Title: **H-EPLM Thermal Model and Analysis**

CI-No: 120 000

A. Hauser K. Wagner

Prepared by: A. Hauser, K. Wagner Date: 22.4.04

Checked by: R. Hohn, G. Jahn 30.04.04

Product Assurance: R. Stritter 03.05.04

Configuration Control: W. Wietbrock W. Wietbrock 03.05.04

Project Management: W. Rühe 03.05.04

Distribution: See Distribution List (last page)

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Issue	Date	Sheet	Description of Change	Release
1	30.11.01	all	First Issue	
2Draft	11.06.02	all	Draft Issue for PDR Sect. 5.3: - HTT, HOT, TS1 and innermost tank suspension straps implemented in ESARAD Geometry Model, - Heat shield Beam entrance baffles merged to a common baffle with 0.8 emissivity and attached to TS2 only, - Cryostat Baffle Insert with 500 mm diameter introduced, - Telescope opening changed from 360 mm to 560 mm. Sect. 5.4: - +Y Radiator rotated by 14° towards Y axis (to avoid collision with filling port), - emissivity of CVV main radiator changed from 0.8 to 0.7, - emissivity of CVV ±Y and –Z Radiator changed from 0.9 to 0.8. Sect. 5.5: - Waveguides implemented in ESARAD Geometry Model, - LOU harness updated acc. to RD 02, - LOU radiator design updated acc. to ECP HP-2-ASED-CP-001, - Telescope mechanical fixation on CVV changed from GFRP struts to T300 CFRP struts, - BOLA direct mounted on CVV and covered with MLI Sect. 5.6: - Scientific harness updated acc. to RD 02, - Thermalization of SPIRE JFET harness shifted from TS 1 to TS 2. Sect. 5.7: - HSS update acc. to. Drawing Set Status “Begin 2002“. Sect. 5.8: - SVM Thermal Shield modified (+Z half deleted), - SVM top MLI set to 230 K boundary acc. to AD 07, - Cross-section to length ratio of SVM/CVV struts changed from 18.42 mm to 13.05 mm. Sect. 6.1:	

Issue	Date	Sheet	Description of Change	Release
			- MLI performance data changed based on RD 08 and RD 09.	
2	17.06.02	all	PDR Issue of document	
2.1	10.12.02	30	Table 5.2-2 corrected (typo: JFET dissipation in wrong column)	
		35, 36	Table 5.3-1 corrected (typo: 9 LOU windows instead 7)	
		37	Explanation of CVV radiator model added as requested in PDR RID 8516	
		41	Table 5.4-1 corrected (typo: 9 LOU windows instead 7)	
		47	Table 5.6-2 corrected (typo: JFET harness length)	
		52	Complete data as requested in PDR RID 8517	
		53, 55	Correction of SVM shield skin data acc. to TMM assumptions	
		58-64	References for material data plots completed as requested in PDR RID 8517	
		74	Table 7.4-1 corrected and completed	
		79	Table 7.4-3 completed as requested in PDR RID 8519	
		80	Figure 7.4-5 exchanged (copy and paste error)	
		86	Table 7.4-6 corrected (typo: HOB temperature uncertainty)	
		90	Introduction of Section 7.4.5 to refer to transient analyses described in RD 06	
		91	Lifetime of PDR Collocation Status added	
		Annex 1	Temperature listings for in orbit hot and cold case as well as for ground case added as requested in PDR RID 8517	
		Annex 2	Input Traceability Matrix added	
3	09.09.03	all	Document entirely modified. Major changes: - Restructuring of H-EPLM GMM/TMM to allow Submodel structure - Refinement of CVV lower bulkhead MLI (HP-2-ASPI-TN-0366) - Increase of CVV radiator (upper bulk and Cryostat Baffle). - Refinement of Telescope Geometry based on ASEF catia model ICD-DT0018251-02-00-3D-TELESCOPE_28_05_02. - Refinement/update of ventline modelling. - Implementation of Cryo-Cooled Cover (low emissive cover shield). - Update LEOP Calculation (PPS Sample 5). - Implementation of HIFI coax cable: Precision Tube JS50141,	

Issue	Date	Sheet	Description of Change	Release
			JN50141. - Refinement/update of beam entrance baffles - Removal of BOLA - Implementation of H-RSVM submodel (ASPI delivery) - Introduction of L3 interfaces. - Update of SVM Thermal Shield material (CFRP panel instead of Al panel). - Removal of Instrument Shield MLI - Introduction of 100 mm EPLM enlargement - Implementation of HSS lower stiffening ribs - Introduction of Safe Mode - Introduction of On-Ground Test Mode (IMT) - Implementation of optimized tank suspension straps - ISO TMM conductance values between suspension bolts and heat shields replaced by physical values - Update/Refinement of LOU TS2 baffle and LOU windows in H-EPLM GMM - Refinement (nodal- break-down) of Cryostat Baffle and Cryostat Baffle MLI - Update of Al 5083 thermal conductivity data (CVV) acc. to NIST data base - Implementation of HSS/SVM closure MLI - Implementation of overall instrument timeline - Update of Lifetime calculation (HP-2-ASED-TN-0065) - Implementation of Instrument Submodels, see below - Integration of PACS RTMM update (delivery date 09.05.2003) - Integration of SPIRE RTMM Issue 2.3 - Integration of HIFI RTMM update (delivery date 28.03.2003)	
4	15.04.04	all	Major changes: - Integration of SPIRE RTMM Issue 2.5 - Refinement of nodal break down of Thermal Shields (in circumferential direction) incl. Ventline and SFW - Implementation of CDR Harness (HP-2-ASED-TN-0010, Issue 3.1) - Update of CVV internal MLI performance data (based on FZ Karlsruhe test results) - Implementation of GFRP and CFRP test data for TSS - Implementation of updated (enlarged) LOU Radiator & LOU - Implementation of Startracker heat load (200mW) - Replacement of L0 thermal link conductance requirements and L1/L3 link conductance by actual geometry and measured (temperature dependent) conductance data - Radiation in filling line - Gas conduction in cover flush line - Update of solar array thermo-optical properties - Merging of the two SPIRE L1 strap I/F points on VL to one I/F - Beam entrance: introduction of TS2 baffle aperture and IMT crown - Update of Pre-Launch/Early Orbit scenario - Update of Lifetime formula	

Issue	Date	Sheet	Description of Change	Release
			- Introduction of IMT transient timeline - Update of instrument interface temperature & heat flow requirements - Update of CVV radiator thermal properties Changes w.r.t. Issue 3 are written in red colour in the following.	

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1 SCOPE

This document describes the CDR status of the HERSCHEL EPLM Detailed Thermal Mathematical Model (DTMM) and Geometrical Mathematical Model (DGMM). The nodal break down and the corresponding assumptions are described in detail. The DTMM with the data described in this document is referenced “herschel.d, Issue 4”.

Material properties used in the DTMM/DGMM are also reported in this document. Finally, the analysis results obtained from this reference DTMM are reported, too. The results are shown basically in form of temperature distribution and heat flow charts. A comprehensive sensitivity analysis is performed with respect to lifetime and EPLM temperatures. Instrument interface temperatures are calculated using a dedicated instrument timeline of 6 x 48h which includes transient operation of and switching between 5 different instrument modes. Finally, lifetime calculations are carried out based on the thermal analysis results including transient in-orbit cool down.

2 Applicable and Reference Documents

2.1 Applicable Documents

AD 01	HERSCHEL/PLANCK Instrument Interface Document IID Part A, Doc.No.: SCI-PT-IIDA-04624, Issue 3.1, 12.02.2004
AD 02	HERSCHEL/PLANCK Instrument Interface Document IID Part B for PACS, Doc.No.: SCI-PT-IIDB/PACS-02126, Issue 3.1, 20.01.2004
AD 03	HERSCHEL/PLANCK Instrument Interface Document IID Part B for SPIRE, Doc.No.: SCI-PT-IIDB/SPIRE-02124, Issue 3.11, 07.01.2004
AD 04	HERSCHEL/PLANCK Instrument Interface Document IID Part B for HIFI, Doc.No.: SCI-PT-IIDB/HIFI-02125, Issue 3.1, 31.01.2004
AD 05	H-EPLM Environment & Test Requirements Specification, Doc.No.: HP-2-ASED-SP-0004, Issue 2, dated 12.11.2003
AD 06	H-EPLM Requirement Specification; HP-ASPI-SP-0250, Issue 3.1, 28.01.2004
AD 07	Herschel EPLM Interface Specification; HP-2-ASPI-IS-0039; Issue 5, 06.02.2004
AD 08	Herschel EPLM Thermal Interfaces; HP-1-ASP-TN-0413; Issue 1, dated 24.10.2002
AD 09	List of Acronyms, HP-1-ASPI-LI-0077, Issue 1, dated 25.07.2001

2.2 Reference Documents

RD 01	Hypothesis and Methods for Lifetime Calculations; Doc.No.: HP-2-ASED-TN-0065, Issue 2, dated 07.04.2004
RD 02	Harness Inputs for Thermal Analysis Doc.No.: HP-2-ASED-TN-0010, Issue 3.1, dated 19.03.04
RD 03	Reduced PACS Instrument TMM provided by PACS on 09.05.2003
RD 04	Reduced SPIRE Instrument TMM, Issue 2.5 provided by SPIRE on 03.02.2004
RD 05	Reduced HIFI Instrument TMM provided by HIFI on 02.04.2003
RD 06	He System Description, HP-2-ASED-RP-0034, Issue 3, dated 15.03.2004
RD 07	Thermal Mathematical Modelling Methods of HPLM Ventline on Optical Bench, HP-2-ASED-TN-0056, Draft Issue, dated 10.06.02
RD 08	Evaluation of LINDE/ESTEC-MLI Measurements and Transformation to the ISO Cryostat MLI Design, Doc.No.: ISO.TN-B1430.007, dated 12.07.88
RD 09	J. Doenecke: Survey and Evaluation of Multilayer Insulation Heat Transfer Measurement, ICES July 1993
RD 10	PACS FPU Drawing No. PACS-KT-ICD-0000W1.22, dated 04.09.01

RD 11 SPIRE Interface Drawing No. 5264 300, dated 30.07.01

RD 12 HIFI-FPU External Configuration Drawing No. 455-3-001-0, dated 29.05.01

RD 13 H-EPLM Pressure Drop Analysis, HP-2-ASED-TN-0071, Issue 1.1, dated 12.03.2004

RD 14 M. Sander: ISO Thermal Mathematical Model, Submodel VENT, Version 3.00, 24.02.1994

RD 15 Test Report of the Additional Pressure Drop Measurements of DASA Valve #990-11 at Different Mass Flows and Temperatures, ISO-TR-BCGI0.008, Issue 1, 02.11.1993

RD 16 SPIRE Cryogenic Interface Thermal Mathematical Model, SPIRE-RAL-PRJ-000728, Issue 2.5, dated 02.02.2004

RD 17 EPLM Thermal Analysis from Fairing Jettison to Launcher Separation, HP-2-ASED-TN-0096, Issue 1, dated 14.04.2004

RD 18 Electrical Power Analysis and Design Report, Doc.No.: HP-2-GAMI-AN-0014, dated 19.05.03

RD 19 Helium Content Determination in Orbit, HP-2-ASED-AN-0010, Issue 1,dated 20.02.04

RD 20 TSS Design Justification, HP-2-ASED-TN-0081, dated 12.05.2003

RD 21 Procurement Specification for Tank Support Suspensions, HP-2-ASED-PS-0017, Issue 2, dated 25.03.03

RD 22 Procurement Specification for Herschel Spatial Framework, HP-2-ASED-PS-0016, Issue 2.1, dated 14.02.03

RD 23 OBA Specification, HP-2-ASED-PS-0015, Issue 2.1, dated 15.03.04

RD 24 Procurement Specification for H-PLM Internal MLI, HP-2-ASED-PS-0028, Issue 2, dated 07.03.03

RD 25 Procurement Specification for Herschel Support Structures, HP-2-ASED-PS-0026, Issue 1, dated 30.07.02

RD 26 Procurement Specification for SVM Thermal Shield, HP-2-ASED-PS-0034, Issue 1, dated 30.06.02

RD 27 Procurement Specification for Herschel Telescope Mounting Structure, HP-2-ASED-PS-0037 Issue 1, dated 30.07.02

RD 28 Procurement Specification for Herschel External MLI, HP-2-ASED-PS-0029, Issue 1, dated 29.07.02

RD 29 Herschel Telescope Thermal Design and Analysis, MoM SCI-PT-18440, dated 27.05.03

RD 30 Thermal Shields Procurement Specification PFM, HP-2-ASED-PS-0044, Issue 1, dated 04.11.02

RD 31 Procurement Specification for Herschel Cryostat Vacuum Vessel, HP-2-ASED-PS-0003, Issue 4, dated 09.10.02

RD 32 Procurement Specification for Cryostat Cover, Cryostat Baffle and Test Components, HP-2-ASED-PS-0018, Issue 2, dated 18.03.03

RD 33 HIFI LOU Cryoharness - Electrical/Thermal Performance, HP-2-ASED-FX-0553-03, dated 27.06.03

RD 34	RYMSA CDR Data Package
RD 35	Evaluation of Thermal Property Tests for the H-EPLM TMM, HP-2-ASED-RP-0095, Issue 1, dated 15.04.2004
RD 36	Evaluation of Calorimeter Tests for Herschel Internal MLI; HP-2-ASED-TN-0083, Issue 1, dated 01.03.2004
RD 37	HSS Thermal Analysis Report, HP-2-DSSA-AN-0013, Issue 3, Feb. 2004,
RD 38	Strut Fitting Design Update, HP-ASED-FX-0037-04, dated 28.01.2004
RD 39	HP-2-AAE-AN-0004 Issue 2, dated 06.10.2003
RD 40	LEOP HTT Temperature Margins and Verification, HP-ASED-FX-0226-04, dated 31.03.2004
RD 41	Herschel Planck Visit at French Guiana Launch Site, HP-1-AEA-MN-0003

Note: Further References concerning material properties are listed in section 6.6 separately.

2.3 Abbreviations

ASED	Astrium GmbH
ASP	Alcatel Space
HSS	Herschel Solar Array & Sunshade
OBA	Optical Bench Assembly
OBP	Optical Bench Plate
SS	Summer Solstice
SSD	Sunshade
TSS	Tank Support Suspensions
WS	Winter Solstice

Further Abbreviations are listed in AD 09.

3 Requirements and Boundary Conditions

3.1 Thermal Requirements

3.1.1 Lifetime

The relevant requirements regarding the H-EPLM lifetime are the following [AD 06]:

HERS-0530:	A cryogenic lifetime of 3.5 years shall be achieved. This requirement shall be met including dispersions.
HERS-2250	The cryostat shall allow for an on-ground autonomy period of 6 days with the helium tank filled and the helium temperature after 6 days below 2.1 K and instruments being non operational.

For lifetime calculations a special thermal-mathematical model (TMM) shall be applied. In this model the instrument TMMs are replaced by the instrument interface nodes of the different temperature levels. Herewith the following maximum instrument dissipations as specified in the IIDA [AD 01] shall be taken into account:

Level 0:	10 mW
Level 1:	25 mW
Level 2:	35 mW
Level 3:	15 mW

An average thermal environment at L2 orbit to be assumed for lifetime prediction as well as a procedure for lifetime calculation has been agreed with ESA, ASP and ASED. The details are reported in [RD 01].

3.1.2 Temperature Requirements of Instruments within Cryostat

The temperature limits required at the instrument interfaces are specified in the instrument interface control documents IIDBs for PACS [AD 02], SPIRE [AD 03] and HIFI [AD 04] and are compiled in Table 3.1-1 to Table 3.1-3.

Instrument Interface	Temp. Level	TMM Node	Operating		Heat Load	Non-operating	
PACS			Min.[K]	Max.[K]	[mW]	Min.	Max.
Red Detector	L0	721	1.6	1.75	0.8		60°C *) 85°C **) (TBC)
Blue Detector	L0	723	1.6	2.0	2.0		60°C *) 85°C **) (TBC)
Cooler Pump	L0	761	1.6	10 5	500 (peak) 2		60°C *) 85°C **) (TBC)
Cooler Evaporator	L0	762	1.6	1.85	15		60°C *) 85°C **) (TBC)
Optics/Structure assy.	L1	781 782 783	2.0	5.0	30	NA	60°C *) 85°C **) (TBC)
OBA Interface	L2			12	0	NA	NA

*) Continuous temperature limit

**) Short-duration temperature limit for bake-out during a maximum of 3 days at 80°C

Table 3.1-1: PACS Temperature Limits

Instrument Interface	Temp. Level	TMM Node	Operating		Heat Load	Non-operating	
SPIRE			Min.[K]	Max.[K]	[mW]	Min.	Max.
Detector Enclosure	L0	814	0	2.0 1.71 (goal)	4.0 1.0 (goal)	NA	60°C *
Cooler Pump	L0	815	0	10 2	500 (peak) 2	NA	
Cooler Evaporator	L0	816	0	1.85 1.75 (goal)	15 15 (goal)	NA	
SPIRE OBA units	L1	800 830	0	5.5 3.7 (goal)	15 13 (goal)	NA	
OBA Interface	L2			12 8 (goal)	0 0 (goal)	NA	NA
Instrument Shield	L2			16	0	NA	NA
PM-JFETs	L3	831	0	15	50	NA	60°C *
SM-JFET	L3	832	0	15	25	NA	

*) Continuous temperature limit, but compliant with bake-out temperature of 80°C for 72 h maximum

Table 3.1-2: SPIRE Temperature Limits

Instrument Interface	Temp. Level	TMM Node	Operating		Heat Load	Non-operating	
HIFI			Min.(K)	Max.(K)	[mW]	Min.	Max.
L0 boundary	L0	949	0	2	6.8	0 K	60°C *
L1 boundary	L1	939	0	6	15.5	0 K	60°C *
FPU structure	L2	910	0	20	22	0 K	60°C *

*) Continuous temperature limit, but compliant with the bake-out of 3 days at 80°C

Table 3.1-3: HIFI Temperature Limits

Temperature Stability Goals of HIFI as specified in AD 04

The following temperature changes shall not be exceeded during operation (i.e. exluding heat peak phases):

Level 2 parts: 0.015 K per 100 s

Level 1 parts: 0.006 K per 100 s

Level 0 parts: 0.006 K per 100 s

3.1.3 Temperature Requirements for LOU (outside Cryostat)

As specified in AD 04 the HIFI Local Oscillator Unit (LOU) shall not exceed the temperature limits at the mounting interfaces compiled in following Table 3.1-4.

Instrument Interface	Thermal node No.	Operating		Functional testing	Start-up	Switch-off	Non-operating	
		Min.(K)	Max.(K)	Max.(K)	Max.(K)	Max.(K)	Min.(K)	Max.(K)
LOU	4200	90	150	298	80	303	60 TBC	328

Table 3.1-4: LOU Temperature Limits

3.1.4 Temperature Requirements for Telescope

For the HERSCHEL Telescope, the following requirements exist [AD 01]:

	Thermal node No.	Operating		Contamination Release (3 weeks)		Non-operating	
		Min.(K)	Max.(K)	Min.(K)	Max.(K)	Min.(K)	Max.(K)
Telescope	8000	70	90	313	323	55 TBC	328

Table 3.1-5: Telescope Temperature Limits

3.1.5 Thermal Interface Requirements for SVM

According to [AD 7] the maximum thermal flux from HSS to SVM shall be less than 15 W distributed as follows:

- maximum 5 W via HSS CFRP struts, uniformly distributed on each interface point,
- maximum 10 W via Sunshield brackets, uniformly distributed on each interface point.

3.2 Thermal Environment

3.2.1 *Ground and Pre-Launch Phase*

The He filled PLM is in a temperature controlled environment at 22±3°C [AD 05].

During transport and storage different environment apply, ranging from –10°C to 50°C at ambient pressure ranging from 970 mbar to 1070 mbar.

3.2.2 *Early Orbit Phase*

The thermal loads to be applied for the H-EPLM during the launch and early orbit phase are defined in detail in [AD 05].

