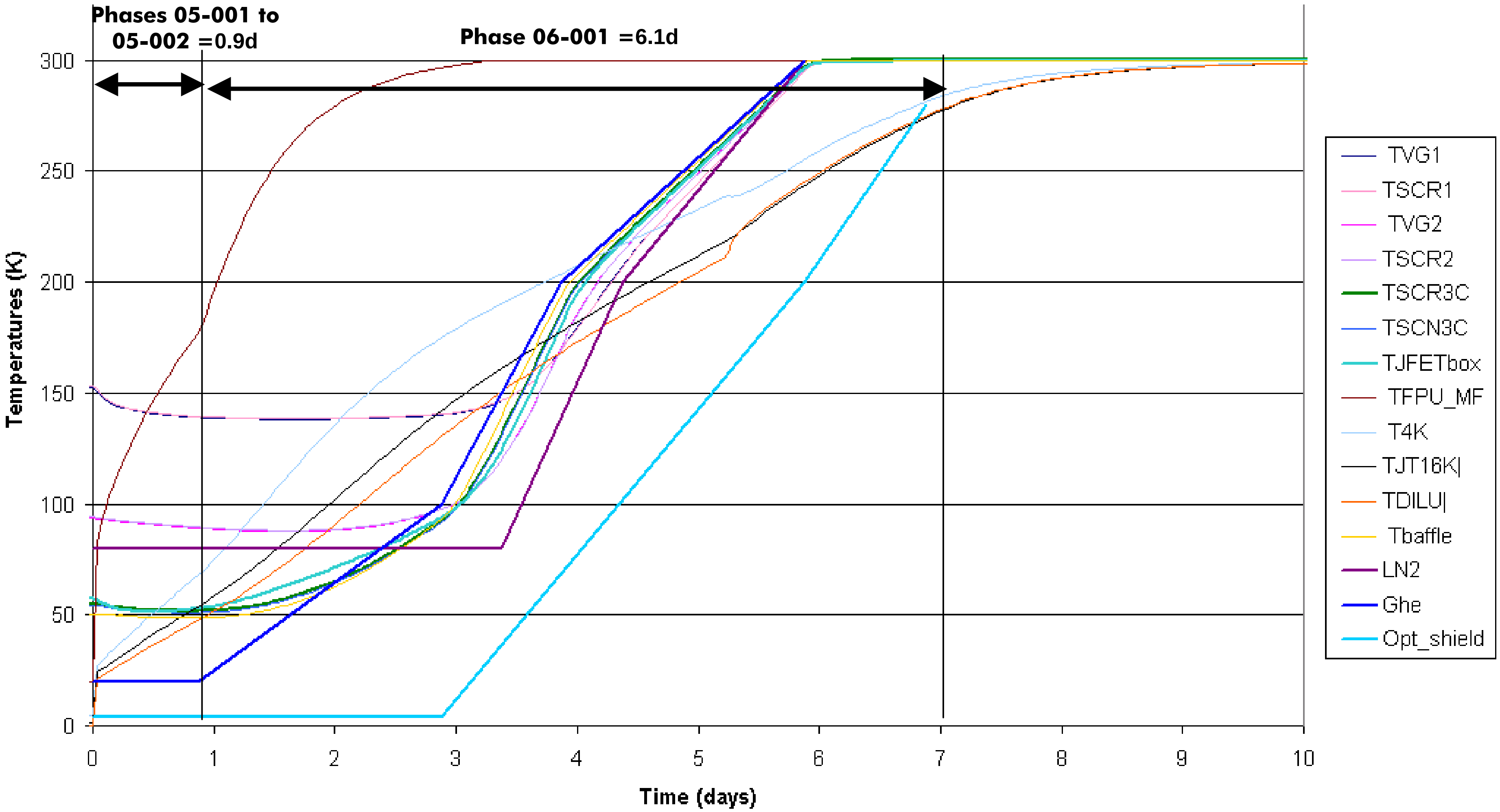


Figure 5-2: S/C warm-up

5.1.12.4 Transient test

Example of temperature evolution during transient test is given in Figure 5-3. Power injection profile is as given in Figure 5-10.

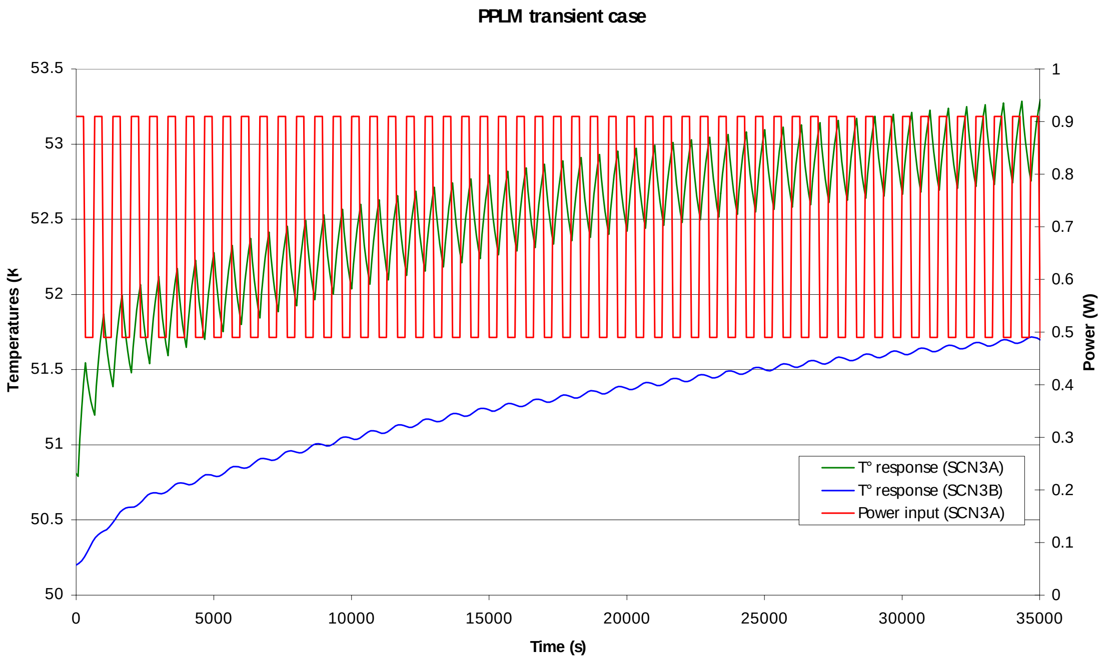


Figure 5-3: Transient case prediction example

5.2 Planck CQM test sequence configurations

This chapter presents synthetically the test configurations all along the test sequence.

5.2.1 Test facility

Planck CQM Test Timeline	Facility check	S/C short functional test	PACE GSE leak check	Final check before pumping	Pump down	Microvibration check	De-soption of CFRP	PACE GSE leak check	Facility leak check	Pre-Cooling loop leak check	4K cooler leak check	Dilution cooler isotope leak check	4K cooler Switch-On –Flushing of 4K Pipes	Shrouds filling	Optical shield & charcoal panel filling	Microvibration check during cooling	PPLM Passive performance : switch ON PPLM	PPLM Cooldown +Y	PPLM Cooldown -Y	Microvibration check during PPLM passive performance
Phase / Configuration	0.0-1	0.0-2	0.0-3	0.0-4	0.1-1	0.1-2	0.1-3	0.1-4	0.1-5	0.1-6	0.1-7	0.1-8	0.1-9	0.2-1	0.2-2	0.2-3	1-1	1-2	1-3	1-4
Time reference (begining of phase)	t0	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-	t1
Test Environment parameters																				
LN2 Shrouds T°	300	300	300	300	300	300	300	300	300	300	300	300	300	Shrouds CD	80	80	80	80	80	80
GHe Shrouds T°	300	300	300	300	300	300	300	300	300	300	300	300	300	Shrouds CD	20	20	20	20	20	20
Optical shield T°	300	300	300	300	300	300	300	300	300	300	300	300	300	free	OS CD	5	5	5	5	5
Pressure (mb)	Patm	Patm	Patm	Patm	Pumping	Pumping	Pumping	Pumping	Pumping	Pumping	Pumping	5 10-5	5 10-5	5 10-5	5 10-5	5 10-5	5 10-5	5 10-5	5 10-5	5 10-5