Solar constant:

The applicable values of the solar constant for the early orbit phase (BOL) are:

- 1425 W/m² during Winter Solstice (WS)
- 1325 W/m² during Summer Solstice (SS)

The solar aspect angle evolution during launch is shown in Figure 3.2-1.

Albedo is the fraction of incident solar radiation that is reflected from the earth back into space. A value of 0.3 ± 0.05 shall be used.

Earth Infrared Thermal Radiation

The Earth infrared radiation shall be assumed to be that of a black body with a characteristic temperature of 288 K. The average infrared radiation emitted by Earth is 230 W/m^2, with variations between 150 W/m² and 350 W/m².

From the a.m. data following load cases can be derived:

Hot Case:	WS solar constant, max. Earth IR radiation, 0.35 albedo BOL thermo-optical properties, Solar power generator in shunt mode
Cold Case:	SS solar constant, min. Earth IR radiation, 0.25 albedo BOL thermo-optical properties, Solar power generator in operating mode

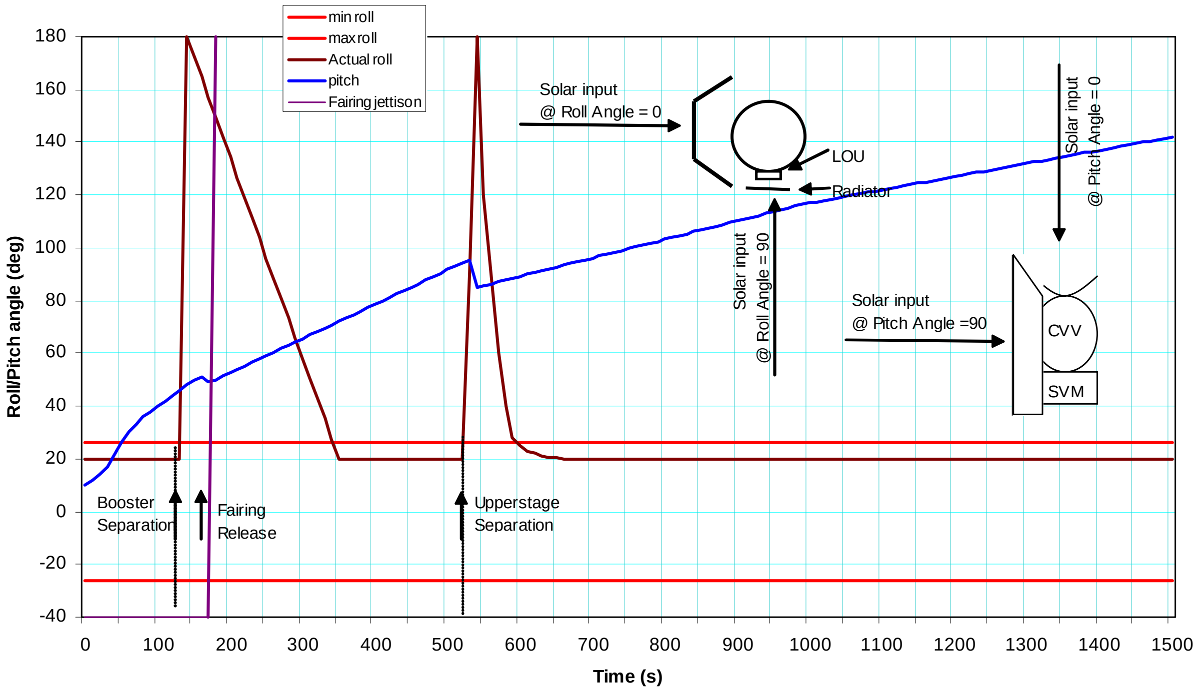


Figure 3.2-1: Roll and Pitch Angle Evolution During Launch

3.2.3 Operation Phase in L2 Orbit

During on-orbit operation at L2 the extremes of solar constant are [AD 05]:

- 1405 W/m² during Winter Solstice (WS)
- 1287 W/m² during Summer Solstice (SS)

During HERSCHEL mission phases and operational modes, the solar aspect angle will be maintained at ± 30 deg around the Y-axis and at ± 1 deg around the X-axis.

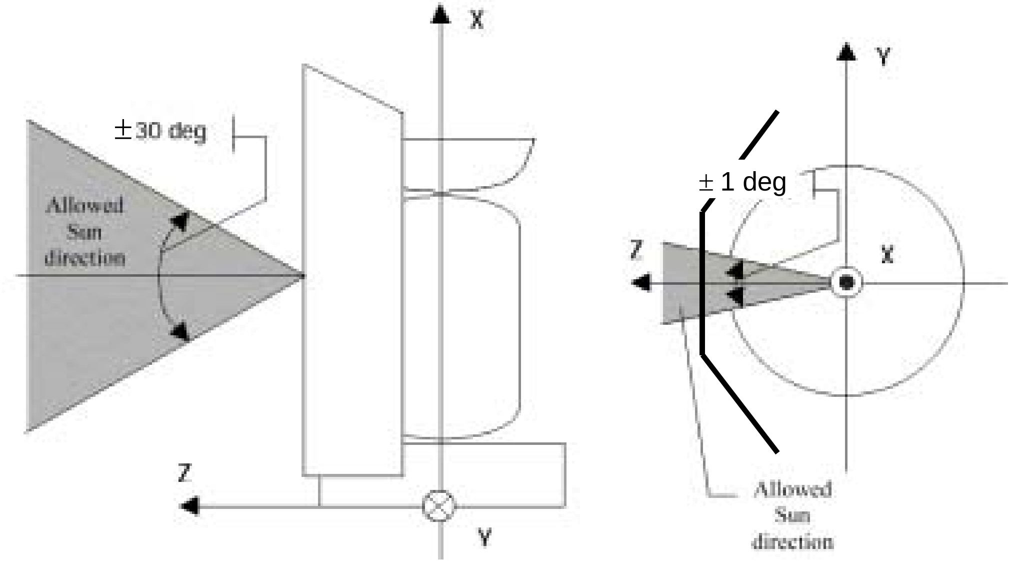


Figure 3.2-2: Solar Aspect Angels on H-EPLM at L2

From the a.m. data the following load cases can be derived:

<u>Hot Case:</u>	WS solar constant with 0° solar aspect angle EOL thermo-optical properties
<u>Cold Case:</u>	SS solar constant with 30° solar aspect angle around Y-axis BOL thermo-optical properties

The temperatures of the H-EPLM structure attachment points on the SVM (conductive I/F) and the temperatures of the SVM outer surfaces like top panel MLI (radiative I/F) are considered according to [AD 07] and [AD 08].

4 DTMM Description

4.1 General

The H-EPLM is written in ESATAN format V 8.9.2, the geometry model is written in ESARAD format V 5.4.8.

The following main calculation modes can be operated:

G	Operation on Ground (steady state)
X	Instrument Testing on Ground (steady state)
P	Prelaunch: On-Ground Autonomy (SUBCASE=1) and Launch Autonomy (SUBCASE=2), including pre-cooling and HOT refill
L	Launch until fairing jettisoning
T	In-orbit transient cool down with telescope decontamination heating
O	Operation at L2 orbit, including nominal steady state modes (hot, cold), transient orbit timeline, safe mode and a lifetime calculation mode acc. to [RD 01] (adjustable via control variables SUBCASE, IMODE, TRANS)

4.2 H-EPLM Model for Lifetime Calculation

The He mass flow (M_{He}) is calculated based on the sum of all heat load into the HTT (ΣQ_{HTT}) and the Helium heat of vapourization (hv) for the average environmental conditions at L2. As required in [AD 06], the nominal initial amount of He m_0 includes a margin of 15%. The increased Helium consumption (m_{trans}) during the in orbit cool down period (t_{trans}) is also considered for the lifetime prediction. In addition the residual He gas ($m_{residual}$) after all HeII is evaporated, and that can not be used for vapour cooling, is considered. Furthermore, a lifetime correction ($t_{uncertainty}$) is introduced reflecting parameter variations. Finally a maximum loss of 0.36% lifetime is considered due to DLCM [RD 19]. Thus, the nominal (contractual) lifetime is calculated according to following formula:

$$\textbf{Lifetime} = 0.9964 * \left((m_{n} - m_{trans} - m_{residual}) / M_{He,avg} + t_{trans} - t_{uncertainty} + t_{others} \right)$$

with

m_n	nominal amount of He at lift off,	$m_n = 0.98/1.15$ * HeII density * HTT volume
m_{trans}	He consumption during in-orbit cool down,	m_{trans} = output of Figure 7.2-6
$m_{residual}$	residual He gas in tank at EOL,	$m_{residual} = 0.94$ * GHe density * HTT volume
M_{He}	mass flow at L2 (at condition defined in RD01),	$M_{He} = \Sigma Q_{HTT} / hv$
t_{trans}	duration of transient cool down until HTT@1.65K,	t_{trans} = output of Figure 7.2-4

$t_{uncertainty}$ = Lifetime correction due to RSS input variations

t_{others} = Lifetime compensation due to changes introduced by ESA and ASPI

(Startracker attached to CVV, SPIRE overall shield and increased LOU radiator)

The He mass flow M_{He} is determined by the sum of all heat flow into the tank and is calculated for in orbit steady state condition applying the heat load allocations defined in [AD 01].

4.3 H-EPLM Model with Implemented Instrument Models

The supplied Instrument Interface Models [RD 03, RD 04, RD 05] are implemented as submodels in the overall H-EPLM Model structure.

4.4 Pressure Drop Model

The pressure drop calculation within the ESATAN model uses the detailed numerical pressure drop model as described in [RD 13].

The detailed pressure drop model is based on the pressure drop model used in the ISO TMM [RD 14] for the final flight predictions. In the detailed model, the pressure drop of the individual vent line components (e.g. PPS, straight pipes, bends, t-pieces, valves, heater, nozzles…) is calculated by dedicated subroutines. Most of these subroutines are directly inherited from the ISO model, with the exceptions being

1. PPS: The Herschel phase separator is different from the ISO PPS. A mini-model-type regression function is used to represent the flight model porous plug which was characterised as Sample 5 in the Herschel PPS Pre-Development test campaign. The regression formula is
$$p_{in}^2 - p_{out}^2 = a \cdot \dot{m}^b \cdot T^c$$
with pressure p [mbar], mass flow rate $\dot{m}$ [mg/s], temperature T [K], and fit parameters a=6.039899454, b=1.532479916, and c=0.439538736.

2. Electromagnetic valves: The original valve function from ISO results in unrealistically small pressure drop values (below 10^{-10} Pa per valve) for the Herschel conditions. The function has therefore been replaced by a mini-model type regression which represents the measurements of the external valves (without filters) carried out in the ISO programme [RD 15]. Filters in the external valves are implemented by calling a dedicated filter function. The impedance coefficient of this function is adjusted to the measurements performed with the Herschel TM valve and filters.

3. CVSE Pump: For the nominal ground steady-state case, a cryo vacuum pump is attached to the V502. The characteristic of this pump is represented by a newly introduced function which calculates the inlet pressure depending on the mass flow rate and the gas temperature. This feature is currently not being used within the TMM.

The pressure drop model is called from ESATAN with the following arguments:
CALL CALCMD (TIMEM, MDOT, T10, T546, T563, T586, T1031, T2031, T3031, T4031, IPPS, INOZZ, SUCCES)
This call calculates the mass flow rates depending on the tank temperature and the temperature distribution along the ventline. Input arguments are

TIMEM: current time step, used for control output

MDOT:	initial value for mass flow rate calculation, new value after calcmd returns
T10-T4031:	temperatures of the individual elements
IPPS:	integer switch: =1 for flow through PPS, =0 for bypass via V104, <0 for closed HTT
INOZZ:	integer switch: =1 for flow through small nozzles, =2 flow through big and small nozzles, <= 0 for flow via V502
SUCCESS:	integer flag: =0 if iteration was successful (calcmd output)

To calculate the tank temperature depending on a given mass flow rate and temperature distribution along the vent line, the pressure drop model is called with the subroutine
CALL CALCTT (TIMEM, MDOT, T10, T546, T563, T586, T1031, T2031, T3031, T4031, IPPS, INOZZ, SUCCES). This subroutine uses the same arguments as for the mass flow calculation routine calcmd.

CALCMD and CALCTT both call the internal subroutine DPVENT and apply the Regula Falsi to iterate the mass flow rate until the pressure drop along the vent line, together with the nozzle inlet pressure calculated from the choked flow conditions, is equal to the pressure in the tank as defined by the tank temperature (or vice versa for CALCTT). The subroutine DPVENT calculates and sums up the respective pressure drop contributions of the individual vent line components one by one going upstream from the external nozzles to the phase separator. Bends in the pipe routing are modelled using equal or smaller bending radii than defined in the drawings. For the two pairs of parallel redundant valves V103/V106 and V501/V503, it is assumed that the respective valve with the shorter pipe routing does not open. Filling and safety lines as well as the filling port are not represented in the current version of the pressure drop model.

The Fortran code for CALCMD, CALCTT, and all functions and routines which are used internally by the pressure drop model is included in the file calcmd.f, which has to be compiled and transformed to an object library named USRLIB.a. The makefile delivered with the TMM automatically performs these tasks. The Esatan pre-processor requires that the calling names of the subroutines provided in the object library be listed in the file USRLIB.DAT.

The detailed pressure drop model is completely coded in Fortran 77. Thus it can be used either as a stand-alone program with the temperatures of the vent line sections being defined as input, or it can be called from the ESATAN Herschel TMM to perform transient analyses with variable mass flow rate.

The dominating contributions to the overall pressure drop in the orbit cool-down and operation phases are generated by the PPS and the external nozzles. The nozzle throat diameters are adjusted for the combination of desired tank temperature, temperature distribution along the vent line and mass flow rate, and are hard-coded in the pressure drop model. Changes with an impact on the mass flow rate or temperatures will therefore also have an impact on the average tank temperature. The nozzle diameters used in the current version are 1.011 mm for two small and 2.121 mm for one big nozzle. With these settings and the calculated mass flow rates, a nominal HTT temperature of 1.65 K for orbit hot case with average instrument dissipation and a maximum mass flow rate below 20 mg/s (as required by the PPS) during the in-orbit cool-down are achieved.

Detailed information on the calculation fundamentals for each vent line component as well as representative results are given in [RD 13].

5 EPLM Configuration and DTMM Nodal Break Down

5.1 EPLM Configuration Breakdown for Thermal Modelling

Thermal Report	**PDR Collocation** HP-2-ASED-RP-0011, Issue 2.1, dated 10.12.02	**TMM Issue 3** HP-2-ASED-RP-0011, Issue 3.0, dated 09.09.03	**TMM Issue 4** HP-2-ASED-RP-0011, Issue 4.0, dated April 04
Thermal Mathematical Model	TMM (ESATAN): herschel.d, dated 13.09.02. GMM (ESARAD): HERSCHEL_EOL.erg, dated 13.09.02	TMM (ESATAN): herschel.d, Issue 3, dated 12.05.2003. GMM (ESARAD): HERSCHEL_EOL.erg, Issue 3, dated 12.05.03	TMM (ESATAN): herschel.d, Issue 4, dated 19.03.2004. GMM (ESARAD): HERSCHEL_EOL.erg, Issue 4, dated 19.03.04
HTT	Herschel HTT Interface Drawing: HP-2-ASED-ID-0001, Issue A	Herschel HTT Interface Drawing: HP-2-ASED-ID-0001, Issue D, dated 08.08.03	Herschel HTT Interface Drawing: HP-2-ASED-ID-0001, Issue D, dated 08.08.03
HOT	Herschel HOT Interface Drawing: HP-2-ASED-ID-0002, Issue A	Herschel HOT Interface Drawing: HP-2-ASED-ID-0002, Issue C, dated 06.08.03	Herschel HOT Interface Drawing: HP-2-ASED-ID-0002, Issue C, dated 06.08.03
OBP including Instrument Shield	Optical Bench Assembly Interface drawing HP-2-ASED-ID-0042, dated 18.10.02	Optical Bench Assembly Interface drawing HP-2-ASED-ID-0042, Issue A, dated 31.03.03	Optical Bench Assembly Interface drawing HP-2-ASED-ID-0042, Issue A, dated 31.03.03
L0, L1, L3 Thermal Links and Ventline	ASED reference design	L0 Conductance Values acc. to OBA Specification, HP-2-ASED-PS-0015, Issue 1.3, dated 17.01.03	AIRL Thermal Analysis HP-2-AIRL-AN-0003, Issue 4, dated 13.02.04 and HP-2-AIRL-HO-0010, dated 05.02.04
PACS	Reduced Instrument TMMs provided by ESA, Doc.No.: SCI-PT/09948, dated 04.10.01. ASED made GMM acc. to PACS FPU Drawing No. PACS-KT-ICD-0000W1.22, dated 04.09.01	Reduced PACS Instrument TMM provided by PACS on 09.05.2003. ASED made GMM acc. to PACS FPU Drawing No. PACS-KT-ICD-0000W1.22, dated 04.09.01. (IR emissivity of FPU set to 0.26)	Reduced PACS Instrument TMM provided by PACS on 09.05.2003. ASED made GMM acc. to PACS FPU Drawing No. PACS-KT-ICD-0000W1.22, dated 04.09.01. (IR emissivity of FPU set to 0.26)
SPIRE	Reduced Instrument TMMs provided by ESA, Doc.No.: SCI-PT/09948, dated 04.10.01. ASED made GMM acc. to SPIRE Interface Drawing No.	Reduced SPIRE Instrument TMM, Issue 2.3 provided by SPIRE on 28.03.2003. SPIRE RGMM provided by SPIRE on 20.01.03, Issue 2	Reduced SPIRE Instrument TMM, Issue 2.5 provided by SPIRE on 03.02.2004. SPIRE RGMM provided by SPIRE on 03.02.04, Issue 3 (IR

Thermal Report	**PDR Collocation** HP-2-ASED-RP-0011, Issue 2.1, dated 10.12.02	**TMM Issue 3** HP-2-ASED-RP-0011, Issue 3.0, dated 09.09.03	**TMM Issue 4** HP-2-ASED-RP-0011, Issue 4.0, dated April 04
	5264 300, dated 30.07.01	(IR emissivity of FPU: 0.2)	emissivity of FPU: 0.2)
HIFI	Reduced Instrument TMMs provided by ESA, Doc.No.: SCI-PT/09948, dated 04.10.01. ASED made GMM acc. to HIFI-FPU External Configuration Drawing No. 455-3-001-0, dated 29.05.01 (IR emissivity of FPU set to 0.26)	Reduced HIFI Instrument TMM provided by HIFI on 28.03.2003. ASED made GMM acc. to HIFI-FPU External Configuration Drawing No. 455-3-001-0, dated 29.05.01 (IR emissivity of FPU set to 0.26)	Reduced HIFI Instrument TMM provided by HIFI on 28.03.2003. ASED made GMM acc. to HIFI-FPU External Configuration Drawing No. 455-3-001-0, dated 29.05.01 (IR emissivity of FPU set to 0.26)
Thermal Shields with TS2 Baffle and LOU Baffle	Thermal Shield FM Drawing No. IZ-1120109, dated 18.12.2001	Geometry as Issue 2.1	Thermal Shield Geometry as Issue 2.1, Baffles acc. to. HP-2-ASED-ID-0065, dated Jan 04
TSS	ASED reference design	Dimensions acc. to HP-2-ASED-TN-0081, dated 12.05.2003	Dimensions acc. to HP-2-ASED-TN-0081, dated 12.05.2003
Cryostat Baffle and Beam Entrance	Drawing No.: HP-2-ASED-ID-0039-01-0A, dated 20.09.02.	Drawing No.: HP-2-ASED-ID-0063-01-0A, dated 31.01.03.	Drawing No.: HP-2-ASED-ID-0063, dated 31.01.03 and HP-2-ASED-ID-0095, dated 25.07.03
Cryo Cover	Drawing No.: HP-2-ASED-ID-0039-01-0A, dated, 18.09.02.	Drawing No.: HP-2-ASED-ID-0063-01-0A, dated 31.01.03.	HP-2-AAE-IC-0001, Issue 3, dated 18.10.03
CVV including Radiators	Herschel Overall Dimensions, HP-2-ASED-ID-0009, Issue A	Herschel Overall Dimensions, HP-2-ASED-ID-0009, Issue B, dated 08.07.03	Herschel CVV Radiator Assembly, HP-2-APCO-DW-0015-01-0A
LOU	ASED reference design acc. to HP-2-ASED-CP-0001, dated 06.03.02	as Issue 2.1	Thermal Analysis Handout from ABAQUS, dated 28.01.04
Telescope	ASED made GMM acc. to ASEF catia model DT0018251-02-00-3D-TELESCOPE-28-05-02.model	ASED made GMM acc. to ASEF catia model DT0018251-02-00-3D-TELESCOPE-28-05-02.model. (IR emissivity of M1 set to 0.01, RD29)	ASED made GMM acc. to ASEF catia model DT0018251-02-00-3D-TELESCOPE-28-05-02.model. (IR emissivity of M1 set to 0.01, RD29)
Harness	Harness Inputs for Thermal Analysis Doc.No.: HP-2-ASED-TN-0010, Issue 1.1, dated 08.05.02	LOU harness: RD 33 HIFI Coax: Precision Tube JS50141 and JN50141 other harness as Issue 2.1	Harness Inputs for Thermal Analysis Doc.No.: HP-2-ASED-TN-0010, Issue 3.1, dated 12.03.04
Sunshade	Drawing ref. no.	Sunshade Panels I/F drawing	Sunshade Panels I/F drawing

Thermal Report	**PDR Collocation** HP-2-ASED-RP-0011, Issue 2.1, dated 10.12.02	**TMM Issue 3** HP-2-ASED-RP-0011, Issue 3.0, dated 09.09.03	**TMM Issue 4** HP-2-ASED-RP-0011, Issue 4.0, dated April 04
Panels	HP-2-ASED-ID-0009-01-0A dated 28.05.02	HP-2-ASED-ID-0051, Issue B, dated 17.03.03	HP-2-ASED-ID-0051, Issue B, dated 17.03.03
Solar Array Panels	Drawing ref. no. HP-2-ASED-ID-0009-01-0A dated 28.05.02	Solar Array Panels I/F drawing HP-2-ASED-ID-0043, Issue B, dated 17.03.03	Solar Array Panels I/F drawing HP-2-ASED-ID-0043, Issue B, dated 17.03.03
EPLM Support Structures	ASED reference design	ASED reference design	HP-2-ECAS-AN-0004, Issue 2, dated 28.1103 and Fax HP-ASED-FX-0037-04, 28.01.04
SVM Thermal Shield	Herschel Overall Dimensions, HP-2-ASED-ID-0009, Issue A	Drawing No.: HP-2-ASED-ID-0056-01-0A, not yet released	Drawing No.: HP-2-ASED-ID-0056, Issue A, dated 14.10.03
SVM	Boundary acc. to HP-2-ASPI-IS-0039, Issue 3	SVM Submodel provided by ASPI on 24.10.02, HP-2-ASP-TN-0413; Issue 1	SVM Submodel provided by ASPI on 24.10.02, HP-2-ASP-TN-0413; Issue 1

Table 5.1-1: Drawings and Submodels used for Thermal Modelling

5.2 He Subsystem and Optical Bench Assembly

The Optical Bench Assembly (OBA) is mounted on top of the HTT via the so called Spatial Framework (SFW). The SFW consists of a frame made of aluminium and struts to the HTT made out of T300 CFRP. The OBA is connected to the aluminium frame by means of Titanium blades. The SFW itself is attached to the CVV structure by the tank suspension straps. The nodal break down of the SFW is shown in Figure 5.2-1 and Figure 5.2-2.

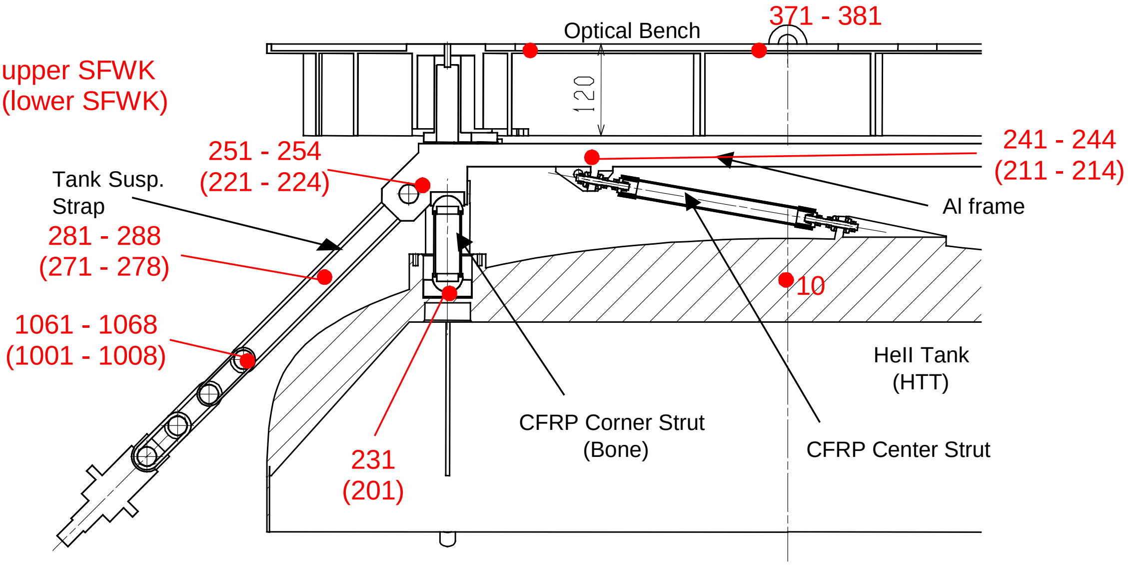


Figure 5.2-1: Nodal Break Down of HTT and SFW

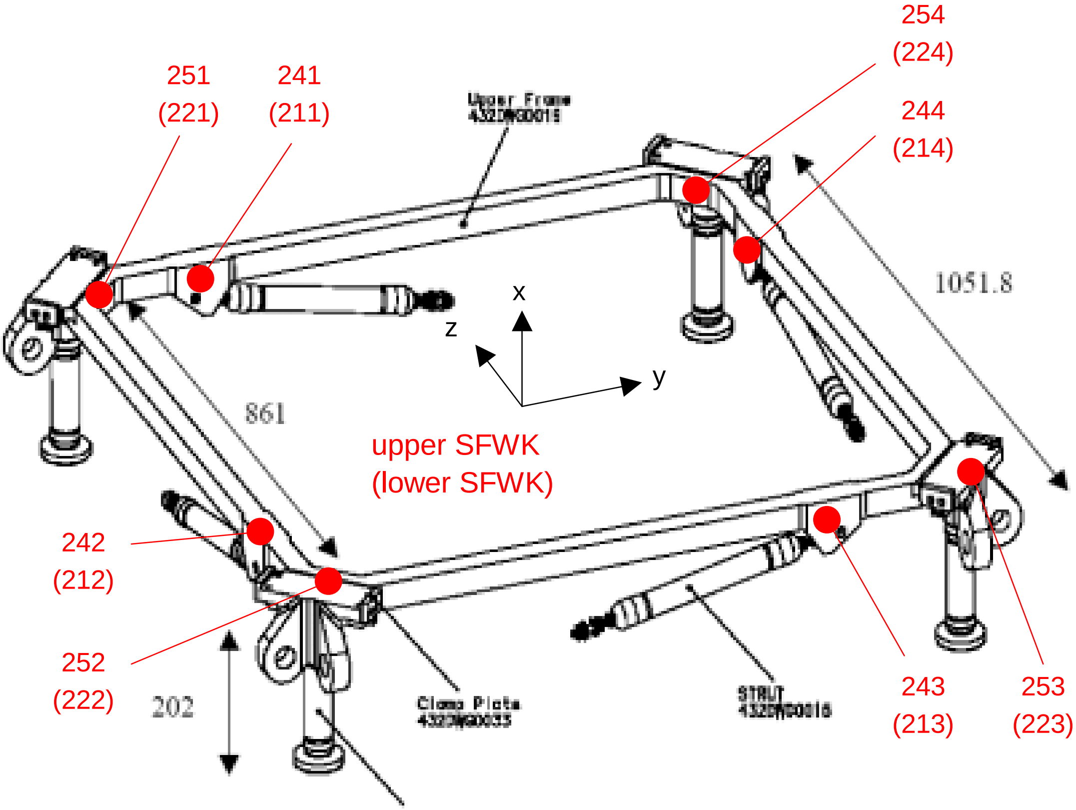


Figure 5.2-2: Nodal Break Down of SFW (detailed)

The OB with the instruments is covered with the Instrument Shield, see Figure 5.2-3. The opening for the beam entrance is modelled with cylindrical baffles, thermally (and mechanically) attached to the Thermal Shield 2 (node 2050) and to the Instrument Shield (node 315). The thermal and material properties are compiled in Table 5.2-1. The Instrument Shield baffle has rectangular cut-outs reflecting the beam pattern for the three instruments, see Figure 5.4-2.

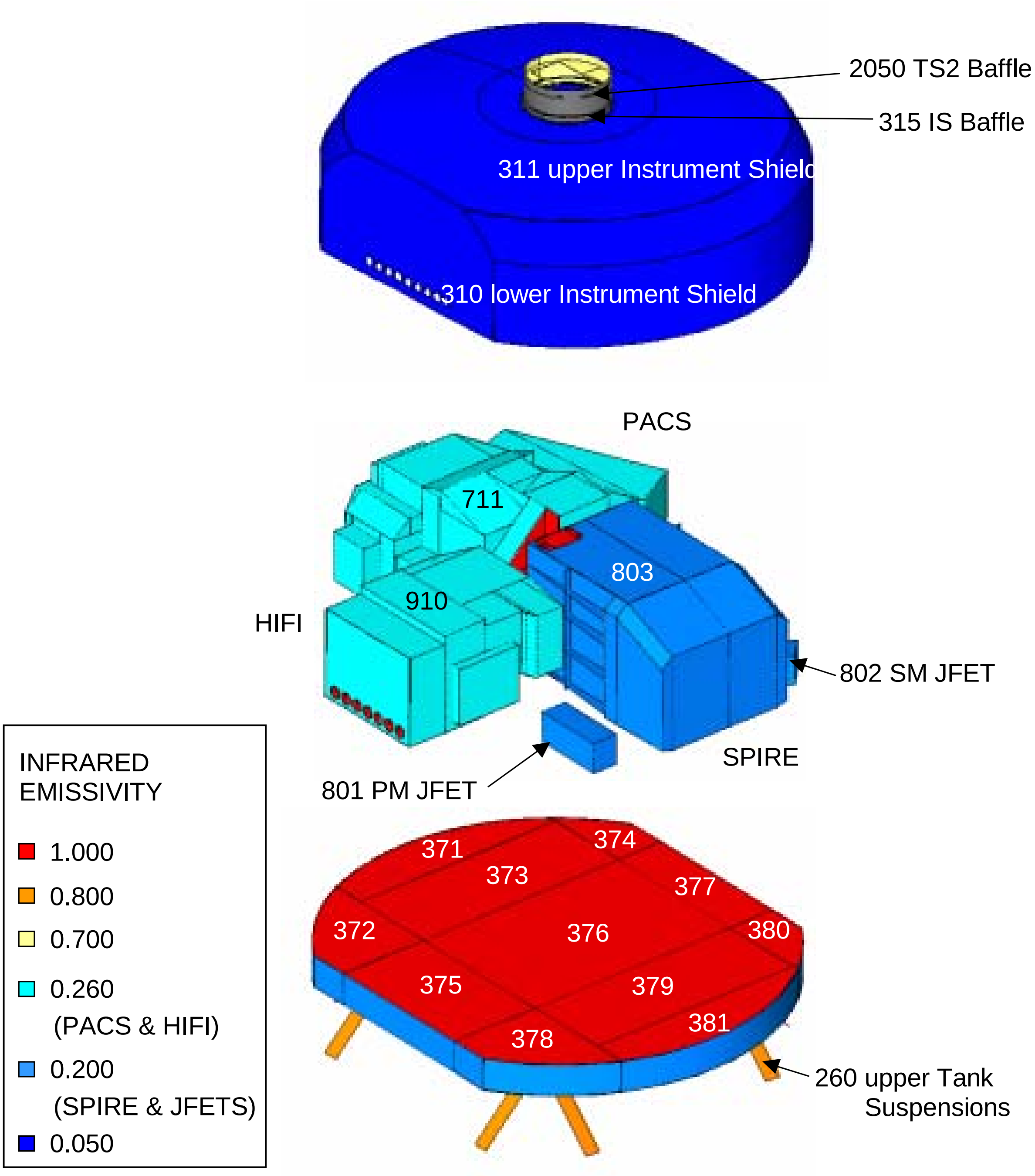


Figure 5.2-3: Nodal Break Down of Optical Bench with Instruments

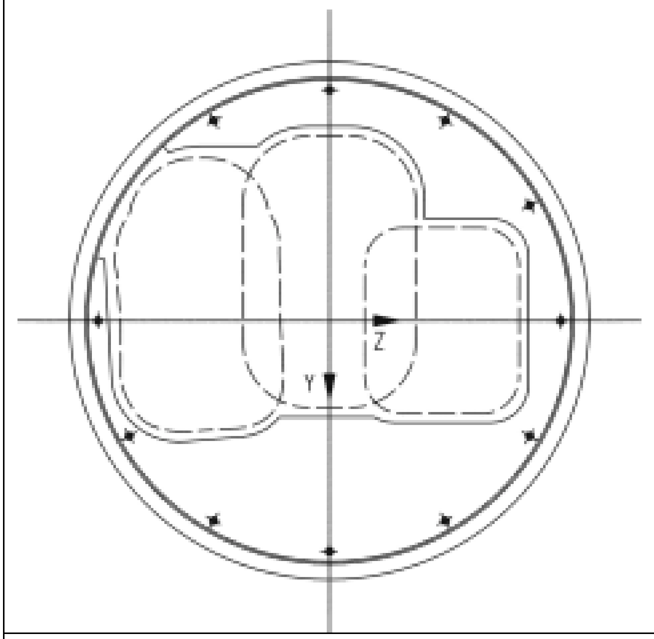
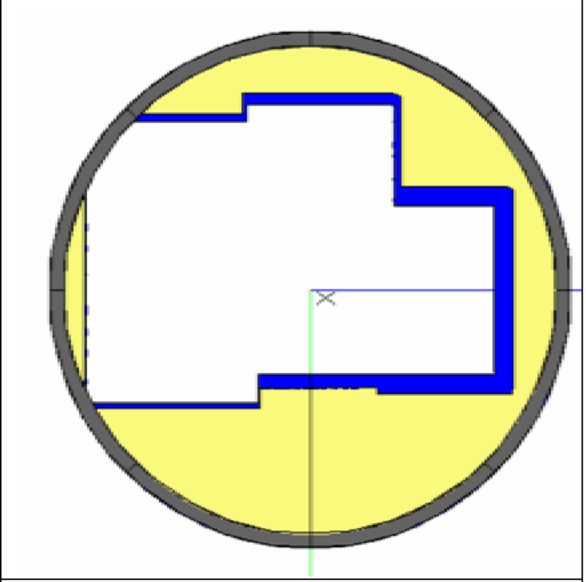
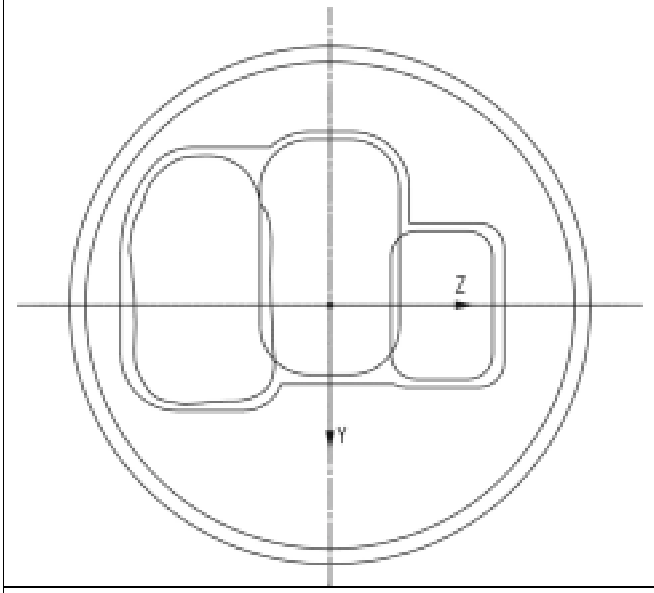
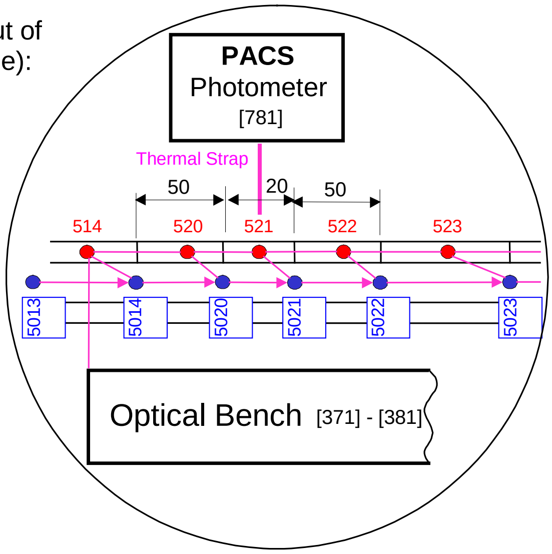
	
	
Apertures of Thermal Shield 2 Baffle (top) and Instrument Shield Baffle (bottom), view from + X	Instrument Shield Baffle (blue, node 315) and Thermal Shield 2 Baffle (yellow, node 2050) in TMM, view from +X

Figure 5.2-4: Beam Pattern for the Three Instruments

A schematic overview of the OB and Thermal Shield ventline modelling is given in following Figure 5.2-5.