Figure 5-4: Test environment (Phases 0 to 1)

Planck CQM Test Timeline	Cryo-Chain testing : Microvibration	Specimen configration	Switch ON PACE GSE	Switch ON pre-cooling loop	Switch ON HFI detection chain	Switch On heaters on RAA FPU	Run 4K cooler at final compressor stroke	Switch OFF HS2	Start 0,1K cooler	Switch OFF HS1	HFI FPU thermal control	HFI Electrical crosstalk
Configuration / Phase	2-1	2-2	2-3	2-4	2-5	2-6	2-7	2-8	2-9	2.10	2-11	2-12
Time reference (begining of phase)	-	-	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-
Test Environment parameters												
LN2 Shrouds T°	80	80	80	80	80	80	80	80	80	80	80	80
GHe Shrouds T°	20	20	20	20	20	20	20	20	20	20	20	20
Optical shield T°	5	5	5	5	5	5	5	5	5	5	5	5
Pressure (mb)	5 10-5	5 10-5	5 10-5	5 10-5	5 10-5	5 10-5	5 10-5	5 10-5	5 10-5	5 10-5	5 10-5	5 10-5

Figure 5-5: Test environment (Phase 2)

Planck CQM Test Timeline	Regulation of 0,1K cold end with PID1	Regulation of 0,1K bolometer plate with PID2	Performance characterisation with temperature regulation ON	Performance characterisation without temperature regulation	HFI EMC test	PACE GSE pressure fluctuation	4K cooler frequency influence on Dilution Cooler and bolometers	4K Cooler heat lift margin	Dilution cooler defrost system test	4K cooler defrost system test	HFI 4K cooler failure test	PACE cooler failure test	Microvibration check	PPLM transient	Stop coolers	Warm up	PPLM Warm-up	Pressure recovery
Configuration / Phase	3-1a	3-1b	3-1c	3-1d	3-2	3-3	3-4	3-5a	3-5b	3-5c	3-6a	3-6b	3-7	4.1	5.1	5.2	6.1	7.0
Time reference (begining of phase)	-				-	-	-	-	-	-	-	-	-	t4	-	-	-	-
	-				-	-	-	-	-	-	-	-	-	-	-	-	-	-
Test Environment parameters																		
LN2 Shrouds T°	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	Shrouds WU	300
GHe Shrouds T°	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	Shrouds WU	300
Optical shield T°	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	OS WU	280
Pressure (mb)	5 10-5	5 10-5	5 10-5	5 10-5	5 10-5	5 10-5	5 10-5	5 10-5	5 10-5	5 10-5	5 10-5	5 10-5	5 10-5	5 10-5	5 10-5	5 10-5	5 10-5	Pa

Figure 5-6: Test environment (Phases 3 to 7)

5.2.2 Planck PLM and RAA Dummy

The PPLM and RAA Dummy configurations are described through the associated test heating lines status. Figure 5-7, Figure 5-8 and Figure 5-9 show the evolution of PPLM & RAA Dummy thermal configuration following the sequence.

Planck CQM Test Timeline	Facility check	S/C short functional test	S/C short functional test	Final check before pumping	Pump down	Microvibration check	De-soption of CFRP	PACE GSE leak check	Facility leak check	Pre-Cooling loop leak check	4K cooler leak check	Dilution cooler isotope leak check	4K cooler Switch-On –Flushing of 4K Pipes	Shrouds filling	Optical shield & charcoal panel filling	Microvibration check during cooling	PPLM Passive performance : switch ON PPLM	PPLM Cooldown +Y	PPLM Cooldown -Y	Microvibration check during PPLM passive performance
Configuration / Phase	0.0-1	0.0-2	0.0-3	0.0-4	0.1-1	0.1-2	0.1-3	0.1-4	0.1-5	0.1-6	0.1-7	0.1-8	0.1-9	0.2-1	0.2-2	0.2-3	1-1	1-2	1-3	1-4
Time reference (begining of phase)	t0	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-	t1
PPLM & RAA Dummy parameters																				
PPLM & RAA Dummy heating lines configuration																				
Configuration (A-B-B'-B"-C-D-E-F-G)	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	A	A	A	A	A	A	B
Criteria for "start of phase" acceptance																				
Time	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sorption Cooler PC3C temperature(+Y)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60K
Instruments VG3 I/F (4K&0.1K&WGs) temperatures	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Instruments Telescope I/F (FPU & JFET) temperatures	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Reflectors I/F temperatures	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
JPL LVHX2 temperature (+Y)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Figure 5-7: PPLM & RAA Dummy parameters (Phases 0 to 1)

Planck CQM Test Timeline	Cryo-Chain testing : Microvibration	Specimen configration	Switch ON PACE GSE	Switch ON pre-cooling loop	Switch ON HFI detection chain	Switch On heaters on RAA FPU	Run 4K cooler at final compressor stroke	Switch OFF HS2	Start 0,1K cooler	Switch OFF HS1	HFI FPU thermal control	HFI Electrical crosstalk
Configuration \ Phase	2-1	2-2	2-3	2-4	2-5	2-6	2-7	2-8	2-9	2.1	2-11	2-12
Time reference (begining of phase)	-	-	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-
PPLM & RAA Dummy parameters												
PPLM & RAA Dummy heating lines configuration												
Configuration (A-B-B'-B"-C-D-E-F-G)	B'	B'	B'	B"	C	D	D	D	D	D	D	D
Criteria for "start of phase" acceptance												
Time	t=t1+ 5(h)	-	-	-	-	-	-	-	-	-	-	-
Sorption Cooler PC3C temperature (+Y)	-	-	-	-	-	-	-	-	-	-	-	-
	-	-	-	60K	-	-	-	-	-	-	-	-
	-	-	-	-	60K	-	-	-	-	-	-	-
	-	-	-	-	50K	-	-	-	-	-	-	-
JPL LVHX2 temperature (+Y)	-	-	-	-	-	#18.6K	-	-	-	-	-	-

Figure 5-8: PPLM & RAA Dummy parameters (Phase 2)

Planck CQM Test Timeline	Regulation of 0,1K cold end with PID1	Regulation of 0,1K bolometer plate with PID2	Performance characterisation with temperature regulation ON	Performance characterisation without temperature regulation	HFI EMC test	PACE GSE pressure fluctuation	4K cooler frequency influence on Dilution Cooler and bolometers	4K Cooler heat lift margin	Dilution cooler defrost system test	4K cooler defrost system test	HFI 4K cooler failure test	PACE cooler failure test	Microvibration check	PPLM transient	Stop coolers	Warm up	PPLM Warm-up	Pressure recovery
Configuration \ Phase	3-1a	3-1b	3-1c	3-1d	3-2	3-3	3-4	3-5a	3-5b	3-5c	3-6a	3-6b	3-7	4.1	5.1	5.2	6.1	7.0
Time reference (begining of phase)	-	-	-	-	-	-	-	-	-	-	-	-	-	t4	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PPLM & RAA Dummy parameters																		
PPLM & RAA Dummy heating lines configuration																		
Configuration (A-B-B'-B"-C-D-E-F-G)	D	D	D	D	D	D	D	D	D	D	D	D	D	E	F	F	G	OFF
Criteria for "start of phase" acceptance																		
Time	-	-	-	-	-	-	-	-	-	-	-	-	-	-	t=t4+ 10(h)	-	-	-
Sorption Cooler PC3C temperature(+Y)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Instruments VG3 I/F (4K&0.1K&WGs) temperatures	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Instruments Telescope I/F (FPU & JFET) temperatures	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Reflectors I/F temperatures	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
JPL LVHX2 temperature (+Y)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Figure 5-9: PPLM & RAA Dummy parameters (Phases 3 to 7)

The heating configurations (A to G) are detailed in Table 5-5 and Table 5-7.

Note :

Configuration E involves a power profile injected at SC3A plate (TBC). See §5.2.2.1.2.