Detail (out of next page):



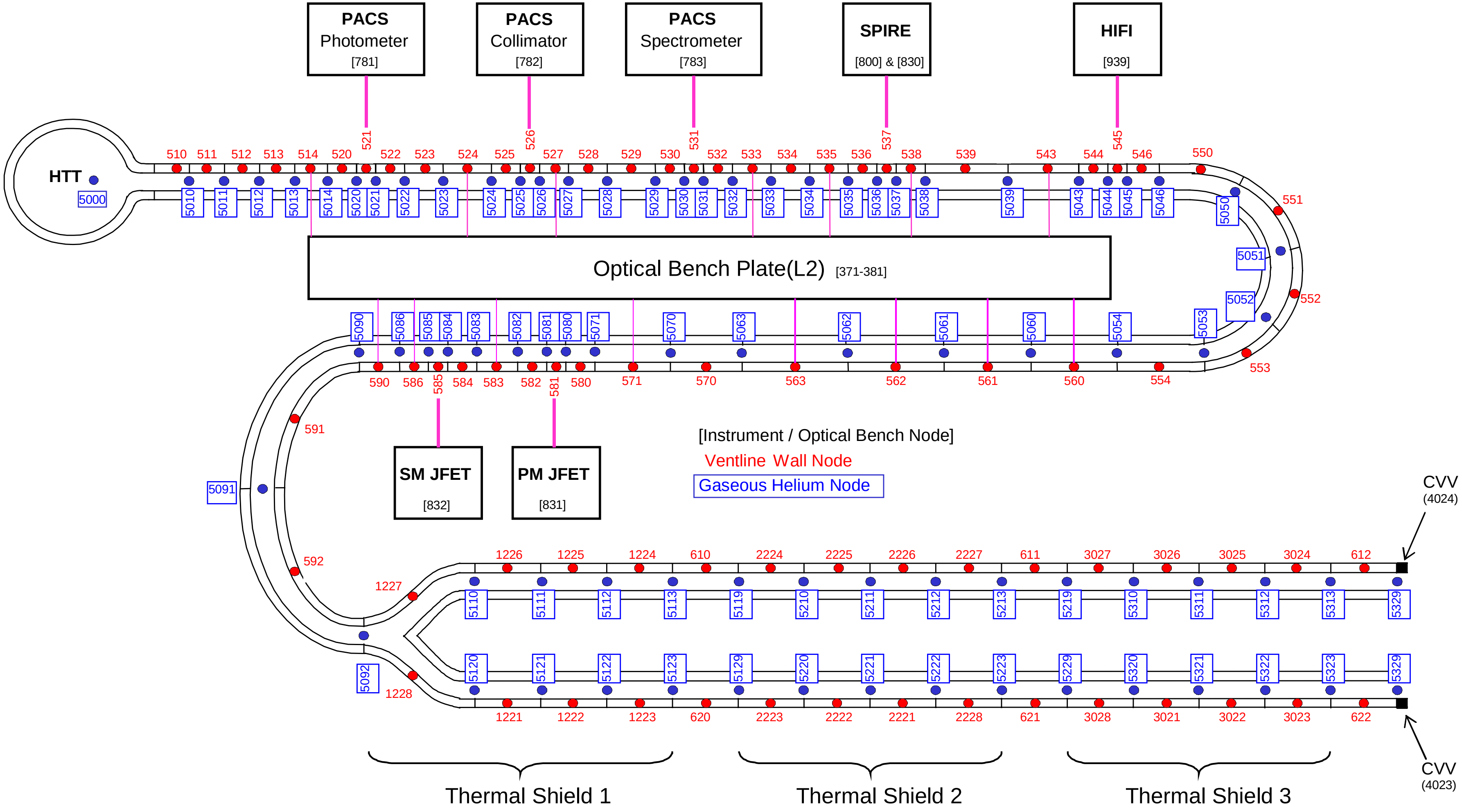


Figure 5.2-5: Nodal Break Down of OB Ventline and Thermal Shield Ventline

Item	Node	Material / Components	Mass	Size	IR Emiss.	Unit Level Requirement	Remark
He II Tank (HTT)	10	superfluid Helium (He II) Al tank (Al 5083, 3.3547)	337 kg 141.8 kg	2367 l (cold volume) D=1.63 m, h=1.352 m			
MLI on He II Tank low cyl. upp.	111 112 113	10 layers	1.1 kg 3.2 kg 1.1 kg	A=3.26m^2 A=2.91 m^2 (D=1.63m, h=0.569m) A=2.94m^2	0.05	R-INM-0220 [RD 24] R-INM-0230 [RD 24]	
He I Tank (HOT)	20	*90% HeI (=~8.7 kg He on ground) ellipsoid shaped Al tank (Al 5083)	13 kg	78 l (cold volume) D=0.88 m, h=0.252 m			
MLI on He I Tank low upp.	121 122	10 layers	0.45 kg 0.45 kg	A=0.66m^2 A=0.66m^2	0.05	R-INM-0320 [RD 24] R-INM-0330 [RD 24]	
Lower Spatial Framework (HOT)	201-224	Al frame (Al 5083) Corner struts T300 to HTT center struts T300 to HTT		A/L = 4 x 2.825 mm A/L = 4 x 0.736 mm		R-SFW-290 [RD 22] R-SFW-300 [RD 22]	
Upper Spatial Framework (OB)	231-254	Al frame (Al 5083) Corner struts T300 center struts T300		A/L = 4 x 2.825 mm A/L = 4 x 0.736 mm		R-SFW-290 [RD 22] R-SFW-300 [RD 22]	
Optical Bench (OB)	371-381	Aluminium structure 4 Titanium blades to AL frame of SFW	60 kg	D=1.63m,H=70mm,2.5mm skins A/L = 28.6 mm Ti6AlV4	1.0	R-OBA-330 [RD 23] R-OBA-145 [RD 23]	
Instrument Shield	310 311	Al 6061 (cylinder) Al 1100 (top), see Figure 5.2-3	3.3 kg 4.5 kg	A=1.70m^2, s= 0.8mm A=2.18m^2, s= 0.8mm	0.05 0.05	R-OBA-326 [RD 23] R-OBA-325 [RD 23]	
Instrument Shield Baffle	315	Al baffle with aperture; cut-out area 0.035 m^2, see Figure 5.2-4	0.12 kg	D=308 mm, s= 0.8mm	0.05 all parts	R-OBA-410 [RD 23]	
GHe Ventline between HTT and Level 1	510-514	stainless steel tube		cross sect. 44.6mm^2 (D=12.7 mm, d=10.2 mm)			
GHe Ventline Level 1	520-546	Al6063 tube CFRP T300 brackets to OB		cross sect. 112.3mm^2 (D=14.9 mm, d=12 mm), incl. fins A/l = 2.016mm		R-OBA-360 [RD 23]	
GHe Ventline between Level 1 and Level 2	550-554	Al6061 tube (not coupled to OB)		cross sect. 44.6mm^2 (D=12.7 mm, d=10.2 mm)		R-OBA-365 [RD 23]	
GHe Ventline Level 2	560-563	Al tube on OB		cross sect. 112.3mm^2			

Item	**Node**	**Material / Components**	**Mass**	**Size**	**IR Emiss.**	**Unit Level Requirement**	**Remark**
		Al brackets to OB		(D=14.9 mm, d=12 mm), incl. fins A/l = 19.60mm		R-OBA-370 [RD 23]	
GHe Ventline between Level 2 and Level 3	570-571	Al6061 tube (not coupled to OB)		cross sect. 44.6mm^2 (D=12.7 mm, d=10.2 mm)		R-OBA-365 [RD 23]	
GHe Ventline Level 3	580-586	Al6063 tube CFRP T300 brackets to OB		cross sect. 61.3mm^2 (D=14.9 mm, d=12 mm) A/l = 9.90mm			
GHe Ventline between Level 3 and TS1	590-592	stainless steel tube		cross sect. 17.3mm^2 (D=12.7 mm, d=11.8 mm)			
GHe Ventline between Thermal Shields/CVV	610-612 620-622	stainless steel tube		cross sect. 17.3mm^2 (D=12.7 mm, d=11.8 mm)			
Filling Port / Tubes	440-452	stainless steel		ISO design			
MLI on Filling Tubes	642-652	10 layers			▮	R-INM-0820 [RD 24]	

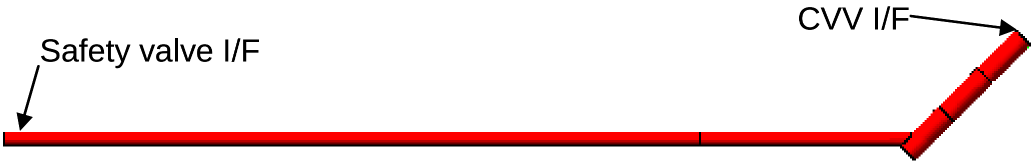
Table 5.2-1: Item List for Tanks, Ventline and Optical Bench

Radiation within filling/safety lines:

To assess the impact of radiation from the CVV interface down the Filling Port and the safety line to the SV123 that is mounted on the HTT a small ESARAD model was established with the following basic assumptions:

- The filling line is invisible from the CVV interface due to the filter and the Joule-Thompson valve in the Filling Port. The filling line is therefore neglected in this model. The FP is closed at the location of the JT valve.
- A straight safety line with the correct length is assumed (conservative wrt bent tube).
- The emissivity of the CVV interface is assumed to be 0.7, the emissivity of the SV123 internal parts is assumed to be 0.9. These assumptions are considered to be conservative.
- The end of the safety line is directly coupled to the HTT, i.e. the heat flow resistance through the SV123 is neglected.
- For the emissivity of the internal surface of the FP and the safety line, a value of 0.05 is assumed. The reflectivity is considered to be 100% specular.

The following picture shows modelling of the Filling Port and the Safety Line in the assessment model.



The calculated radiative coupling is introduced in the Herschel TMM.

5.3 Instruments

The Instrument Interface Thermal Mathematical Models (ITMMs) have been supplied by the instrument people [RD 03, RD 04, RD 05] in ESATAN format and are implemented as submodels in the overall H-EPLM TMM structure. SPIRE in addition has delivered an Interface Geometrical Mathematical Model (IGMM) in ESARAD format. Since no IGMMs of PACS and HIFI were available, they had to be established by ASED according to the corresponding FPU drawings in [RD 10] and [RD 12]. The IGMMs are implemented as submodels in the overall H-EPLM GMM.

5.3.1 PACS

The PACS instrument TMM thermal network is illustrated in Figure 5.3-1. The relevant data of each instrument node are compiled in Table 5.3-1 together with the design data of the thermal links to the Level 0 and Level 1 interfaces. The dissipation timeline during PACS operation and sorption cooler recycling is shown in Figure 5.3-2 and Figure 5.3-3.

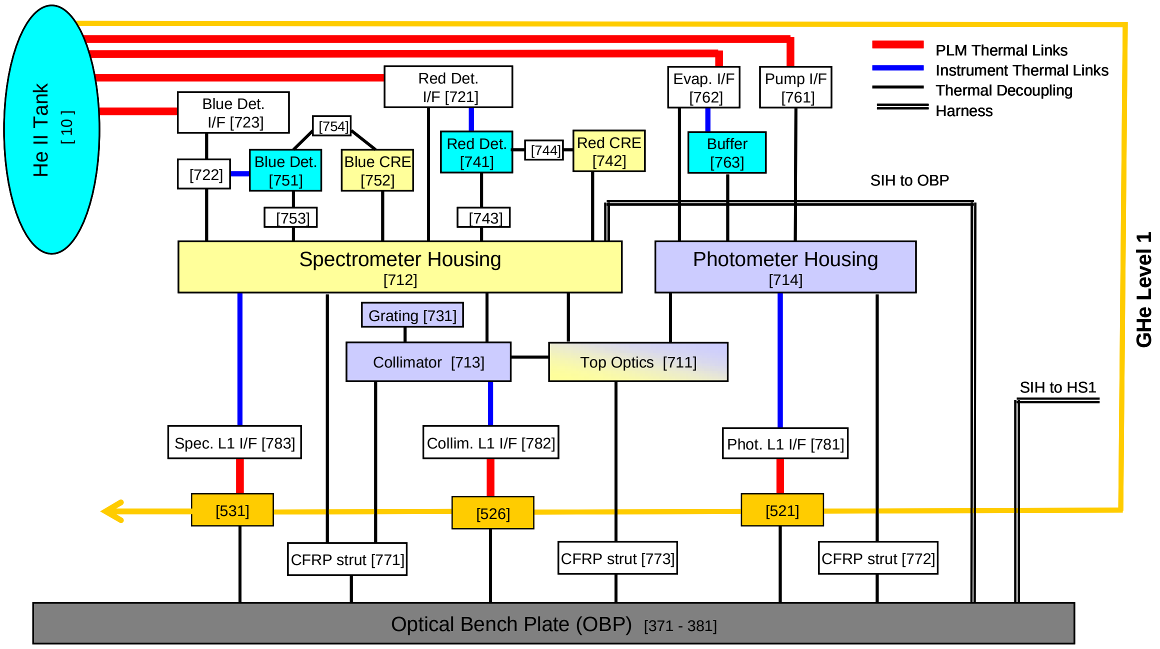


Figure 5.3-1: Reduced PACS Instrument TMM

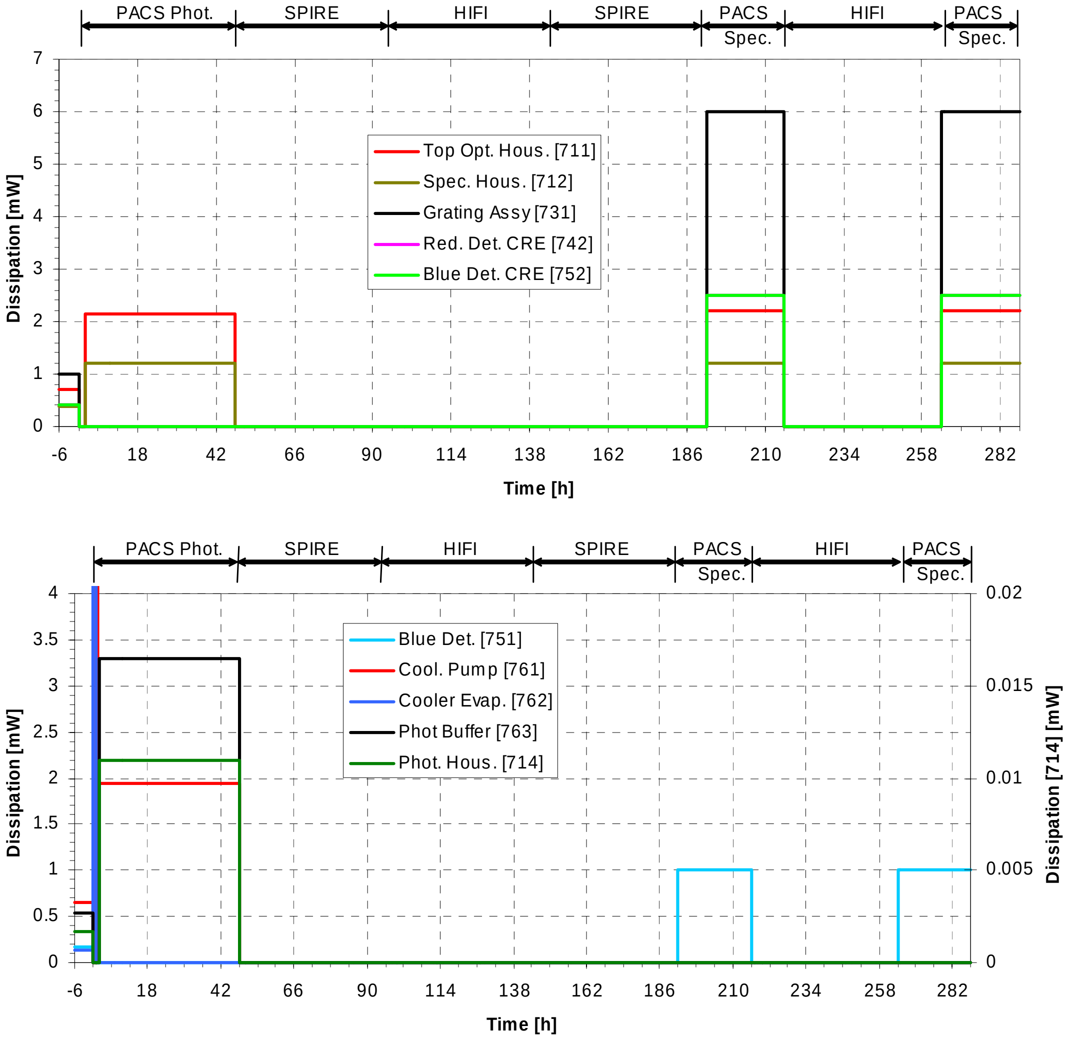


Figure 5.3-2: PACS Dissipation Profile during Operation

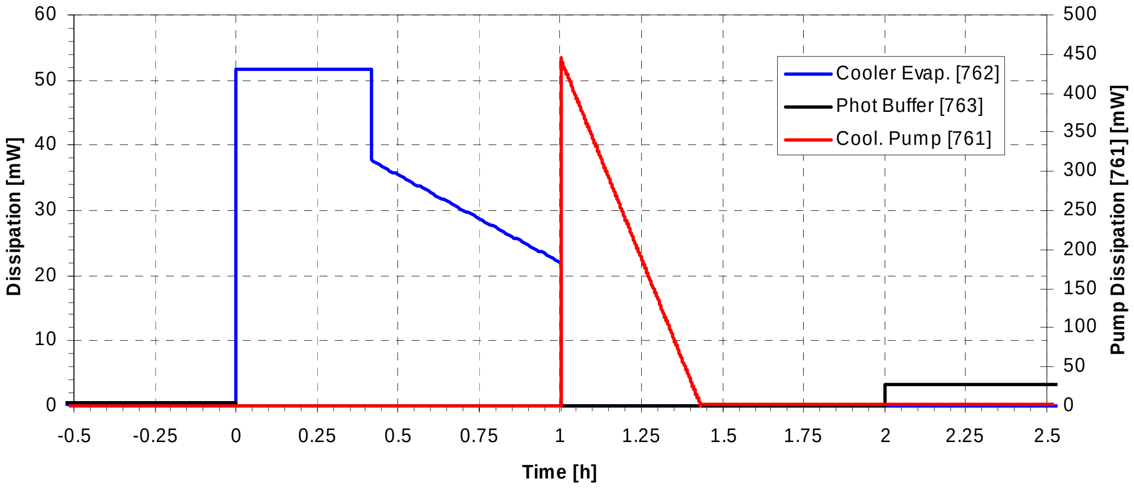


Figure 5.3-3: PACS Dissipation Profile during Recycling

Item	**Node**	**Material / Components**	**Mass [kg]**	**Size / Performance**	**IR Emiss.**	**Unit Level Requirement**	**Remark**
Red Detector I/F	721	Thermal link to HTT (L0) Cu flexible strap Al 1050 pod	0.193	2 x M4 at Instr. I/F cross sect.: 200 mm², l=0.136m 4 x M4 cross sect.: 452 mm², l=0.284m 8 x M5 at HTT I/F		R-OBA-345 [RD 23]	
Feed Through Blue Det.	722						
Blue Detector I/F	723	Thermal link to HTT (L0) Cu flexible strap Al 1050 pod	0.184	2 x M4 at Instr. I/F cross sect.: 88 mm², l=0.222m 4 x M4 cross sect.: 580 mm², l=0.235m 8 x M5 at HTT I/F		R-OBA-345 [RD 23]	
Cooler Pump I/F	761	Cu, Thermal link to HTT (L0) Cu flexible strap Al 1050 pod	0.151	2 x M4 at Instr. I/F cross sect.: 67 mm², l=0.215m 4 x M4 cross sect.: 1130 mm², l=0.235m 8 x M5 at HTT I/F		R-OBA-345 [RD 23]	
Evaporator I/F	762	Cu, Thermal link to HTT (L0) Cu flexible strap Al 1050 pod	0.5	2 x M4 at Instr. I/F cross sect.: 200 mm², l=0.216m 4 x M4 cross sect.: 1130 mm², l=0.235m 8 x M5 at HTT I/F		R-OBA-345 [RD 23]	
Buffer	763	Al, PACS cooling strap to Evaporator I/F	1.45				
Blue Detector	751	Al	2.9				
Red Detector	741	Al	2.25				
Blue Det. CRE	752	Al	0.4				
Red Det. CRE	742	Al	0.4				
CFRP strut Blue Det.	753						
CFRP strut Red Det.	743						
Harness Blue Det. Int.	754						

Item	Node	Material / Components	Mass [kg]	Size / Performance	IR Emiss.	Unit Level Requirement	Remark
Harness Red Det. Int.	744						
Spectr. Housing	712	Al	14.6				
Collimator Housing	713	Al	13.5				
Phot. Housing	714	Al, Ti	15.0				
Top Optics	711	Al	14.2	 Apertures with filters: 0.002 m^2	0.26 1.0		
Grating	731	Al, Cu	4.0				
Phot. L1 I/F	781	Cu Cooling strap to GHe ventline (L1) Cu flexible strap		2 x M4 at Instr. I/F cross sect.: (20x3)mm, l=0.217m 4 x M4 at ventline I/F		R-OBA-345 [RD 23]	
Collimator L1 I/F	782	Cu Cooling strap to GHe ventline (L1) Cu flexible strap		2 x M4 at Instr. I/F cross sect.: (20x2)mm, l=0.128m 4 x M4 at ventline I/F		R-OBA-345 [RD 23]	
Spec. L1 I/F	783	Cu Cooling strap to GHe ventline (L1) Cu flexible strap		2 x M4 at Instr. I/F cross sect.: (20x3)mm, l=0.227m 4 x M4 at ventline I/F		R-OBA-345 [RD 23]	
L2 IF (Phot.)	772	CFRP bracket to OB (L2)		A/L= 7.66 mm			
L2 IF (Top Opt.)	773	CFRP bracket to OB (L2)		A/L= 15.3 mm			
L2 IF (Spec/Coll.)	771	CFRP bracket to OB (L2)		A/L= 23.0 mm			

Table 5.3-1: Item List for PACS

5.3.2 SPIRE

The SPIRE instrument TMM thermal network is illustrated in Figure 5.3-4. All thermal nodes are represented in this sketch and are also compiled in Table 5.3-2, together with the design and performance data of the thermal links to the Level 0, Level 1 and Level 3 interfaces. The dissipation timeline during SPIRE operation and sorption cooler recycling is shown in Figure 5.3-5 and Figure 5.3-6, respectively. A more detailed description of the SPIRE instrument TMM is given in RD 16.