5.2.2.1 Test heaters configurations

5.2.2.1.1 Power values per line

Notes on Table 5-5: PPLM & RAA Dummy test Heating lines configurations :

- HFI harness, which is a major source of heat loads on shields, is part of CQM hardware and therefore cannot be simulated. The heat loads injected at 4K and JFET, corresponding here to max allocated ones, may be lowered by further detailed analyses in accordance with ESA&Instruments.
- The HFI 744mW(VG3)/24mW(VG2)/60mW(VG1) allocations are spread on JFET line (300mW), 4K cooler line (350mW), RAA-VG3 (94mW), RAA-VG2 (24mW), RAA-VG1(60mW). For example, 6829mW for RAA Groove 1 correspond to (6444+60)*1.05.
- 5% margin is added to allocated values in order to take into account power injection uncertainty (<5%).

Heating Line identification	Heater A Passive perf. PC3C +Y	Heater B Passive perf. PC3C -Y	Heater B' Passive perf. VG3&Tel	Heater B'' Passive perf. Tel	Heater C Sorp Cooler cool-down	Heater D HFI cool down & test	Heater E PPLM transient	Heater F FPU Warm-up	Heater G Warm-up global
RAA groove 1	6829 mW	6829 mW	6829 mW	6766 mW	6766 mW	6766 mW	6766 mW	0 mW	0 mW
RAA groove 2	731 mW	731 mW	731 mW	706 mW	706 mW	706 mW	706 mW	0 mW	0 mW
RAA groove 3	993 mW	993 mW	993 mW	895 mW	895 mW	895 mW	895 mW	0 mW	0 mW
Sorp cool Nom Sh 1	0 mW	707 mW	0 mW	0 mW	0 mW	0 mW	0 mW	0 mW	0 mW
Sorp cool Nom Sh 2	0 mW	558 mW	0 mW	0 mW	0 mW	0 mW	0 mW	0 mW	0 mW
Sorp cool Red Sh 1	707 mW	0 mW	0 mW	0 mW	0 mW	0 mW	0 mW	0 mW	0 mW
Sorp cool Red Sh 2	558 mW	0 mW	0 mW	0 mW	0 mW	0 mW	0 mW	0 mW	0 mW
Sorp cool Nom A Sh	0 mW	978 mW	0 mW	0 mW	0 mW	0 mW	Profil SC3A	0 mW	0 mW
Sorp cool Nom B Sh	0 mW	258 mW	0 mW	0 mW	0 mW	0 mW	0 mW	0 mW	0 mW
Sorp cool Nom C Sh	0 mW	122 mW	0 mW	0 mW	0 mW	0 mW	0 mW	0 mW	0 mW
Sorp cool Red A Sh	978 mW	0 mW	0 mW	0 mW	0 mW	0 mW	0 mW	0 mW	0 mW
Sorp cool Red B Sh	258 mW	0 mW	0 mW	0 mW	0 mW	0 mW	0 mW	0 mW	0 mW
Sorp cool Red C Sh	122 mW	0 mW	0 mW	0 mW	0 mW	0 mW	0 mW	0 mW	0 mW
4K cooler	368 mW	368 mW	368 mW	0 mW	0 mW	0 mW	0 mW	0 mW	0 mW
JFET	315 mW	315 mW	315 mW	315 mW	0 mW	0 mW	0 mW	0 mW	0 mW
Main Frame Area 1	0 mW	0 mW	0 mW	0 mW	0 mW	134 mW	134 mW	0 mW	0 mW
Main Frame Area 2	0 mW	0 mW	0 mW	0 mW	0 mW	59 mW	59 mW	0 mW	0 mW
Main Frame Area 3	0 mW	0 mW	0 mW	0 mW	0 mW	59 mW	59 mW	0 mW	0 mW
Main Frame Area 4	0 mW	0 mW	0 mW	0 mW	0 mW	100 mW	100 mW	0 mW	0 mW
Main Frame Area 5	0 mW	0 mW	0 mW	0 mW	0 mW	100 mW	100 mW	0 mW	0 mW

Table 5-5: PPLM & RAA Dummy test Heating lines configurations

5.2.2.1.2 Transient power profile

Profile to be injected is given in Figure 5-10. Amplitude and period are given for information and will be refined following detailed further analyses. The injection location (SCN3A, SCN3B and/or C) may also be adapted.

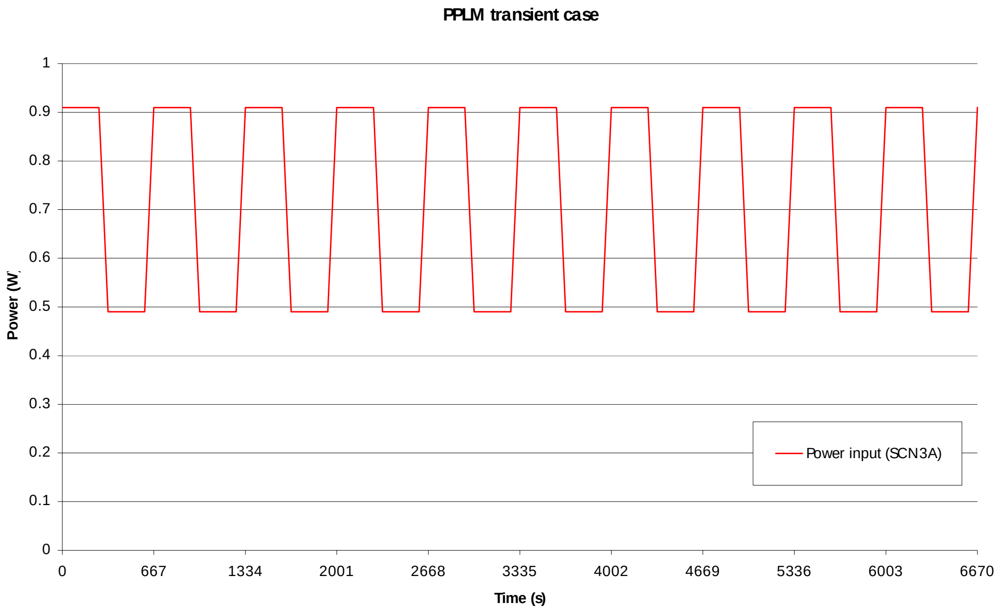


Figure 5-10: Transient power profile

5.2.2.1.3 Configurations for passive demonstration

Phases (see §5.1)	Step#1	Loads (see §1.2 &Table 5-5)	Sorption Cooler I/F (VG1&2&3)	Wave Guides I/F (VG1&2)	Wave Guides I/F (VG3)	4K and 0.1K I/F (VG3)	JFET & FPU I/F	Refflectors I/F
Ph01-002 & Ph01-003	HL Sorp Cooler	Max load + 5%	YES	YES	NO	NO	NO	NO
	HL Wave Guides	Max load + 5%						
	HL HFI VG3	Max load + 5%						
	HL JFET	Max load + 5%						
Phase (see §5.1)	Step#2	Loads (see §1.2 &Table 5-5)	Sorption Cooler I/F (VG1&2&3)	Wave Guides I/F (VG1&2)	Wave Guides I/F (VG3)	4K and 0.1K I/F (VG3)	JFET & FPU I/F	Refflectors I/F
Ph02-003	HL Sorpt Cooler	None	-	-	YES	YES	NO	NO
	HL Wave Guides	Max load + 5%						
	HL HFI VG3	Max load + 5%						
	HL JFET	Max load + 5%						
Phase (see §5.1)	Step#3	Loads (see §1.2 &Table 5-5)	Sorption Cooler I/F (VG1&2&3)	Wave Guides I/F (VG1&2)	Wave Guides I/F (VG3)	4K and 0.1K I/F (VG3)	JFET & FPU I/F	Refflectors I/F
Ph02-004	HL Sorpt Cooler	None	-	-	-	-	YES	YES
	HL Wave Guides	Max load + 5%						
	HL HFI VG3	None						
	HL JFET	Max load + 5%						

Table 5-6: Description of the three steps of passive demonstration

Table 5-6 presented here above is intended to clarify how the passive performance is demonstrated during the sequence.

The passive performance is checked at three different steps. This table gives :

- When (during which step or phase) the different Interface temperatures are checked
- What is the configuration of injected heat loads (HL) during each check

For example, it can be read in the table that :

- Wave Guides VG3 interface temperature is checked at step#2 (Ph02-003).
- During this check, all test heaters are ON (at max load) excepted Sorption Cooler simulation heaters and with PACE GSE operating (PACE GSE operated at nominal flow at Ph02-003).

5.2.2.2 "Decontamination heaters" configurations

Heating Line identification	Heater A Passive perf. PC3C +Y	Heater B Passive perf. PC3C -Y	Heater B' Passive perf. VG3&Tel	Heater B'' Passive perf. Tel	Heater C Sorp Cooler cool-down	Heater D HFI cool down & test	Heater E PPLM transient	Heater F FPU Warm-up	Heater G Warm-up global
FPU1	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**20W**	20W (1)
FPU2	**0**	**0**	**0**	**0**	**0**	**0**	**0**	0	20W (1)

Table 5-7: Decontamination Heating lines configurations

Notes :

(1) Power will be adjusted at the end of the warm-up in order to keep the RAA Main Frame around 300K (±10K)

5.2.3 Instruments and coolers

The mode of each equipment in each phase is given in the document HFI CQM CSL Cryo-Test macro-sequences RD26.

Planck CQM Test Timeline	Facility check	S/C short functional test	PACE GSE leak check	Final check before pumping	Pump down	Microvibration check	De-soption of CFRP	PACE GSE leak check	Facility leak check	Pre-Cooling loop leak check	4K cooler leak check	Dilution cooler isotope leak check	4K cooler Switch-On –Flushing of 4K Pipes	Shrouds filling	Optical shield & charcoal panel filling	Microvibration check during cooling	PPLM Passive performance : switch ON PPLM	PPLM Cooldown +Y	PPLM Cooldown -Y	Microvibration check during PPLM passive performance
Phase / Configuration	0.0-1	0.0-2	0.0-3	0.0-4	0.1-1	0.1-2	0.1-3	0.1-4	0.1-5	0.1-6	0.1-7	0.1-8	0.1-9	0.2-1	0.2-2	0.2-3	1-1	1-2	1-3	1-4
Time reference (begining of phase)	t0	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-	t1
Instruments and Coolers parameters																				
DPU	OFF	CONF	CONF	CONF	CONF	CONF	CONF	CONF	CONF	CONF	CONF	CONF	CONF	CONF	CONF	CONF	CONF	CONF	CONF	CONF
REU Proc	OFF	CONF	CONF	CONF	CONF	CONF	CONF	CONF	CONF	CONF	CONF	CONF	CONF	CONF	CONF	CONF	CONF	CONF	CONF	CONF
4K CDE	OFF	NOM	NOM	NOM	NOM	NOM	NOM	NOM	NOM	NOM	NOM	NOM	NOM	NOM	NOM	NOM	NOM	NOM	NOM	STBY
0.1K DCCU	OFF	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON
REU belts, PAU belts, JFET	OFF	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
REU dummy, PAU dummy, JFET	OFF	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
4K Compressor (32V), 4K Ancillary Unit	OFF	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON
4K compressor range	0	3 mm	2 mm	2 mm	2 mm	2 mm	2 mm	2 mm	2 mm	2 mm	2 mm	2 mm	2 mm	2 mm	2 mm	2 mm	2 mm	2 mm	2 mm	2 mm
Getter	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	ON	ON	ON	ON	ON	ON	ON	ON
Heat Switch 1	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
Heat Switch 2	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
0,1K Precooling loop flow rate (ml/mn)	2 ml/mn	2 ml/mn	2 ml/mn	2 ml/mn	OFF/purge	OFF/purge	OFF/purge	OFF/purge	OFF/purge	20 bars	2 ml/mn	2 ml/mn	2 ml/mn	2 ml/mn	2 ml/mn	2 ml/mn	2 ml/mn	2 ml/mn	2 ml/mn	2 ml/mn
Isotope flow rate (ml/mn)	OFF/press	OFF/press	OFF/press	OFF/press	OFF/purge	OFF/purge	OFF/purge	OFF/purge	OFF/purge	OFF/purge	OFF/purge	20 bars	OFF/purge	OFF/purge	OFF/purge	OFF/purge	2 ml/mn	2 ml/mn	2 ml/mn	2 ml/mn
PACE PGSE	OFF	OFF	ON	OFF	OFF	OFF	OFF	OFF	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
FPU PIDs 4K	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
FPU PIDs 1,6K	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
FPU PID1 100mK	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
FPU PID2 100mK	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
0,1K defrost heaters	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
4K defrost heaters	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
Criteria for "start of phase" acceptanc																				
LVHX2 temperature																				
VG3																				
RHC02-TempK (4K)																				
RHC00-TempK (100mK)																		release clamp 220		
RHC01-TempK (1.6K)																				
Ther_0.1K1																				
Ther_PID1.6R																				
Ther_PID4R																				
JFET Box therm																				

Planck CQM Test Timeline	Cryo-Chain testing : Microvibration	Specimen configration	Switch ON PACE GSE	Switch ON pre-cooling loop	Switch ON HFI detection chain	Switch On heaters on RAA FPU	Run 4K cooler at final compressor stroke	Switch OFF HS2	Start 0,1K cooler	Switch OFF HS1	HFI FPU thermal control	HFI Electrical crosstalk
Phase / Configuration	2-1	2-2	2-3	2-4	2-5	2-6	2-7	2-8	2-9	2-10	2-11	2-12
Time reference (begining of phase)	-	-	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-
Instruments and Coolers parameters												
DPU	CONF	CONF	CONF	CONF	CONF/OBS	CONF	CONF	CONF	CONF	CONF	CONF/OBS	CONF/VI
REU Proc	CONF	CONF	CONF	CONF	CONF	CONF	CONF	CONF	CONF	CONF	CONF	CONF
4K CDE	NOM	NOM	NOM	NOM	NOM	NOM	NOM	NOM	NOM	NOM	NOM	NOM
0.1K DCCU	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON
REU belts, PAU belts, JFET	OFF	OFF	OFF	OFF	OFF	ON	ON	ON	ON	ON	ON	ON
REU dummy, PAU dummy, JFET	OFF	OFF	OFF	OFF	ON	ON	ON	ON	ON	ON	ON	ON
4K Compressor (32V), 4K Ancillary Unit	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON
4K compressor range	2 mm	2 mm	2 mm	2 mm	2 mm	2 mm	3,9 mm	3.9 mm	3.9 mm	3.9 mm	3.9 mm	3.9 mm
Getter	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON
Heat Switch 1	OFF	OFF	OFF	OFF	ON	ON	ON	ON	ON	OFF	OFF	OFF
Heat Switch 2	OFF	OFF	OFF	OFF	ON	ON	ON	OFF	OFF	OFF	OFF	OFF
0,1K Precooling loop	2 ml/mn	2 ml/mn	2 ml/mn	1200 ml/mn	1200 ml/mn	1200 ml/mn	1200 ml/mn	1200 ml/mn	OFF/purge	OFF/purge	OFF/purge	OFF/purge
Isotope flow rate (ml/mn)	2 ml/mn	2 ml/mn	2 ml/mn	2 ml/mn	2 ml/mn	2 ml/mn	2 ml/mn	2 ml/mn	33/11	33/11	33/11	33/11
PACE PGSE	OFF	OFF	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON
FPU PIDs 4K	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	ON	ON
FPU PIDs 1,6K	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	ON	ON
FPU PID1 100mK	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
FPU PID2 100mK	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
0,1K defrost heaters	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
4K defrost heaters	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
Criteria for "start of phase" acceptance												
LVHX2 temperature			<175K									
VG3				<60K								
RHC02-TempK (4K)							<30K	<19K				
RHC00-TempK (100mK)									<19K			
RHC01-TempK (1.6K)										<6K		<6K
Ther_0.1K1												500 mK
Ther_PID1.6R											1,45	
Ther_PID4R											5,5	
JFET Box therm					<60K							