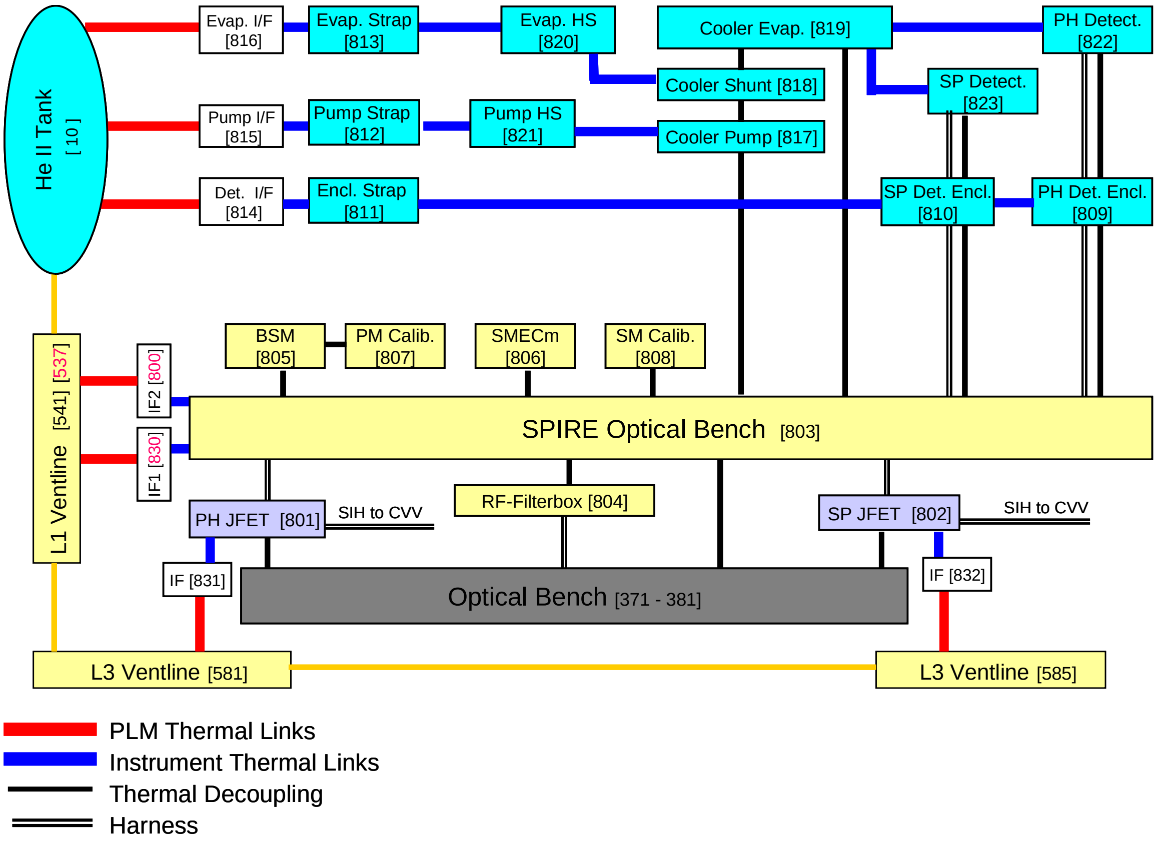


Figure 5.3-4: Reduced SPIRE Instrument TMM

The following radiative couplings (GR) inside the SPIRE TMM exist:
GR (819,820) = 6.619E-3 m²
GR (817,821) = 6.619E-3 m².

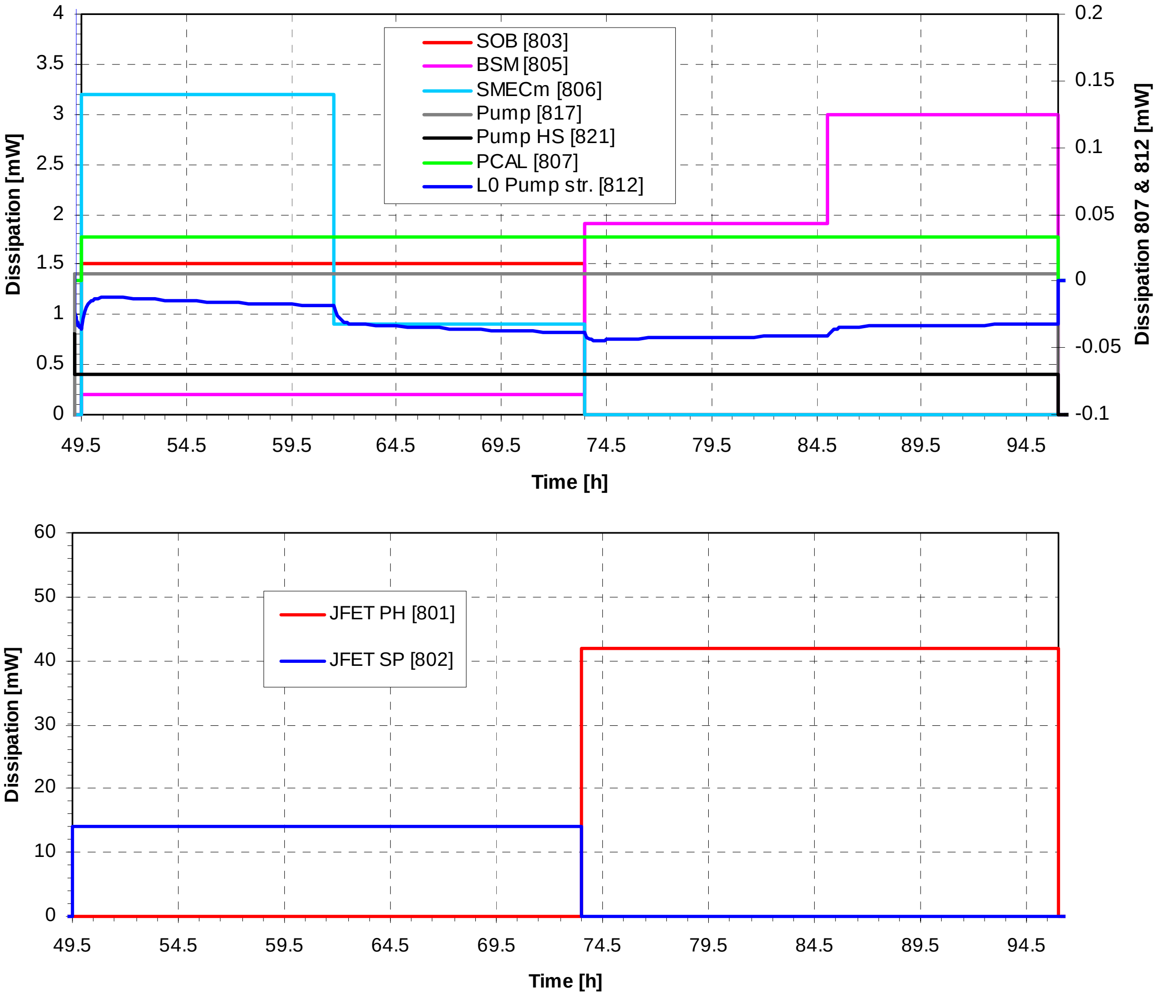


Figure 5.3-5: SPIRE Dissipation Profile during Operation

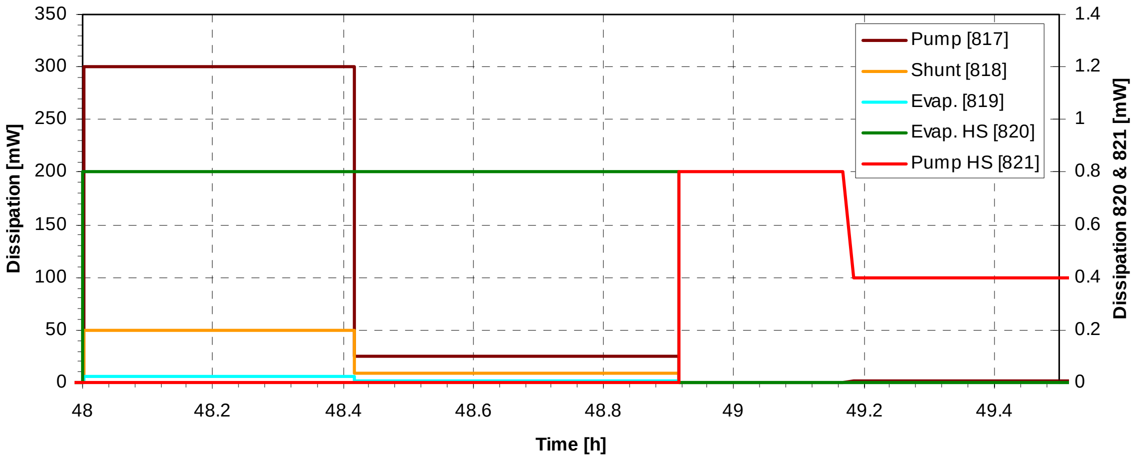


Figure 5.3-6: SPIRE Dissipation Profile during Recycling

Item	**Node**	**Material / Components**	**Mass [kg]**	**Size / Performance**	**IR Emissivity**	**Unit Level Reqirement**	**Remark**
PM Det. enclosure	809	Al, St. Steel, Invar, Silicon	3.91				
SM Det. enclosure	810	Al, St. Steel, Invar, Silicon	1.70				
Enclosure Strap	811		6.16E-3				
Pump Strap	812		6.16E-3				
Evap. Strap	813		6.16E-3				
Enclosure Strap I/F	814	Thermal link to HTT (L0) Al1050 pod		4 x M4 at Instr. I/F cross sect.: 960 mm², l=0.340m 8 x M5 at HTT I/F		R-OBA-345 [RD 23]	
Pump Strap I/F	815	Thermal link to HTT (L0) Al1050 pod		4 x M4 at Instr. I/F cross sect.: 960 mm², l=0.340m 8 x M5 at HTT I/F		R-OBA-345 [RD 23]	
Evap. Strap I/F	816	Thermal link to HTT (L0) Al1050 pod		4 x M4 at Instr. I/F cross sect.: 960 mm², l=0.340m 8 x M5 at HTT I/F		R-OBA-345 [RD 23]	
Cooler Pump	817	Ti	0.15				
Cooler Shunt	818	Ti	0.01				
Cooler Evaporator	819	Ti	0.084				
Cooler Evapor. HS	820	Ti	0.074				
Cooler Pump HS	821	Ti	0.074				
PM Detector	822	Invar, Cu	1.144				
SM Detector	823	Invar, Cu	0.535				
L1 strap I/F1	800	Cooling strap to GHe ventline (L1) Cu flexible strap		0.5 x M8 + 1 x M4 at Instr. I/F cross sect.: (20x2)mm, l=0.173m 4 x M4 at ventline I/F		R-OBA-345 [RD 23]	
L1 strap I/F2	830	Cooling strap to GHe ventline (L1) Cu flexible strap		0.5 x M8 + 1 x M4 at Instr. I/F cross sect.: (20x2)mm, l=0.173m 4 x M4 at ventline I/F		R-OBA-345 [RD 23]	
SPIRE Optical Bench (SOB)	803		26.75	 aperture	0.20 1.0		

Item	Node	Material / Components	Mass [kg]	Size / Performance	IR Emissivity	Unit Level Reqirement	Remark
		4 stainless steel brackets to OB *)		A/L= 3.2284 mm x 0.25 *)			
RF Filter box	804	Al casing/structure	1.465				
BSM	805		1.10				
SMECm	806		1.043				
PM Calibration	807		0.03				
SM Calibration	808		2.041E-4				
PM JFET Encl.	801	Al, 4 CFRP T300 brackets to OB	2.348	A/L= 29.30 mm	0.20		
PM JFET I/F	831	Cooling strap to Level 3 Cu flexible strap		2 x M4 at Instr. I/F cross sect.: (20x4)mm, l=0.252m 4 x M4 at ventline I/F			
SM JFET Encl.	802	Al, 5 CFRP T300 brackets to OB	0.81342	A/L= 36.36 mm	0.20		
SM JFET I/F	832	Cooling strap to Level 3 Cu flexible strap		2 x M4 at Instr. I/F cross sect.: (20x4)mm, l=0.308m 4 x M4 at ventline I/F			

*) A factor of 0.25 is applied in the SPIRE TMM to account for new isolating supports

Table 5.3-2: Item List for SPIRE

5.3.3 HIFI

The HIFI instrument TMM thermal network is illustrated in Figure 5.3-7. All thermal nodes are represented in this sketch and are also compiled in Table 5.3-3 together with the design and performance data of the thermal links to the Level 0 and Level 1 interfaces.

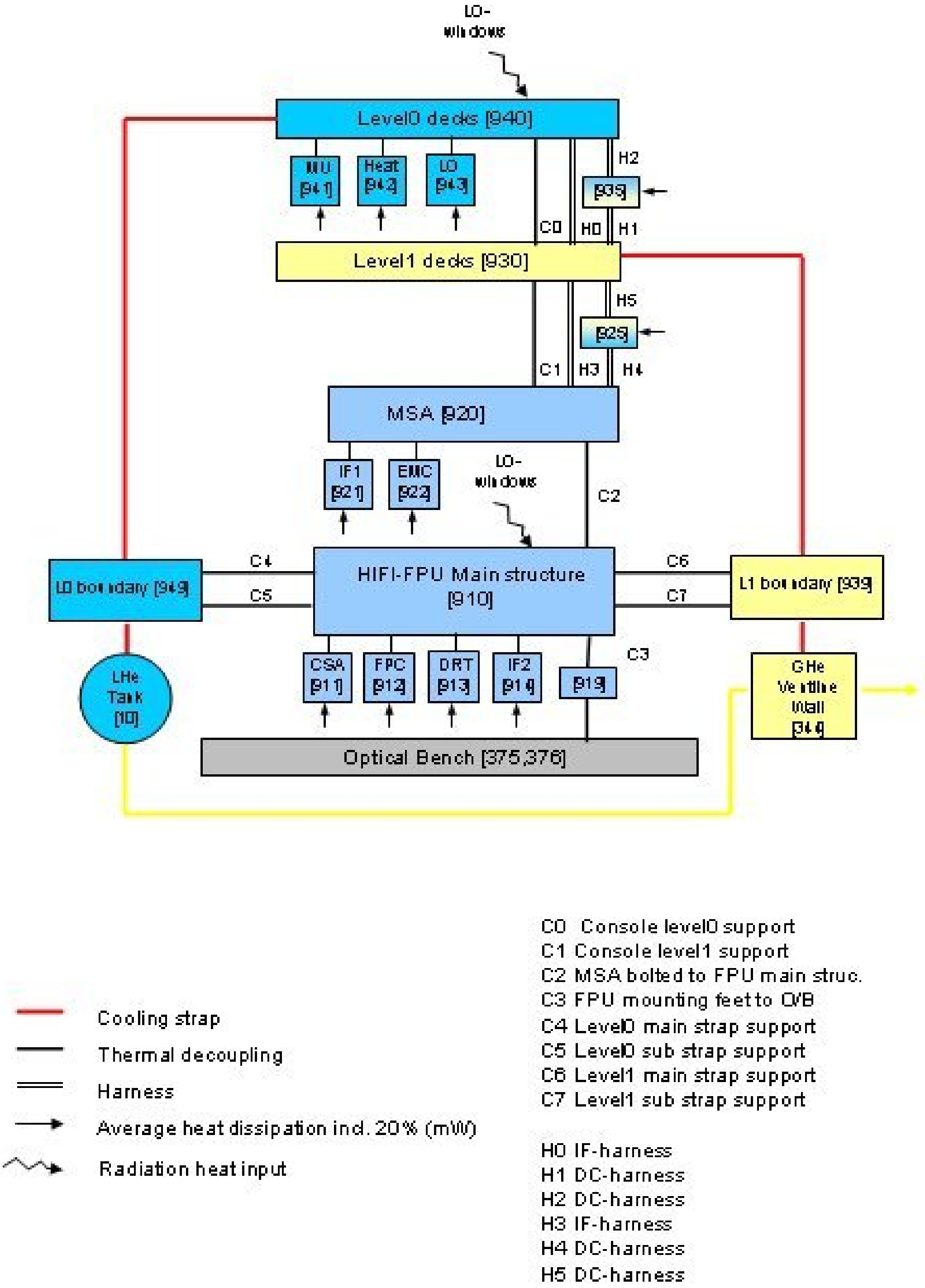


Figure 5.3-7: Reduced HIFI Instrument TMM

The dissipation timeline during HIFI operation is shown in Figure 5.3-8.

The following radiative couplings (GR) from the LOU windows (Node 4090 in H-EPLM TMM) to the HIFI Level 0 exist:
GR (4090 , 940) = 1.02E-5 m²

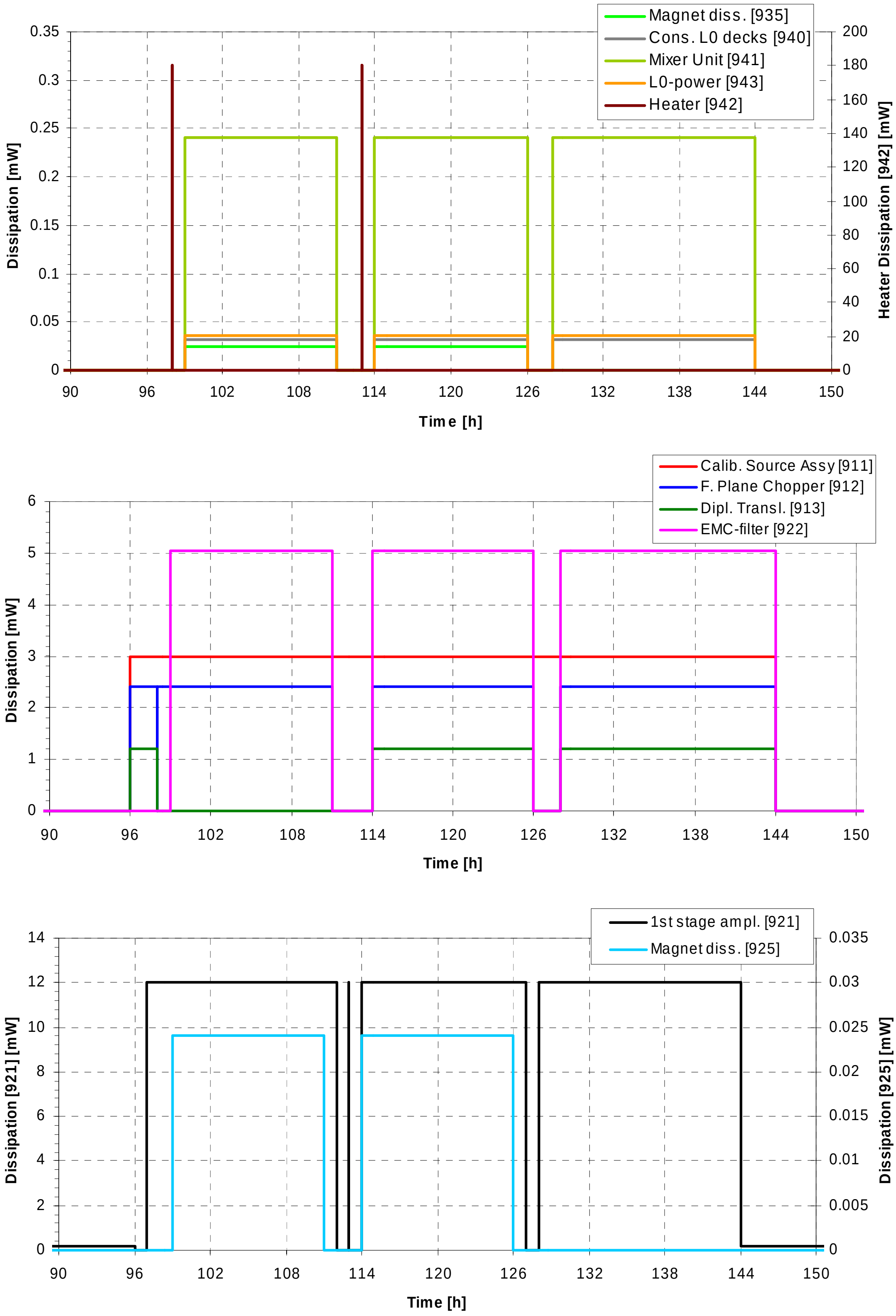


Figure 5.3-8: HIFI Dissipation Profile during Operation

Item	Node	Material / Components	Mass [kg]	Size / Performance	IR Emiss.	Unit Level Requirement	Remark
FPU Structure	910	Al	35.72	 Aperture	0.26 1.0		
Calib. Source Assy	911	Al	1.5				
Focal Plane Chopper	912	Al	0.40				
Dipl. Rooftop transl.	913	Al	0.59				
2nd stage amplifier	914	Al	2.30				
L2 boundary	919			thermal coupl. to OB: 1.2 W/K			
Mixer Sub Assy	920	Al	2				
1st stage amplifier	921						
EMC filtering	922						
Magnet current diss.	925						
Console L1 decks	930	Al	0.56				
Magnet current diss.	935						
L1 boundary	939	Al, Cu Cooling strap to GHe ventl. (L1)	0.40	4 x M4 at Instr. I/F cross sect.: (20x3.5)mm, l=0.172m 4 x M4 at ventline I/F		R-OBA-345 [RD 23]	
Console L0 decks	940	Al	1.68				
Mixer Unit	941	Al	1.05				
Heater	942						
LO-power	943						
L0 boundary	949	Al, Thermal link to HTT (L0) Cu flexible strap Al 1050 pod	0.40	4 x M4 at Instr. I/F cross sect.: 105 mm², l=0.236m 4 x M4 cross sect.: 392 mm², l=0.404m 8 x M5 at HTT I/F		R-OBA-345 [RD 23]	

Table 5.3-3: Item List for HIFI

5.4 Thermal Shields and Tank Suspensions

The tank suspension consists of GFRP and T300 CFRP chains with heat interceptions at each Thermal Shield. The two innermost chains are made out of T300 CFRP; the other ones are made out of S-glass. The cross section and material selection of each chain has been optimized w.r.t. thermal and mechanical performance. The details are described in [RD 20]. The nodal break-down of the chains is shown in Figure 5.4-1 and the relevant data are compiled in Table 5.4-1.