Planck CQM Test Timeline	Regulation of 0,1K cold end with PID1	Regulation of 0,1K bolometer plate with PID2	Performance characterisation with temperature regulation ON	Performance characterisation without temperature regulation	HFI EMC test	PACE GSE pressure fluctuation	4K cooler frequency influence on Dilution Cooler and bolometers	4K cooler frequency influence on Dilution Cooler and bolometers	Dilution cooler defrost system test	4K cooler defrost system test	HFI 4K cooler failure test	PACE cooler failure test	Microvibration check	PPLM transient	Stop coolers	Warm up	PPLM Warm-up	Pressure recovery
Phase / Configuration	3-1a	3-1b	3-1c	3-1d	3-2	3-3	3-4	3-5a	3-5b	3-5c	3-6a	3-6b	3-7	4,1	5,1	5,2	6,1	7
Time reference (begining of phase)	-				-	-	-	-				-	-	t4	-	-	-	-
	-				-	-	-	-				-	-	-	-	-	-	-
Instruments and Coolers parameters																		
DPU	CONF/OBS	CONF/OBS	CONF/OBS	CONF/OBS	OBS	CONF	CONF/OBS	CONF	CONF	CONF	CONF	CONF	CONF	CONF	CONF	CONF	OFF	OFF
REU Proc	CONF	CONF	CONF	CONF	CONF	CONF	CONF	CONF	CONF	CONF	CONF	CONF	CONF	CONF	CONF	CONF	OFF	OFF
4K CDE	NOM	NOM	NOM	NOM	NOM	NOM	NOM	NOM	NOM	NOM	NOM	NOM	NOM	NOM	STBY	STBY	OFF	OFF
0.1K DCCU	ON	ON	ON	ON	ON	ON	ON/OFF	ON	ON	ON	ON	ON	ON	ON	ON	ON	OFF	OFF
REU belts, PAU belts, JFET	ON	ON	ON	ON	ON	ON	ON/OFF	ON	ON	ON	ON	ON	ON	ON	ON	ON	OFF	OFF
REU dummy, PAU dummy, JFET	ON	ON	ON	ON	ON	ON	ON/OFF	ON	ON	ON	ON	ON	ON	ON	ON	ON	OFF	OFF
4K Compressor (32V), 4K Ancillary Unit	ON	ON	ON	ON	ON	ON	ON/OFF	ON	ON	ON	ON	ON	ON	ON	ON	ON	OFF	OFF
4K compressor range	3.9 mm	3.9 mm	3.9 mm	3.9 mm	3.9 mm	3.9 mm	3.9/0	3.9 mm	3.9 mm	3.9 mm	3.9/0	3.9 mm	3.9 mm	3.9 mm	0	0	0	0
Getter	ON	ON	ON	ON	ON	ON	ON/OFF	ON	ON	ON	ON	ON	ON	ON	OFF	OFF	OFF	OFF
Heat Switch 1	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	ON	ON	OFF	OFF
Heat Switch 2	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	ON	ON	OFF	OFF
0,1K Precooling loop flow rate (ml/mn)	OFF/purge	OFF/purge	OFF/purge	OFF/purge	OFF/purge	OFF/purge	OFF/purge	OFF/purge	OFF/purge	OFF/purge	OFF/purge	OFF/purge	OFF/purge	OFF/purge	OFF/purge	OFF/purge	OFF/purge	OFF/purge
Isotope flow rate (ml/mn)	33/11	33/11	33/11	33/11	33/11	33/11	33/11	33/11	33/11	33/11	33/11	33/11	33/11	33/11	2	2	2	2
PACE PGSE	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	OFF	OFF	OFF
FPU PIDs 4K	ON	ON	ON	ON	OFF	ON/OFF	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	OFF	OFF
FPU PIDs 1,6K	ON	ON	ON	ON	OFF	OFF	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	OFF	OFF
FPU PID1 100mK	ON	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
FPU PID2 100mK	OFF	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
0,1K defrost heaters	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	ON/OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
4K defrost heaters	OFF	OFF	OFF	OFF	OFF	OFF	OFF	ON/OFF	OFF	ON/OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
Criteria for "start of phase" acceptance																		
LVHX2 temperature																		
RHC02-TempK (4K)																		
RHC00-TempK (100mK)																		
RHC01-TempK (1.6K)																		
Ther_0.1K1	<105mK																45K	
Ther_PID1.6R	<2.1K																	
Ther_PID4R	<5,5K																	
JFET Box therm	120K+/-10K																	

5.3 Parameters to be measured/Measurement accuracy

5.3.1 PPLM thermal parameters

5.3.1.1 RTAP / Octopussy (PPLM & RAA Dummy test sensors acquisition by CSL)

Type	Temperature
Description	110 measurements on PPLM & RAA Dummy (46 PT100 and 64 DT470) (see §3.2.1.1)
Accuracy and range	PT100 : δT≤ ±1K over [80-320K] DT470 : δT≤ ±0.5K over [10-100K] and ±1K over [100K-320K]

Note :

Sensors are acquired through 4-wire measurement.

5.3.1.2 Power EGSE (PPLM & RAA Dummy test heating lines)

Type	Power (or Voltage) at heaters
Description	20 redunded heating lines (see §3.2.1.2)
Accuracy and range	For all lines, δP/P≤ ±3% over [Pmax/10, Pmax] and ±6% over [0, Pmax/10]

Notes :

- Pmax (for each line) is given in §3.2.1.2.

- Test heating lines are supplied through 4-wire harness. Heaters resistance variation with temperature will be measured during dedicated elementary tests and results will be injected in acquisition software.

5.3.1.3 PLM EGSE

Type	Temperature
Description	13 measurements (see §3.1.2.1.1)
Accuracy and range	Functional check on T° range achieved during test, no required accuracy

Type	Power at EGSE output
Description	2 redunded heating lines (see §3.1.2.1.2.2)
Accuracy and range	±7% over [0, 30W]

5.3.2 Instrument parameters

5.3.2.1 HFI monitoring sensor list

See RD26 and RD28.

5.3.2.2 PACE GSE parameters

During the test only the nominal parameters are handled. Nevertheless, if case of failure it is possible to use the redundant way by manual operation at PACE GSE I/F.

5.3.2.2.1 Heaters

The PACE heaters are defined in section 3.2.2.2.1.

The following table gives the accuracy of the PACE GSE only

Control mode	Power range (W)	Accuracy
PID loop	0 to 2.0	+/-0,1% injection power
On-Off	4	+/-6% Max

5.3.2.2.2 Temperature sensors

The PACE temperature sensors are defined in section 3.2.2.2.2

Only the nominal temperature will be used. The T11 sensor is not working on the CQM PACE.

The sensors and the acquisition system accuracy give the accuracy of the whole chain. The sensors calibration data given by the JPL has been implement in the lakeshore system. Based on the Lakeshore M340 user Manuel, the temperature accuracy is around 0.1K at 77K for the Cexnox sensors mounted on the PACE.

5.3.3 SVM dummy parameters

SVM dummy thermal control objectives during the test are (see table) :

- to ensure safe temperature of HFI units within operating/non operating range depending on their switching status

- to ensure PACE heat exchanger interface temperature within its design range

- to ensure correct and stable interface fluxes with PLM

Units	**Location**	**Maximum Dissipation (W)**	**Operating temp range (°C)**	**Non operating temp range (°C)**
0,1 K HFI units				
DPU	+Z	22	-10 ;+40	-20 ;+50
DCCU	+Z+Y	16	-10 ;+40	-20 ;+50
Piping	+Z+Y	-	- 10; +40	- 20 ; +50

Units	Location	Maximum Dissipation (W)	Operating temp range (°C)	Non operating temp range (°C)
4 K HFI units				
REU	+Z	92	-10 ;+40	-20 ;+50
CCU	+Y	60	-10 ;+40	-20 ;+40
CAU	+Y	15	-10 ;+40	-20 ;+50
CRU	+Y	20	-10 ;+40	-20 ;+50
CEU	+Y	41	-10 ;+40	-20 ;+50
Piping	+Y	-	- 10 ; +40	- 20 ; +50
Subplatform HFI units				
PAU	Sub +X	15	-10 ;+40	-20 ;+50
BEU (*)	Sub +X	32	-20 ;+40	-30 ;+50
20 K heat exchanger				
PACE radiator	+Y-Z	5	-13.15 ; +6.85	-
Interface temperatures (**)				
PAU radiator	+X on sub platform	None (related to sub platform)	20	NA
BEU radiator	+X on sub platform	None (see *)	7	NA
Struts interface points	+X on sub platform	None (related to sub platform)	20	NA
Sub platform	+X	69.4	20	NA
Upper closure	+X	69.4	20	NA

(*) BEU is a Mechanical Thermal Model equipped with internal heaters on the baseplate, dissipation can be adjusted if needed, default value will be taken as 32W which is the flight dissipation of this unit. Temperature ranges are the flight ones, theoretically they could be exceeded but it will safer to stay within the limits to avoid any damage on the internal heaters.

(**) Maximum dissipation are related to installed heating power, this power can be adjusted during the test to meet temperature objectives allowing compliance with flux requirements.

Since EGSE do not provide automatic regulation to control temperatures/fluxes during the test, therefore human real time monitoring using thermo-couples acquisition is needed.

The injected power is manually tuned using voltage adjustment for each of the following heating line :

- DPU (+Z) : Pmax=28.6W (under 50V)
- PACE (+Y-Z) : Pmax=11.5W (under 50V)
- DCCU (+Y+Z) : Pmax=28.6W (under 50V)
- 4K (+Y) : Pmax=183W (under 50V)
- Upper closure (+X) : Pmax=69.4W (under 50V)
- subplatform (+X) : Pmax=69.4W (under 50V)
- Cone : Pmax=80.6W (under 50V)
- TRA (not used) : Pmax=4x68W (under 28V)

Standard thermo-couples accuracy (+/-1°) is sufficient to monitor temperature since no specific stability or gradient is requested during the test.

Additionnal thermo-couples are foreseen in dedicated area allowing future correlation (see §1.1.3) on interface ring, thermal ring adaptor, cone…but don't require real time monitoring during test since there is no risk of damage on these parts.

5.3.4 Microvibration parameters

Acceleration time signals shall be recorded in order to characterise microvibration up to 300 Hz.

PSD and 3σ values shall be computed 'on line' at the FPU interface and at the SC bracket interface in order to guarantee that the specifications are met (see section 4.5).

5.4 Conditions to be verified for test execution

5.4.1 Operations to be performed before test

- Functional verification of test heating lines

- Control of thermal sensors (test + PT2000) identification/location by observation of thermal response when heated

- Verification that thermal sensors locations are conform to required ones. Potential deviations to be recorded

<u>Important</u> : Pictures, allowing to visualise the location of all thermal sensors mounted on S/C and test facility interfaces, will systematically be taken during the integration activities.

- Check of time synchronisation between all teams

A visual inspection of accessible set-up elements will be performed by the test conductor before the door closure.

5.4.2 Operations to be performed after test

Functional verification of test heating lines

S/C Short Functional test

Systematic pictures of potential defaults

A visual inspection of accessible set-up elements will be performed by the test conductor after the door opening.

6. SUCCESS CRITERIA

6.1 PPLM passive thermal control success criteria

→ Passive thermal performance (phase 1)

All specified Instruments / PLM interfaces are below the required temperatures (see §1.2), with test environment as required - see Table 5-5 for power injection (heater A&B configurations), §3.1.4 for SVM I/F and §4.2 for test facility -

No stability required on P-PLM.

Stability required at PPLM boundaries :

- SVM I/F : Variation of average temperature of TC31 to TC44 and TC47 to TC60 inferior to 5K from Ph0.0-002 to Ph02-004
- Flux injection : Variation of injected power P (for all test lines ON) inferior to 1% × P from Ph01-001 to Warm-Up (theoretical power with given heater resistance).

→ Dynamic behaviour (phase 4)

Required duration is achieved (15h)

→ Flight temperature acquisitions (all phases)

PT2000 sensors are acquired during test. Read temperatures are close (within ±10°C) to neighbour test acquisitions (see Table 3-1).

→ Test temperature acquisitions on PLM (all phases)

Test sensors failures are within allowable ones (see Table 3-6, Table 3-7 and [RD7]).

→ Test power injection on PLM (all phases)

Power values are injected as described in Table 5-5 with accuracy as defined in §5.3.1.2 and §5.3.1.3.

6.2 Cryo chain testing success criteria

→ Temperature : to maintain during the phase Ph03-001 the following temperatures :

Ther_0.1K1 < 105mK

Ther_PID1.6R < 2.1K

Ther_PID4R < 5.5K

(JFET Box therm) = 120 K +/- 10 K

LVHX2 (T3&T4 PACE) < 22.5 K

LVHX1 (T&T2 PACE) < 19 K

→ Temperature fluctuation : to acquire the temperature during at least 670 s (during Ph03-001) at 100 mK, 1.6 K and 4 K stages. Then to check that the temperature average density spectrum in the range 16 mHz-80Hz less than twice the following ones :

(Ther 100mK) : 20 nK $Hz^{-1/2}$, (2 10^{-8} K $Hz^{-1/2}$)

(Ther PID 1.6K N) : 28 μK $Hz^{-1/2}$ (2.8 10^{-5} K $Hz^{-1/2}$)

(Ther 4K LFI1) : 10^{-5} K $Hz^{-1/2}$

6.3 Instrument functional testing success criteria

See success criteria in each phase of Chapter 5.

6.4 Microvibration success criteria

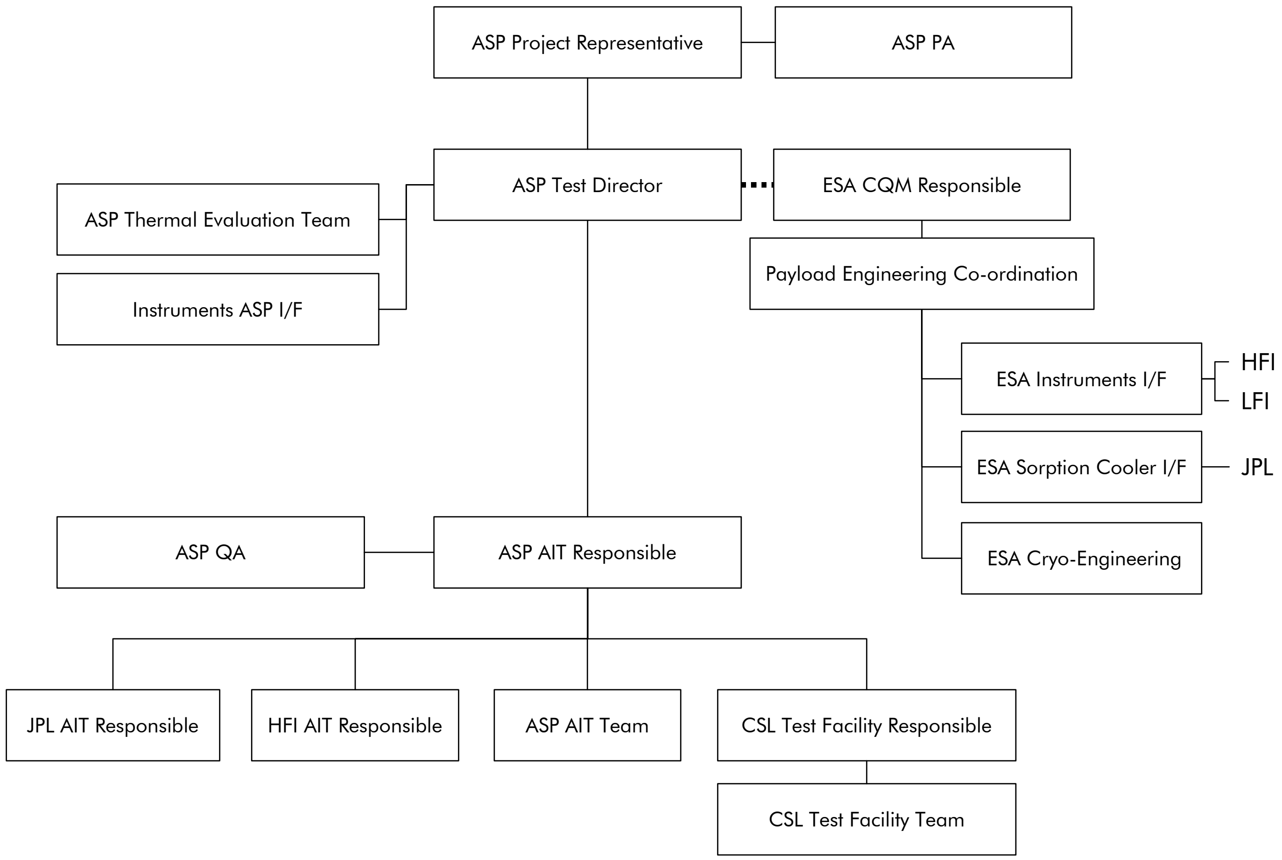
→ The test realisation has to be in accordance with the test specification and the test procedure.