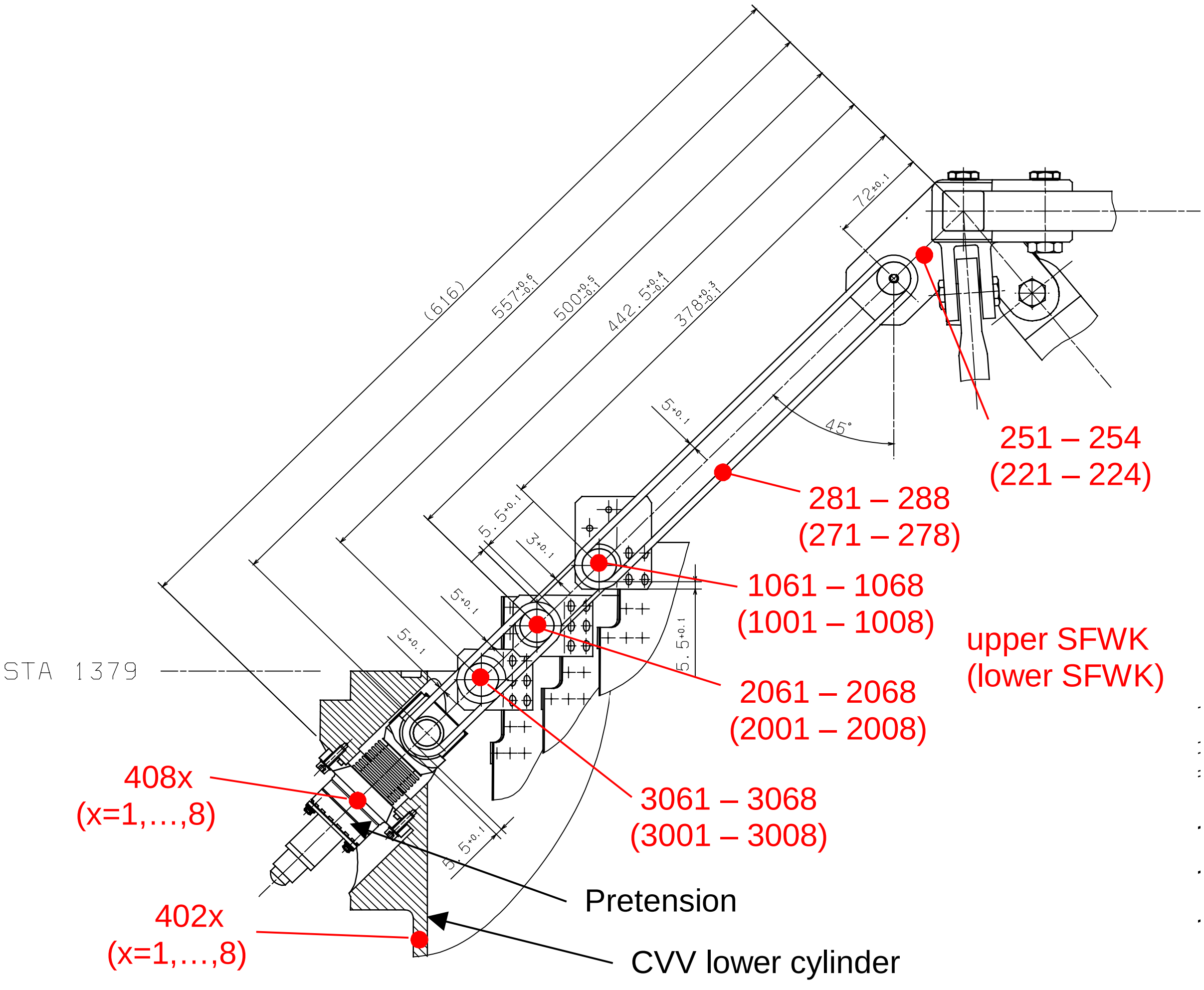


Figure 5.4-1: Nodal Break-Down of Tank Suspensions

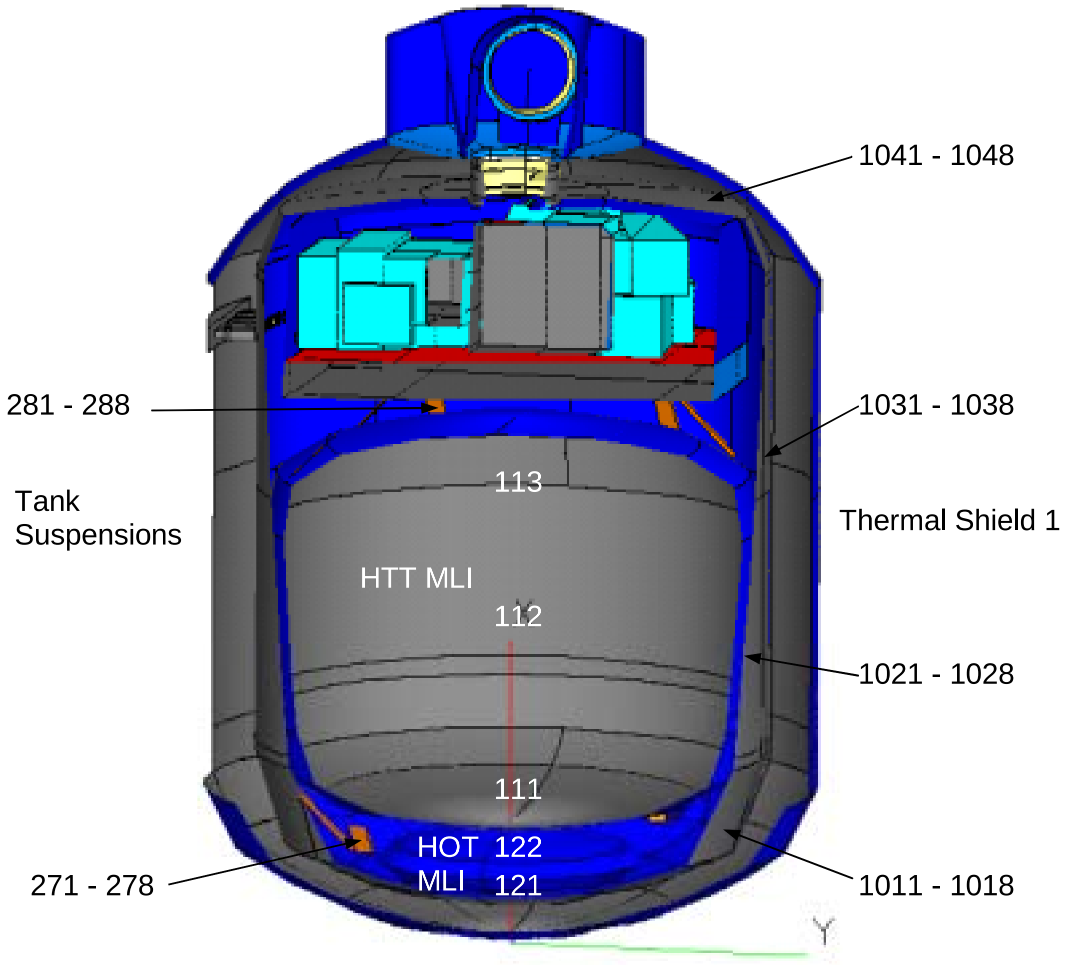


Figure 5.4-2: Nodal Break-Down of Tanks and Thermal Shield 1

Item	**Node**	**Material / Components**	**Mass [kg]**	**Size**	**IR Emiss.**	**Unit Level Requirement**	**Remark**
Susp. Bolt TS1 lo	1001-1008	stainless steel	0.15				
Susp. Bolt TS1 up	1061-1068	stainless steel	0.15				
Susp. Straps lo	271-278	8 CFRP T300, between TS1 and SFW		8x137 mm^2, l= 306 mm	0.8	R-TSS-200 [RD 21]	A)
Susp. Straps up	281-288	8 CFRP T300, between TS1 and SFW		8x137 mm^2, l= 306 mm			
Thermal Shld 1 low bulk	1011-1018	Al 6061	10.0	A= 3.708 m^2, s=0.8 mm	0.05	R-FTS-170 [RD 30]	
Thermal Shld 1 low cyl.	1021-1028		12.1	D=1.69m, h=0.842m, s=0.8 mm			
Thermal Shld 1 upp cyl.	1031-1038		10.0	D=1.69m, h=0.696m, s=0.8 mm			
Thermal Shld 1 upp bulk	1041-1048		8.2	A= 3.021 m^2, s=0.8 mm			
Thermal Shield 1 MLI	1111-1118	2 x 5 layers	1.9	A= 3.708 m^2	0.05	R-INM-0510 [RD 24]	B)
	1121-1128		2.0	D=1.69m, h=0.842m		R-INM-0530 [RD 24]	
	1131-1138		1.9	D=1.69m, h=0.696m			
	1141-1148		1.4	A= 3.021 m^2			
Susp. Bolt TS2 lo	2001-2008	stainless steel	0.15				
Susp. Bolt TS2 up	2061-2068	stainless steel	0.15				
		2x8 CFRP T300, susp. straps to TS1		2x8x131 mm^2, l= 64.5 mm		R-TSS-200 [RD 21]	A)
Thermal Shld 2 low bulk	2011-2018	Al 6061	11.1	A= 4.124 m^2, s=0.8 mm	0.05	R-FTS-173 [RD 30]	
Thermal Shld 2 low cyl.	2021-2028		12.6	D=1.76m, h=0.842m, s=0.8 mm			
Thermal Shld 2 upp cyl.	2031-2038		10.4	D=1.76m, h=0.696m, s=0.8 mm			
Thermal Shld 2 upp bulk	2041-2048		9.0	A= 3.319 m^2, s=0.8 mm			
Thermal Shield 2 Baffle	2050	Al baffle with aperture; cut-out area 0.040 m^2, see Figure 5.2-4		290 mm diameter	0.7 cyl. 0.7 +x side 0.05-x side		
TS 2 LOU Baffle	2090	Al tubes (LOU)		7 x 38 mm inner diameter	0.7		
		Al tubes (Alignment)		2 x 31 mm inner diameter			
Thermal Shield 2 MLI	2111-2118	4 x 5 layers	2.1	A= 4.124 m^2	0.05	R-INM-0610 [RD 24]	B)
	2121-2128		2.1	D=1.76m, h=0.842m		R-INM-0630 [RD 24]	
	2131-2138		1.9	D=1.76m, h=0.696m			
	2141-2148		1.7	A= 3.319 m^2			
Susp. Bolt TS3 lo	3001-3008	stainless steel	0.15				
Susp. Bolt TS3 up	3061-3068	stainless steel	0.15				
		2x8 GFRP suspension straps to TS2		2x8x168 mm^2, l= 57.5 mm		R-TSS-200 [RD 21]	A)
		2x8 GFRP suspension straps to CVV		2x8x167 mm^2, l= 57 mm			

Item	**Node**	**Material / Components**	**Mass [kg]**	**Size**	**IR Emiss.**	**Unit Level Requirement**	**Remark**
Thermal Shld 3 low bulk	3011-3018	Al 6061	12.2 kg	A= 4.503 m², s=1mm	0.05	R-FTS-173 [RD 30]	
Thermal Shld 3 low cyl.	3021-3028		13.1 kg	D=1.83m, h=0.842m, s=1mm			
Thermal Shld 3 upp cyl.	3031-3038		10.8 kg	D=1.83m, h=0.696m, s=1mm			
Thermal Shld 3 upp bulk	3041-3048		10.5 kg	A= 3.886 m², s=1mm			
Thermal Shield 3 MLI	3111-3148	4 x 5 layers	2.5 kg 4.6 kg 2.1 kg		0.05	R-INM-0710 [RD 24] R-INM-0730 [RD 24]	B)

A) Thermal conductivity of material confirmed by sample tests

B) MLI Performance test data of Forschungszentrum Karlsruhe included (details are reported in [RD 36])

Table 5.4-1: Item List for Thermal Shields

The thermal property data of the cryostat internal MLI are described in Section 6.1.

5.5 Cryostat Vacuum Vessel and Radiators

The nodal break-down of the CVV is shown in Figure 5.5-1. About one half of the cylindrical part and a 90° section of the upper bulkhead of the CVV serve as radiator, this area is called the CVV main radiator. The remaining surface of the CVV is covered with MLI. Three additional radiators are located at the –Z, +Y and –Y sides.

The ±Y radiators shadow the CVV main radiator from the warm Solar Array MLI and increase further the CVV radiative area to space. The radiator (-Z) side of the ±Y radiators (as well as both sides of the –Z radiator) are black anodized with 50 µm thickness. The rear (+Z) sides of the ±Y radiators are covered with MLI.

The ±Y radiators have an area of 350 mm x 1687 mm, respectively. The –Z radiator is split in two parts: the upper part (+X) with 350 mm x 926 mm and the lower part (-X) with 350 mm x 506 mm area. The thermal / mechanical attachment of each radiator to the CVV is provided with M8 bolt connections as listed in Table 5.5-1. The contact conductance between radiators and CVV structure are calculated using the values shown in Figure 6.3-1.

The heat spreading effect on CVV and radiators has been taken into account in the TMM using appropriate formulas in the corresponding "GL" conductance calculations (serial conductance of contact conductance and linear conductance of the corresponding CVV radiator). On the CVV two arithmetic nodes are introduced at the –Z Radiator I/F on the lower (node 4051) and upper part (4052). Thus, node 4051 connects the radiator node 4050 with the CVV nodes 4024 and 4025. Node 4052 connects the radiator node 4053 with the CVV nodes 4034 and 4035.

A cryostat baffle is arranged between the Telescope and the CVV upper bulk. The external surface of this baffle is covered with MLI except a 90° section at the -Z side that serves as radiator area. This area is also black anodized. The internal surface has a low IR emissivity. Inside this cryostat baffle there is an additional internal conical baffle with a low IR surface emissivity.