→ All data have to be recorded, fulfilling the constraints of sections 3.2.4.

7. ORGANISATION & RESPONSABILITIES

7.1 Organisation

The overall organisation during the test is as follows:



7.2 Responsibilities

The overall responsibility during the test is as follows:

The responsibilities linked to the test progress shall be mentioned in the ASP test leading procedure.

Organization	Responsibility
ASP Project Representative D. Montet / P. Armand	Alcatel project interface Represents ASP during the test and he is also the I/F point with the ESA representative
ASP PA	ASP Project Assurance Manager
ASP Test Director P. Armand for Phase [0,7] E. Gavila for Phases [1,4,5,6] J.P. Chambelland for Phase [2,3]	 Issue the test specification of the relevant test to be performed Go ahead for the test reviews (TRR, key point, PTR) Single point of contact with the ASP Evaluation team concerning the test result status.

Organization	Responsibility
ESA CQM Responsible M. Braghin	ESA point of contact I/F with ESA project I/F with ASP test director & ESA Payload Engineering Co-ordination
ESA Co-ordination B. Guillaume	I/F with ASP test director & Instruments evaluation teams
ESA Instruments I/F J. Marti Canales	I/F with HFI & LFI evaluation teams
ESA Sorption cooler I/F A Heske	I/F with JPL evaluation teams
ESA Cryo-Engineering Support C. Damasio	ESA cryo expert
ASP Thermal Evaluation Team Resp. E. Gavila	Evaluate the test data in order to help the test director concerning the "Key point" status. Thermal control of SVM dummy during all phases (limited on structure up to Instruments interfaces) Thermal control of PPLM during all phases (limited on structure up to Instruments interfaces)
ASP AIT responsible	Responsible of the ASP AIT Team Issue the leading procedure of all activities Manage all activities done during the test including "key point" meeting. I/F point with the CSL Test Facility Team Responsible I/F point with the HFI AIT Team Responsible I/F point with JPL responsible Organize the Daily meeting Initialize NCR…
ASP AIT Team	Realize all S/C AIT activities within the arrival and the leaving Issue of the relevant test procedures Operate the ASP GSE (including the PACE GSE) Provide the ASP test data Issue the ASP test report.
Instruments ASP I/F J.P. Chambelland	Issue section of the test specification relevant to the instrument ASP instrument expert
ASP QA	Organize the review (TRR/PTR…) Minute the running meeting (Key point)
HFI AIT Team Responsible	Is in charge of I/F point with the ASP AIT responsible Provide relevant test data in order to help the test director concerning the

Organization	Responsibility
	"Key point" status.
HFI AIT Team	ISSS-GSE and I.EGSE full use Issue the relevant test procedures Process the HFI test data and HFI Test data analysis Issue the HFI test report.
JPL Responsible	I/F point with the ASP AIT responsible Control the right use of the PACE CQM Assist the PACE GSE operators
CSL Team Responsible	I/F point with the ASP AIT responsible
CSL Test Facility Team	Issue the test facility leading procedure (in case of different activities) Issue the relevant test procedures Operate the CSL Test facilities Provide the CSL test data Issue the CSL test report.

7.3 Tasks distribution

7.3.1 General Tasks breakdown

ASP is in charge of

- the satellite activities and test management:
- Preparation (tests definition, except for instruments) and execution
- S/C Cleaning, handling, mechanical mounting, electrical checkout, instruments modes set-up.
- Test management (reviews, leading procedure, daily meeting, key points , …)
- Dedicated GSE installation/validations and use
- S/C data analysis.
- Responsible of the test management and for interfaces between the PLANCK satellite and CSL facility.
- Running the CQM test

HFI is in charge of:

- Preparation, tests definition for HFI instruments
- Dedicated GSE installation/validations and use (ISSS-PGSE and I.EGSE)
- Responsible for interfaces between the HFI GSEs (including the piping) and CSL facility.
- Execution and interpretation of instrument performance data
- Provide relevant test data in order to help the test director concerning the "Key point" status.

CSL is in charge of

- Dedicated GSE installation/validations and use
- Cleaning of every GSE's and Containers under the control of an ASP responsible.
- The overall test facility activities
- Preparation of the test facility.
- Running the test facility.

JPL is in charge of:

- Controlling the right use of the PACE CQM
- Assisting the PACE GSE operators wrt to the PACE behaviours.

7.3.2 ASP thermal team

The ASP thermal team will (responsible: E. Gavila):

- Perform the analyses related to the test predictions and issue a report (all phases)
- Verify that the actual behaviour is consistent with the test predictions (all phases)
- Give instructions to AIT team for SVM Dummy test heating lines command (all phases)
- Give instructions to AIT team for PPLM test heating lines command, including RAA Dummy Main Frame (all phases)
- State upon “thermal passive performance” phase :
    - Start conditions acceptance
    - Success criteria
    - End and start of next phase acceptance
- State upon “transient” phase
    - Start conditions acceptance
    - Success criteria
    - End and start of next phase acceptance
- Process the test results (all phases)

↳ Processing limited to ASP temperature sensors acquisition

7.3.3 ASP AIT team

The ASP AIT team is in charge:

- Realize all S/C AIT activities within the arrival and the leaving
- Preparation (tests definition, except for instruments) and execution
- S/C Cleaning, handling, mechanical mounting, electrical checkout, instruments modes set-up.
- Dedicated GSE installation/validations and use
- Operate the ASP GSE (including the PACE GSE)
- Provide the ASP test data
- Issue the ASP test report.

8. DOCUMENTATION

8.1 Documents required before the test

S/C configuration (CIDL, etc)

Test set-up configuration (CIDL, Definition drawings)

Test Set-up validation and calibration status

Test specification

Test predictions

Instrumentation plan [RD7] (PPLM CQM thermal sensors list and location)

Test leading procedure + elementary procedures

SVM Dummy thermal control user manual

8.2 Data acquired during the test

8.2.1 S/C sensors (ASP & CSL)

A listing (paper format) will provide the following information (output frequency TBD) about each type of specimen sensors (thermal, μ-vibration):

- Test phase designation
- Acquisition date/time
- Temperature sensor number
- Sensor designation
- Measured value (time & frequency domain for μ-vib)
- Alarms status

An excel file grouping information <Time, Temperature> of all specimen thermal sensors will be updated at a given frequency (TBD) and delivered on request to ASP thermal team.

An excel file grouping information <Time, Time domain> of all μ-vib sensors will be updated at a given frequency (TBD) and delivered on request to ASP evaluation team.

An excel file grouping <Time, Power / Amperage> of all specimen heating lines (including RAA Dummy) will be updated at a given frequency (TBD) and delivered on request to ASP evaluation team.

8.2.2 Test environment sensors (CSL)

A listing (paper format) will provide the following information (output frequency TBD) about test environment sensors:

Test phase designation

Acquisition date/time

For each sensors (temperature, pressure, μ vibration etc.)

Sensor number

Sensor designation

Measured value

Alarms status

8.2.3 Instrument sensors (HFI)

A listing (paper format) will provide the following information (output frequency TBD) about each type of specimen sensors (thermal, μ-vibration):

- Test phase designation
- Acquisition date/time
- Temperature sensor number
- Sensor designation
- Measured value
- Alarms status

An excel file grouping information <Time, Temperature> of all specimen thermal sensors will be updated at a given frequency (TBD) and delivered on request ASP/ESA evaluation team.

8.3 Documents issued after the test

8.3.1 Test Reports

8.3.1.1 Specimen AIT reports (ASP)

Test progress description

Contamination control report

Logbook reporting all significant events about specimen

Pictures taken on the specimen in test configuration

Record (CD-ROM) of all acquired data during test

Test measurements devices calibration reports

8.3.1.2 Microvibration Test Report for (ASP & CSL)

The deliverables are:

Logbook reporting all measurement conditions and events.

CDR ROM containing the following data:

Data shall be delivered within an universal file (*.unv or *.uff) SDRC DATASET 58.

Calibration of each acquisition channel

Noise floor of each acquisition channel

Time signal and PSD for all accelerometers.

FRF in between FPU IF and:

4K cooler

PLM/SVM I/F

SC I/F

Facility I/F

PSD shall also be delivered in an excel format to validate universal file data post-process.

Pictures and drawings clearly showing all accelerometer locations shall be provided.