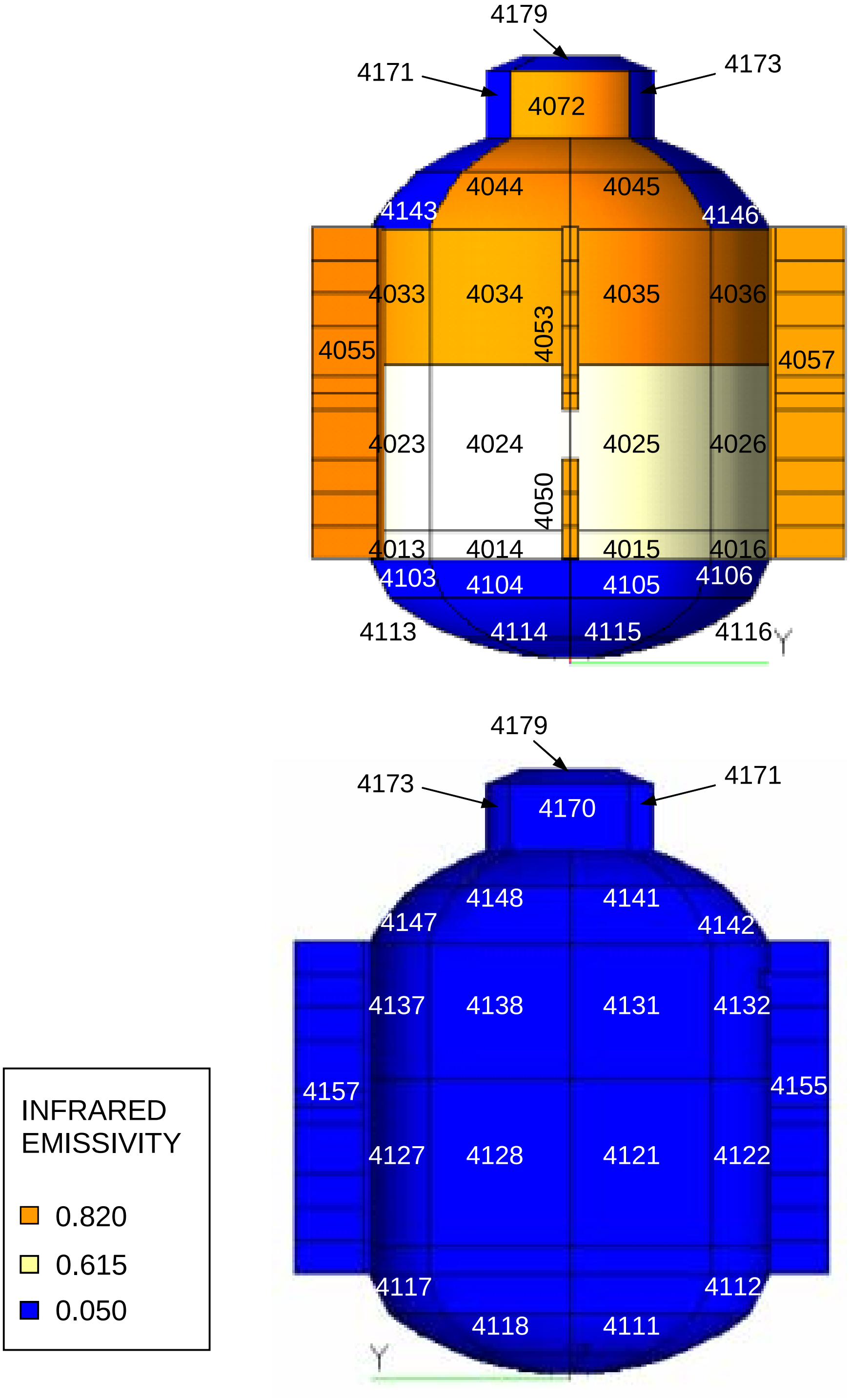


Figure 5.5-1: CVV Nodal Break-Down

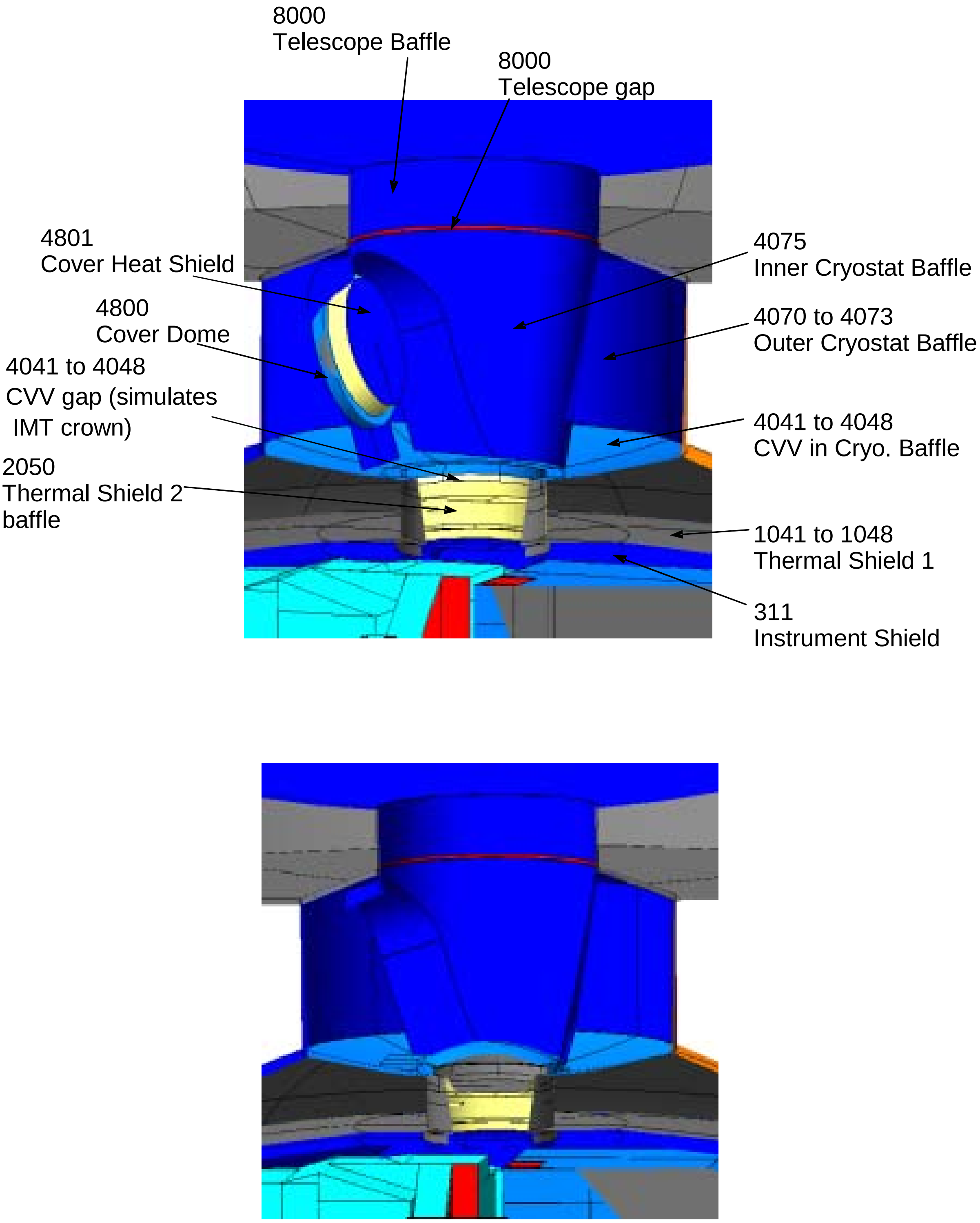


Figure 5.5-2: Cryostat Baffle and Cover Nodal Break-Down (Cover open & closed View)

Thermal conductance due to gaseous Helium in the Cryo Cover flushing line

According to [RD 39], the total linear heat conductance between the Cover and the CHS is 0.00325 W/K. The cited value does not include the heat conduction through the gaseous Helium, which is left in the tube after cover flushing. To avoid leakage of air and water vapour into the flushing lines, the lines will be sealed off with a slight He overpressure inside during the ground hold time / launch autonomy.
For the current worst-case calculation, a Helium pressure of 1.5 bar (150kPa) is assumed. The thermal conductivity of He varies between 0.137 W/mK and 0.156 W/mK for temperatures between 250 K and 300 K according to NIST. Two parallel stainless steel (1.4404) lines, free effective length L = 60 mm, outer diameter da = 5.0 mm, inner diameter di = 4.6 mm. [RD 38]This leads to a pipe wall conductance of 0.0015 W/K.

Since the warm part (Johnston coupling) is above the cold part (CHS), convection will not take place. Conduction in the He gas is:

$$C = 2 \cdot \lambda \cdot \frac{\pi d_i^2}{4L} = 8.30951\mathrm{E}-05\ \mathrm{W/K}$$

This linear conductor has been implemented in the CDR TMM version.

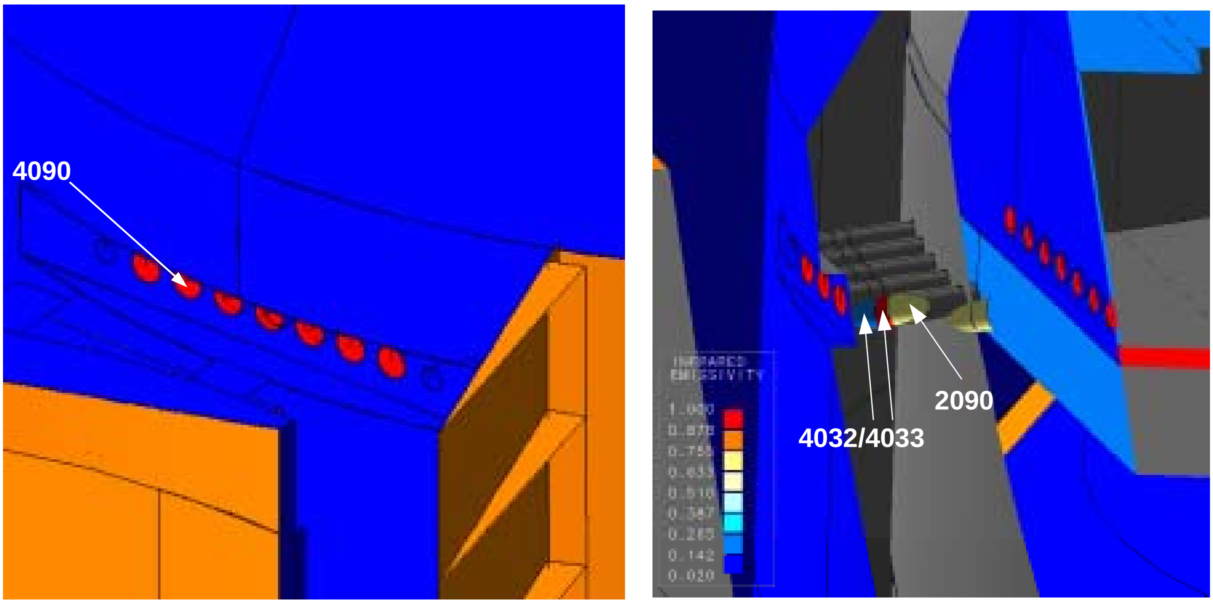


Figure 5.5-3: LOU Windows / Baffles

Item	Node	Material / Components	Mass [kg]	Size	Solar Absorpt.	IR Emiss.	Unit Level Requirement	Remark
CVV lower bulk	4011-4018	Al 5083, 3.3547, outside: black anodized inner side: polished	88.5	A= 8 x 0.585 m² 7 mm thickness (average)	α=0.95	0.75*0.82 0.06	R-CVV-F-640 [RD 31] R-CVV-F-645 [RD 31]	B)
CVV lower cylinder	4021-4028	Al 5083, 3.3547, outside :black anodized inner side: polished	95.0	D = 1.9 m, h=0.842 m 7 mm thickness (average)	α=0.95	0.75*0.82 0.06	R-CVV-F-640 [RD 31] R-CVV-F-645 [RD 31]	B)
CVV upper cylinder	4031-4038	Al 5083, 3.3547, outside: black anodized inner side: polished	78.5	D = 1.9 m , h= 0.696 m 7 mm thickness	α=0.95	0.82 0.06	R-CVV-F-640 [RD 31] R-CVV-F-645 [RD 31]	B)
CVV upper bulk	4041-4048	Al 5083, 3.3547, outside: black anodized inner side: polished	78.1	A= 8 x 0.516 m² 7 mm thickness (average)	α=0.95	0.82 0.06	R-CVV-F-640 [RD 31] R-CVV-F-645 [RD 31]	B)
CVV lower bulk MLI	4111-4118 4103-4106	25 layers (4x6+1)			α=0.13	0.05	R-EXM-530 [RD 28]	A)
CVV lower cyl. MLI	4121-4128	25 layers (4x6+1)			α=0.13	0.05	R-EXM-530 [RD 28]	A)
CVV upper cyl. MLI	4131-4138	25 layers (4x6+1)			α=0.13	0.05	R-EXM-530 [RD 28]	A)
CVV upper bulk MLI	4141-4148	25 layers (4x6+1)			α=0.13	0.05	R-EXM-530 [RD 28]	A)
CVV –Z Radiator (+X)	4053	Al 6063, both sides black anodized		(0.35 x 0.926) m² 15 x M8	α=0.95	0.82	R-CVV-F-480 [RD 31]	B)
CVV –Z Radiator (-X)	4050	Al 6063, both sides black anodized		(0.35 x 0.506) m² 9 x M8	α=0.95	0.82	R-CVV-F-480 [RD 31]	B)
CVV -Y Radiator	4055	Al 6063, -Z side black anodized		(0.35 x 1.687) m² 24 x M8	α=0.95	0.82	R-CVV-F-485 [RD 31]	B)
CVV +Y Radiator	4057	Al 6063, - Z side black anodized		(0.35 x 1.687) m² 24 x M8	α=0.95	0.82	R-CVV-F-485 [RD 31]	B)
CVV -Y Radiat. MLI	4155	25 layers (4x6+1)			α=0.13	0.05	R-EXM-530 [RD 28]	A)
CVV +Y Radiat. MLI	4157	25 layers (4x6+1)			α=0.13	0.05	R-EXM-530 [RD 28]	A)
LOU Windows	4090	Glass windows (LOU) Glass windows (Alignment)		7 x ∅34 mm opening in CVV 2 x ∅24 mm opening in CVV		0.9		
Cover	4800	If opened: -107° rotated around Y axis	7			0.15	R-CC-090 [RD32]	
Cover Heat Shield	4801	 Heat shield rim/short cone	0.46			0.05 0.7	R-CC-080 [RD32]	
Outer Cryostat Baffle	4070,4071, 4073,4079 4072	Al 5083 90° radiator section	5	D=850mm 0.229 m²		0.15 0.82	R-CB-135 [RD32] R-CB-135 [RD32]	 B)

Inner Cryostat Baffle	4075	Al 5083 outer surface	1	Conical: D=500, d=300		0.05 0.1	R-CB-135 [RD32]	
Cryostat Baffle MLI	4170,4171, 4173,4179	25 layers (4x6+1)	0.6 0.3		α=0.13	0.05	R-EXM-830 [RD 28]	A)
CVV gap	4041-4048	simulates IMT crown		D = 290mm, h = 14.5mm		0.6		
Pretension 1 - 8	4081-4088	Ti brackets	8 x 0.15					

A) ASED PDR Reference design assumed

B) Test results obtained from sample testing [RD 35], for CVV lower part 75% degraded view factor assumed

Table 5.5-1: Item List for CVV and Cryostat Baffle

The thermal property data of the CVV MLI are described in Section 6.1.