8.3.1.3 Test environment - CSL

Test progress description

Pictures taken on the test set-up

Logbook reporting all significant events about test set-up

Record (CD-ROM) of all acquired data during test

Test measurements devices calibration reports

8.3.2 Evaluation reports

8.3.2.1 Evaluation report for PPLM and SVM dummy

The deliverable by ASP thermal team are :

Logbook reporting all significant events about specimen thermal control

CQM PPLM thermal test report including :

Thermal performance demonstration (TBT & transient test objectives)

Test results processing for all phases (on PLM and SVM dummy, limited to ASP/CSL sensors)

A selection of test set-up Interfaces temperatures useful for specimen behaviour understanding

Updated PPLM TMM and associated flight predictions in case of significant deviation between test predictions and test measurements. No modification of SVM Dummy TMM.

8.3.2.2 Evaluation report for cryo chain and instruments (HFI)

The deliverable by HFI thermal team are:

Logbook reporting all significant events about HFI and HFI/cryochain interfaces thermal control

CQM HFI and HFI/cryochain interfaces test report including :

Thermal performance demonstration of the HFI Warm units

Thermal performance demonstration of the 4K cooler and Dilution cooler

Thermal performance demonstration of the HFI external thermal interfaces : V-grooves, Sorption cooler

Performance demonstration of the HFI internal thermal interfaces : in between cold stages, fromm20K to 100 mK

Tests results processing for all HFI test sequences

A selection of Interfaces temperatures useful for HFI and cryochain thermal behaviour understanding

Updated HFI TMM and updated flight predictions

8.3.2.2.1 Evaluation report for instrument functional testing (HFI)

The deliverable by HFI team are:

Logbook reporting all functional tests sequences

HFI CQM functional test report including:

Main performances of S/S and comparison with performance specification

A set of significant scientific data processed showing the noise spectrum and response of each channel (12)

The thermal control performance of the FPU thermal control (4 PIDs)

The result of the EMC susceptibility tests with the comparison with the IID-A specifications.

A set of processed significant scientific data released during EMC test

PD N

HERSCHEL / PLANCK

Addendum to Planck CQM Cryogenic & Thermal Test Specification

Product Code : 212000

Rédigé par/*Written by*	**Responsabilité-Service-Société** ***Responsibility-Office -Company***	**Date**	**Signature**
P ARMAND/JP CHAMBELLAND	PLANCK AIV RESPONSIBLE	15/9/05	[signature]
Vérifié par/*Verified by*			
J.Y. CHARNIER P/o JP. HAYET	PLANCK RESPONSIBLE AIT	17/9/05	[signature]
Approbation/*Approved*			
C MASSE P/o E.POURRIOT.	PA MANAGER	17/09/05	[signature]
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Data management : Christiane GIACOMETTI

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		Clt Documentation	Orig.

ENREGISTREMENT DES EVOLUTIONS / *CHANGE RECORD*

Issue. Revision	DATE	§ : CHANGE RECORD	AUTHOR
1.0	10/08/2005	First Issue	P. Armand
2.0	10/09/2005	Modification of the phase Ph03-006A (addendum 2)	P. Armand
~~2.0~~ 3.0	10/09/2005	Transfer of the HFI detection chain "switch-off" from phase Ph06-001 to phase Ph07-001 (addendum 3).	P. Armand

TABLE OF CONTENTS

1. INTRODUCTION

The aim of this document is to formalised an addendum of the Planck CQM cryogenic & Thermal test specification [AD01].

2. DOCUMENTATION

2.1 Applicable document

Ref.	Reference of Document	Title
AD01	H-P-3-ASP-TS-0645 is 3.0	Planck CQM cryogenic & Thermal test specification

2.2 Reference document

Ref.	Reference of Document	Title
RD01	H-P-3-ASP-TR-307	Test Report of the functional test of the PACE at ambient
RD02	H-P-3-ASP-TS-0966	HFI CQM CSL CRYO TEST MACROSQUENCE TR

2.3 Acronyms

N.A.

3. ADDENDUM 1

In the AD[01], during the phase Ph0.1-005 a functional check at nominal pressure in H2 is requested at the end of leak detection in He. The aim of this functional is to check the system before cool-down and to train the AAS peoples with the support of Air Liquide France (manufacturer of PACE-GSE). Nevertheless due to the slippage of the schedule due to 4K anomaly investigation the support of the skilled person of AL France was not guaranteed. A decision has been taken to advance this phase before the chamber closure. This training has been done see RD[01].

After a check with AAS PACE responsible, the necessity (training, safety, functional test) to re done this test is not justify, that why the phase Ph0.1-005 is modified as follows:

- Switch-on the PACE GSE at max operational pressure of 53 bars (He) to check the leak.
- Switch he PACE GSE in Stand-By. The PACE remains at $7x10^{-4}$ mbars after the test.
- If the pressure inside the PACE raise up to 100 mbars, pump down the PACE back to $1\ 10^{-3}$ until Ph02.003.

4. ADDENDUM 2

In the AD[01], during the phase Ph03-006A (4K failure test) the simulation of 4K failure is done by a switch-off and switch-on of the compressor. Nevertheless, due to the complex switch-on/off procedure (due to severals NCR) it has been decided to simulate the 4K failure test by a set the stroke at 0mm during 1h and come back to nominal stroke after.

This change implies the following modifications in RD[02].

Pages	Comments
229	Step 500 Canceled Step 85-1 replaced by set the 4K stroke at 0mm during 1 hr: • TC4K-FreqImbCancel-8002 HC022260=0 (Disable theVCS) • TC4K-CompAmplDemand-8002 "HC019260" (Ampliture stroke at 0mm) Step 89-1 Canceled Wait HFI Go-ahead (typical duration 1hrs) to set the stroke at 3,7mm with nominal procedure
230->239	Canceled
240	Step 6 deleted

5. ADDENDUM 3

In the AD[01], the HFI detection chain is switch-off at the beginning of phase Ph06-001 (PPLM warm-up). On HFI request the switch-off of the HFI detection chain shall be done during the phase Ph07-001 (pressure recovery) after opening the chamber on HFI go-head.

6. ADDENDUM 4

Since the 100 mK temperature is not reached, the bolometers are not giving any useful signal. Therefore, the noise will be measured only on the thermometers (channels 90 to B5) and on the capacitor and resistance (channels 15 and 21). Besides, HFI decided that it was not useful to tune the PIDs during this sequence._The order of the frequencies has also been changed in order to finish with the 35 Hz frequency which seems to be the optimal one for cold temperature.

Ph03-004	**Title** 4K cooler frequency influence on Dilution Cooler and bolometers		**Duration** 15 h
	Start Criteria End of Ph03-003	**End Criteria** Tests completed	
	Activity Variation of the 4K cooler frequency by TC in accordance with [AD12] & [AD13] • Restore REU parameters from EEPROM • ~~Restart all PIDs : Note 4K PID is on from previous sequence Ph03-003 (PACE Fluctuations)~~ • Switch to observation mode ~~Noise observation on QLA during 2 hours~~ • Switch to configuration mode 1. Save the REU parameters. Stop Cooler and switch OFF HFI. Switch ON HFI and restore the REU parameters 2. Change to Fi Frequency (F1=35.07, then F2=37.69, then F3=44.69) 3. Run the Vibration Cancellation System Calibration. Switch OFF HFI. Switch ON HFI. Restore REU parameters. Run the compressor at ~~3.9~~ mm. 4. Change to observation mode, and observe NOI on the QLA during 75 mn. ~~5.Adjust PID set point according to 4K temperature and wait for stabilisation (around 30 mn). Wait the go ahead from HFI QLA analysis to proceed.~~ 5. ~~Mode configuration n° 100~~. ~~All bolometer channels (12 bolometers) are red successively~~ during 5 minutes in raw signal data 6. Go back to 1. for the next frequency ~~Save the REU parameters. Stop Cooler and switch OFF HFI. Switch ON HFI and restore the REU parameters~~ ~~Change to 40.08 Hz Frequency~~ ~~Run the Vibration Cancellation System Calibration. Switch OFF HFI. Switch ON HFI. Restore REU parameters. Run the compressor at 3.9 mm~~ • ~~Change to observation mode, and observe NOI on the QLA during 75 mn~~		

END OF DOCUMENT