5.6 LOU and Telescope

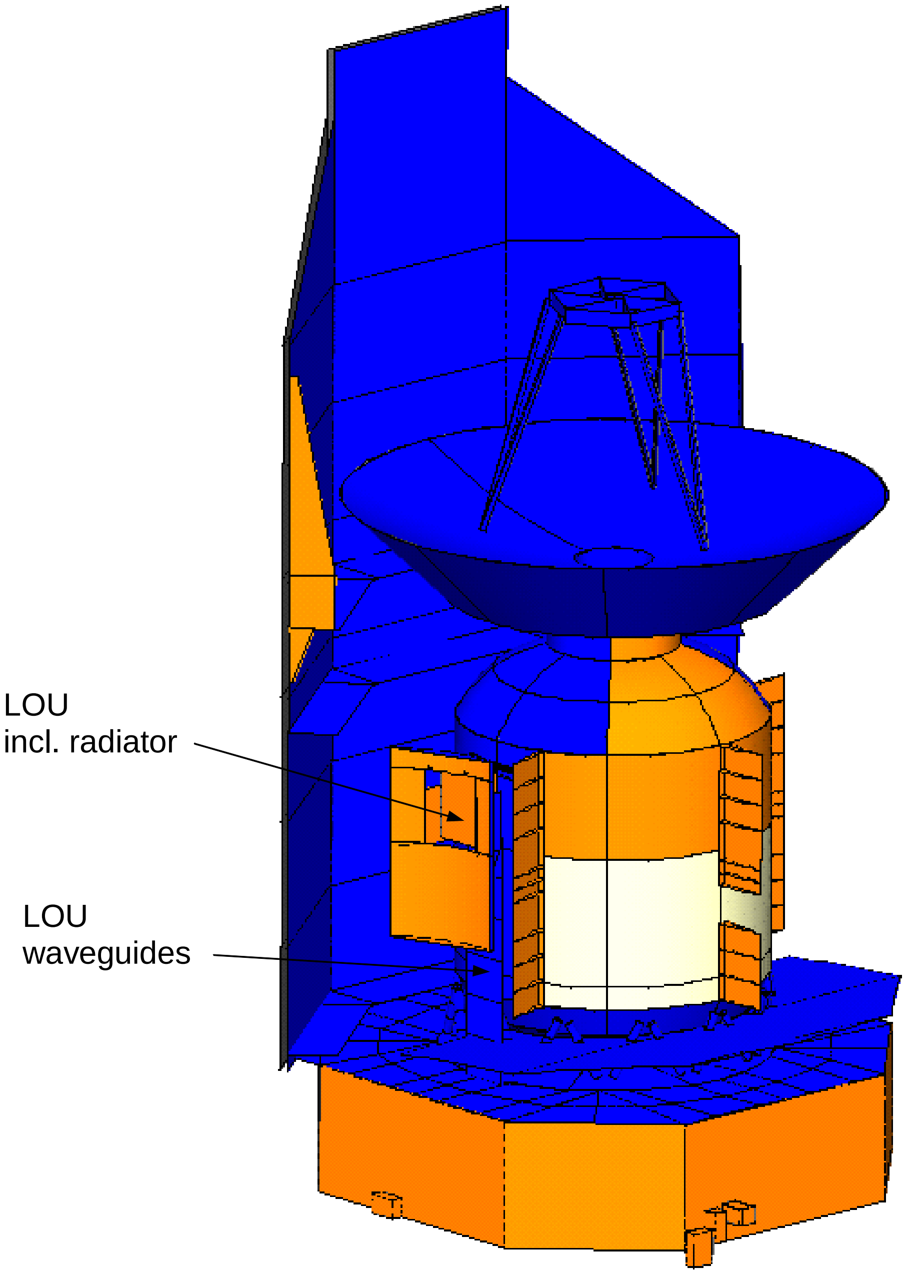


Figure 5.6-1: H-EPLM GMM External Overall View including H-SVM RGMM

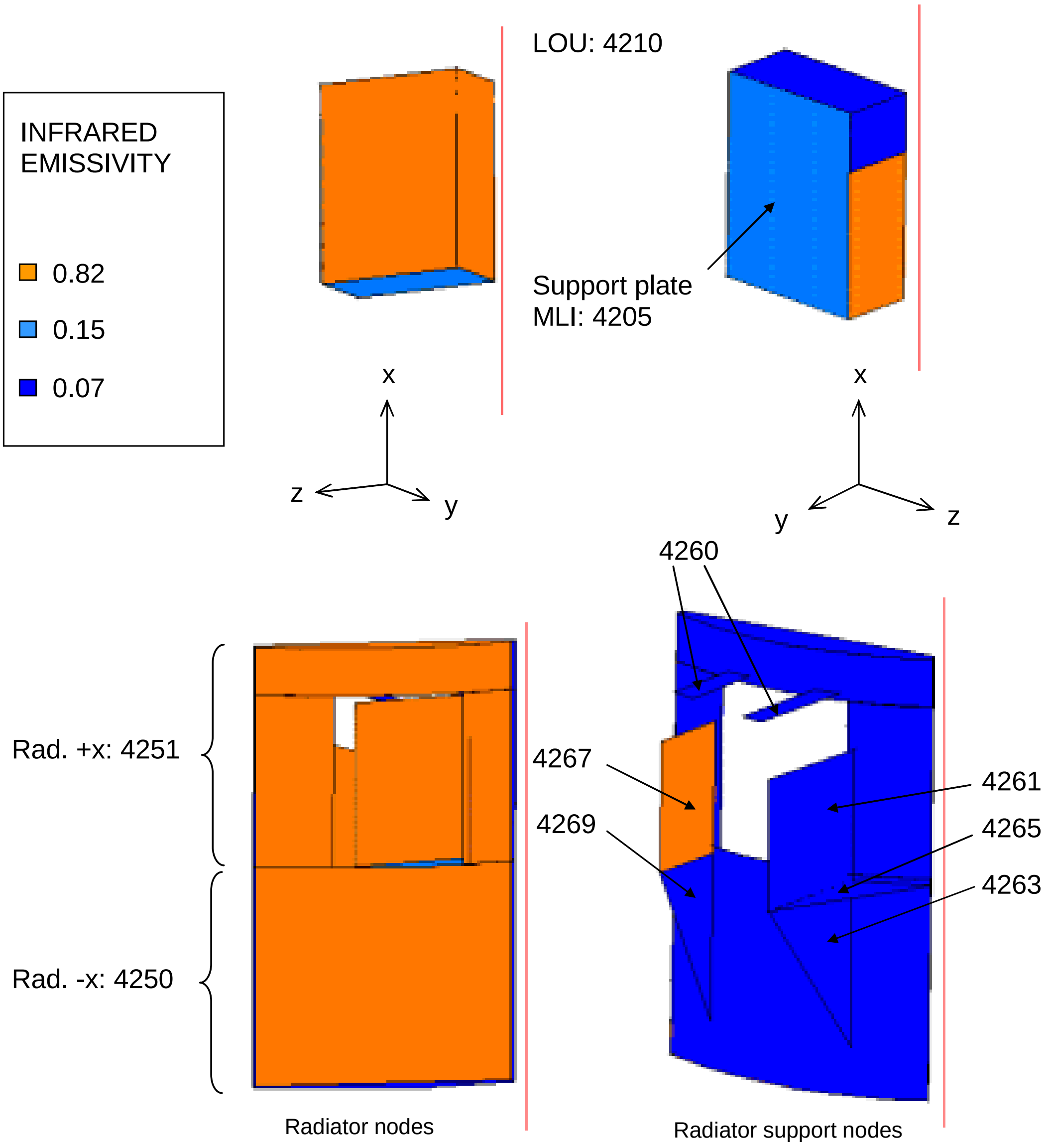


Figure 5.6-2: LOU & LOU Radiator GMM

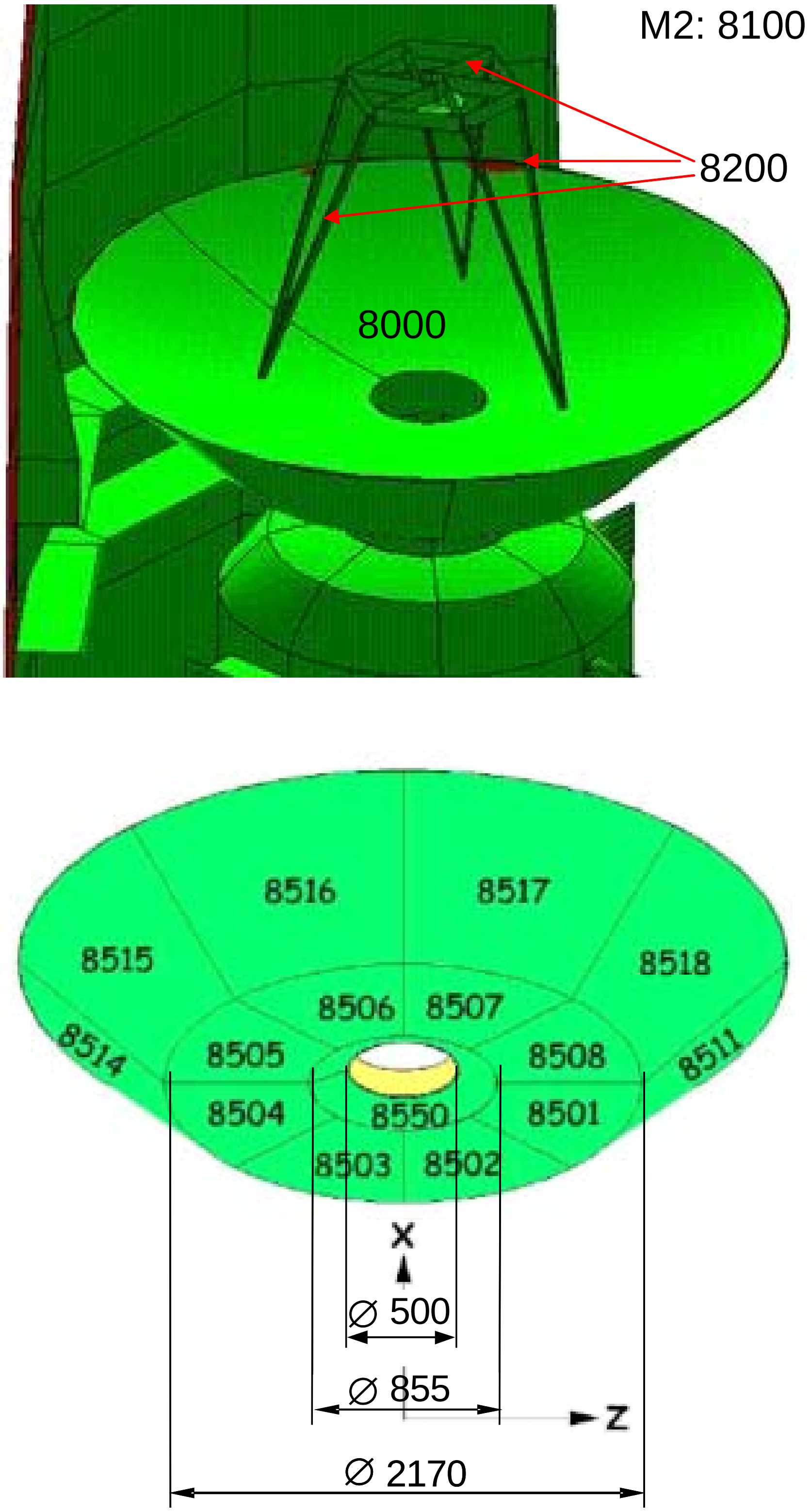


Figure 5.6-3: Telescope GMM

LOU:

The LOU is modelled as one common box connected to the LOU baseplate with 1 W/K and with a heat dissipation of 7 W [AD 01 and AD 04].

The LOU baseplate has a conductive interface to the CVV via 8 GFRP struts with 6.39 mm cross-section to length ratio in total and an assumed conductive coupling to the LOU radiator of 1 W/K.

In addition to the LOU radiator the +X and –Z side of LOU box serve also as radiator, the other sides of the box are covered with MLI.

The LOU Waveguide bundle is subdivided in 6 nodes, see Figure 5.6-4.

Radiative coupling between SVM and LOU via waveguide tubes: GR=0.383E-3 m²

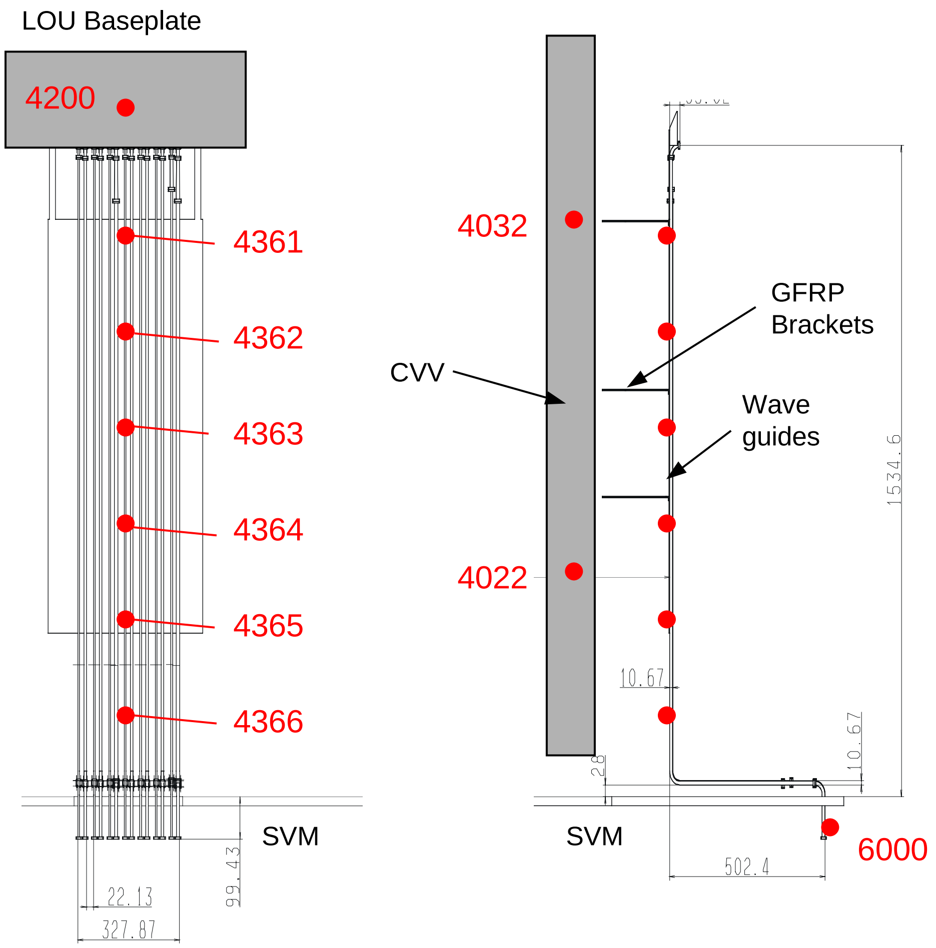


Figure 5.6-4: Nodal Break-Down of LOU Waveguides and Harness

Item	**Node**	**Material / Components**	**Mass [kg]**	**Size**	**Solar Abs.**	**Emiss.**	**Unit Level Requirement**	**Remark**
LOU Support Structure	4200	Al 6061 8 GFRP struts to CVV 32xM5 to LOU Baseplate 20xM5+6xM4 to LOU Radiator support		(507x439x10) mm A/L = 6.39 mm GFRP			R-SS-0330 [RD 25]	
LOU	4210	thermally equivalent to Al	35	(466x352x170) mm				
radiative area (-Y)				0.16 m²		0.82		
+/-Z side (partly)						0.82		
others						0.07-0.15		
LOU +Y MLI	4205	specularity = 0.7 (IR)			0.13	0.15		
LOU Radiator	4250-4251	black painted Al		0.933 m²	0.95	0.82 front 0.07 rear		
LOU Radiat. supp. +X	4260				0.13	0.07		
LOU Radiat. supp. +Z,+X	4261					0.82/0.07 (-Z/+Z)		
LOU Radiat. supp. +Z,-X	4263					0.07		
LOU Radiat. supp. +Z	4265					0.07		
LOU Radiat. supp. -Z,+X	4267					0.82/0.07 (+Z/-Z)		
LOU Radiat. supp. -Z,-X	4269					0.07		
LOU Waveguides	4361-4366	13x WR28 + 1xWR34 St. Steel WG's to SVM	1.917	A=168 mm², l=1.47 m		0.1		RD 34
		GFRP WG support brackets on CVV		A/l = 3.6 mm GFRP				
Telescope	8000	Primary Reflector M1 (SiC)	210	∅3.5 m		0.01		
		Telescope Baffle		∅0.5 m		0.05		
		Gap to internal Cryostat Baffle		∅0.5 m x 8 mm		1.0		
	8100	M2 Mirror (SiC)	20			0.01		
	8200	Hexapod (SiC)	70			0.02		
	8400	CFRP T300 struts to CVV GFRP struts to Cryostat Cover		A/L = 12.63 mm CFRP T300 A/L = 1.94 mm GFRP			R-TMS-0330 [RD 27]	
Telesc. M1 MLI	8501-8518, 8550	"Two screen" concept		D = 3.5 m, d = 0.5 m		0.05		decontamin.
						0.02		nominal in-orbit

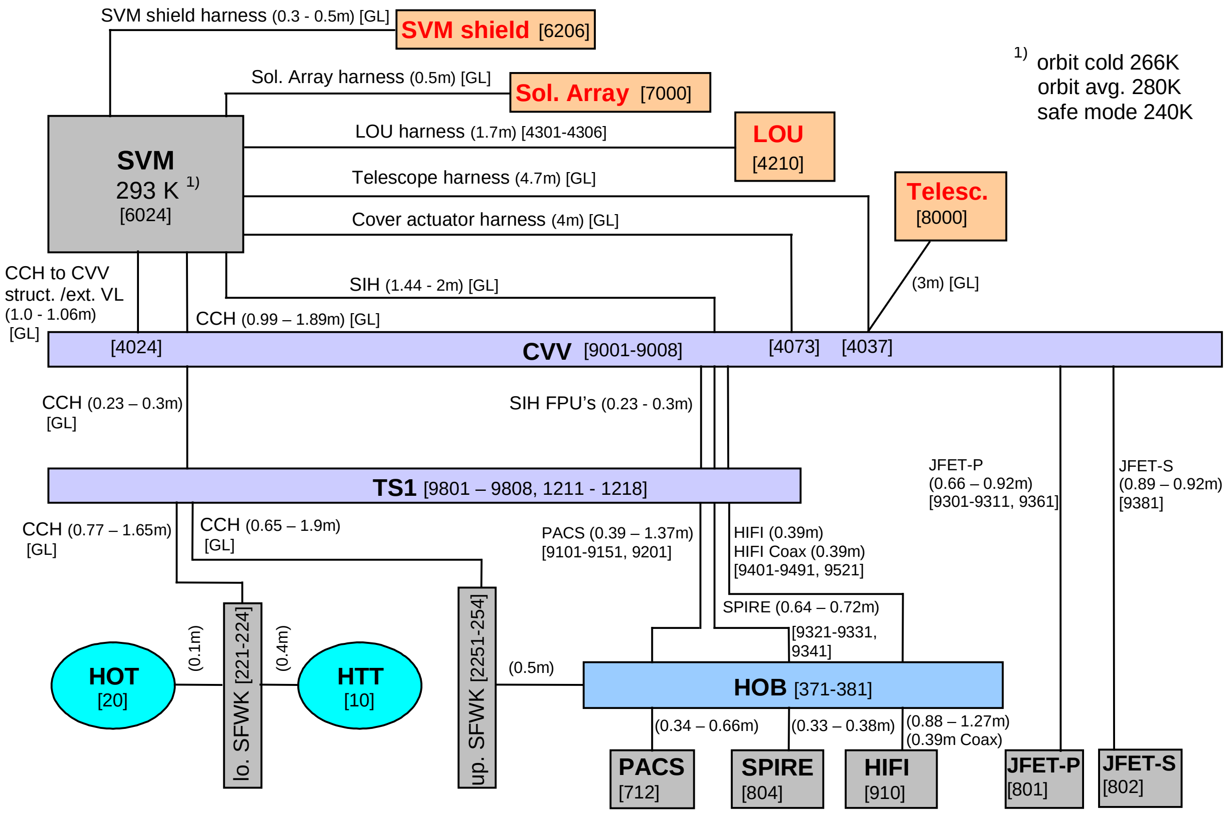
Table 5.6-1: Item List for LOU and Telescope

5.7 Harness

The harness implementation principle in the H-EPLM TMM is shown in Figure 5.7-1. Depending on the harness dissipation, the different harness branches are modelled either by dedicated nodes or via a thermal conductance coupling using thermal conductivity integral functions. For the latter ones, the harness dissipation is distributed to the corresponding interface at the cold end. An overview for the CVV internal harness modelling is given in Table 5.7-1.

Instrument	Branches with dedicated nodes	Branches with (integral) thermal conductance	Remark
PACS FPU	3	12	
SPIRE FPU	1	3	
HIFI FPU	5	4 (coax)	
SPIRE JFET Phot.	1	6	
SPIRE JFET Spec.	0	2	

Table 5.7-1: Modelling of the CVV Internal Harness Branches in the EPLM TMM



values in ( ) are thermal isolating lengths

Figure 5.7-1: Harness Chart used in TMM

The LOU waveguides and the LOU harness are located outside the CVV and are subdivided in 6 nodes in x-direction, each. The waveguides are also modelled in the GMM. All other external harness is implemented by means of conductive couplings between the corresponding I/F nodes and the dissipation is distributed to 100% to the corresponding cold end.

The cross-section and dissipation values of the scientific harness (SIH) and the cryostat control harness (CCH) have been evaluated based on the data listed in RD 02. The SIH data are summarized in Table 5.7-2 and Table 5.7-3; the CCH data are listed in Table 5.7-4 and Table 5.7-5.

The thermally isolating harness lengths are defined between the following I/F points, see Figure 5.7-1:

- at SVM: all harness assumed to have SVM temperature at SVM / CVV strut I/F
- at CVV: all harness assumed to have CVV temperature at the CVV / tank suspension strap I/F. Thermal connection via connector brackets, additional thermal connections at CVV internal wall (if necessary)
- at TS1: thermal connection of SIH (except SPIRE JFET harness) and CCH by means of "Stycast brackets", similar as done on ISO
- at OBA: thermal connection of PACS FPU, SPIRE FPU and HIFI FPU harness by means of "Stycast brackets”.

Thermal isolation length means the "free" length between the end of the harness thermal connection section at the CVV and the begin of the thermal connection section at the TS 1. The harness routing length between CVV connector brackets and the tank suspension straps is not taken as thermal isolating length, which is a conservative assumption. Harness conduction across the fixation ties on the tank suspension straps is considered to be negligible and therefore not taken into account in the TMM.

The SPIRE JFET harness is directly routed from the CVV to the JFET units.

The thermal contact conductance across a "Stycast bracket" is estimated to 0.05 W/K per branch.

Internal Harness (SIH)	Node	from	to	Length *	Average Dissip at 77K	Spec Mode Dissip at 77K	Phot Mode Dissip at 77K	Stainl. St.	Brass	SiO_2	PTFE
				m	mW/m	mW/m	mW/m	mm^2	mm^2	mm^2	mm^2
PACS FPU	9101- 9151, 9201	CVV TS1 OB	TS1 OB FPU	0.228-0.3 0.391-1.366 0.340-0.655	4.32	19.9	6.03	37.594	5.1	-	367
SPIRE FPU	9321- 9331, 9341	CVV TS1 OB	TS1 OB FPU	0.3 0.636-0.723 0.327-0.378	1.186	7.116	1.217	11.068	6.216	-	103
SPIRE JFET-P	9301- 9311, 9361	CVV	JFET-P	0.658-0.917	0.034	0	0.202	40.792	0.914	-	318
SPIRE JFET-S	9381	CVV	JFET-S	0.888-0.919	0.007	0.043	0	13.306	0.594	-	92
HIFI FPU (incl. coax)	9401- 9491, 9521	CVV TS1 OB	TS1 OB FPU	0.236-0.3 0.383-0.394 0.385-1.272	4.55	HIFI on: 13.66		30.805	6.014	21.024	123

*) thermally isolating length

Table 5.7-2: CVV Internal Harness Data for PACS, SPIRE and HIFI

External Harness (SIH)	from	to	Length *	Average Dissip **	Spec Mode Dissip **	Phot Mode Dissip **	Stainl. St.	Brass	Cu	SiO_2	Manganin	PTFE
			m	mW/m	mW/m	mW/m	mm^2	mm^2	mm^2	mm^2	mm^2	mm^2
PACS FPU	SVM	CVV	1.5 - 2.0	2.9	8.21	9.17	37.536	5.132	-	-	17.517	367
SPIRE FPU	SVM	CVV	1.44-2.0	1.96	11.8	2.43	9.646	6.019	-	-	12.1	107
SPIRE JFET-P	SVM	CVV	1.44-2.0	0.0567	0	0.34	28.864	2.942	-	-	26.21	270
SPIRE JFET-S	SVM	CVV	1.44-2.0	0.0475	0.285	0	8.416	1.028	-	-	6.048	83
HIFI FPU	SVM	CVV	1.67-2.0	7.0	HIFI on: 21		30.73	6.014	-	21.02	8.64	121
HIFI LOU (RD 33)	SVM	LOU	1.7	29	LOU on: 86		7.72	0.914	75.12	-	24.31	107

*) thermally isolating length

**) with the exception of LOU harness all dissipation values are valid for 293 K, dissipation at lower temperature expected to be lower

Table 5.7-3: CVV External SIH Data

Internal Harness (CCH)	from	to	Length *	Dissip	Stainl. St.	Brass	PTFE
			m	mW/m	mm^2	mm^2	mm^2
CCH to HOT & HTT	CVV low CB	TS1	0.24-0.3	0	2.23	3.05	34.2
	TS1	low SFW	0.77-1.65		2.23	3.05	34.2
	low SFW	HOT	0.1		0.552	0.912	9.1
	low SFW	HTT	0.4	0	1.48	2.124	23.4
CCH to OB	CVV upp CB	TS1	0.23-0.3	0	1.98	-	18
	TS1	up. SFW	0.65-1.9		1.62		14.7
	upp SFW	OB	0.5		1.62		14.7

*) thermally isolating length

Table 5.7-4: CVV Internal CCH Data

External Harness (CCH and Telescope)	from	to	Length *	Dissip.	Stainl. St.	Brass	Cu	Manganin	PTFE
			m	mW/m	mm^2	mm^2	mm^2	mm^2	mm^2
CCH to CVV lower CB	SVM	CVV low. CB	0.99-1.68	0	2.384	3.0	-	5.3	35.6
CCH to CVV upper CB	SVM	CVV upp. CB	1.46-1.89	0	2.352	-	-	1.992	21.3
CCH to CVV structure/VL	SVM	CVV	1.0-1.06	0	1.12	1.224	2.4	7.02	16.17
CCH to Cover	SVM	CVV /Cover	4		0.128	2.856	-	1.968	8.76
Telescope heater via CVV	SVM	CVV	4.7	0	0.384	-	8.0	3.24	11.17
	CVV	Telescope	3						
CCH to SVM Thermal Shield	SVM	SVM Shield	0.3 - 0.5	0	0.128	-	0.6	0.648	1.18

*) thermally isolating length

Table 5.7-5: CVV External CCH Data

5.8 HERSCHEL Solar Array and Sunshade with Struts

The HERSCHEL Solar Array and Sunshade (HSS) is split in two parts, the upper part is the Sunshade (SSD), providing the shade mainly for the telescope and the lower part is the Solar Array (SA), which provides shading for the CVV and the electrical power. The SA +Z side therefore is covered with solar cells and the SSD +Z side is covered with OSRs. The rear side (-Z side) of the HSS is covered with high efficient MLI. The HSS nodal break-down is shown Figure 5.8-1 and the corresponding thermally relevant data are listed in Table 5.8-1.

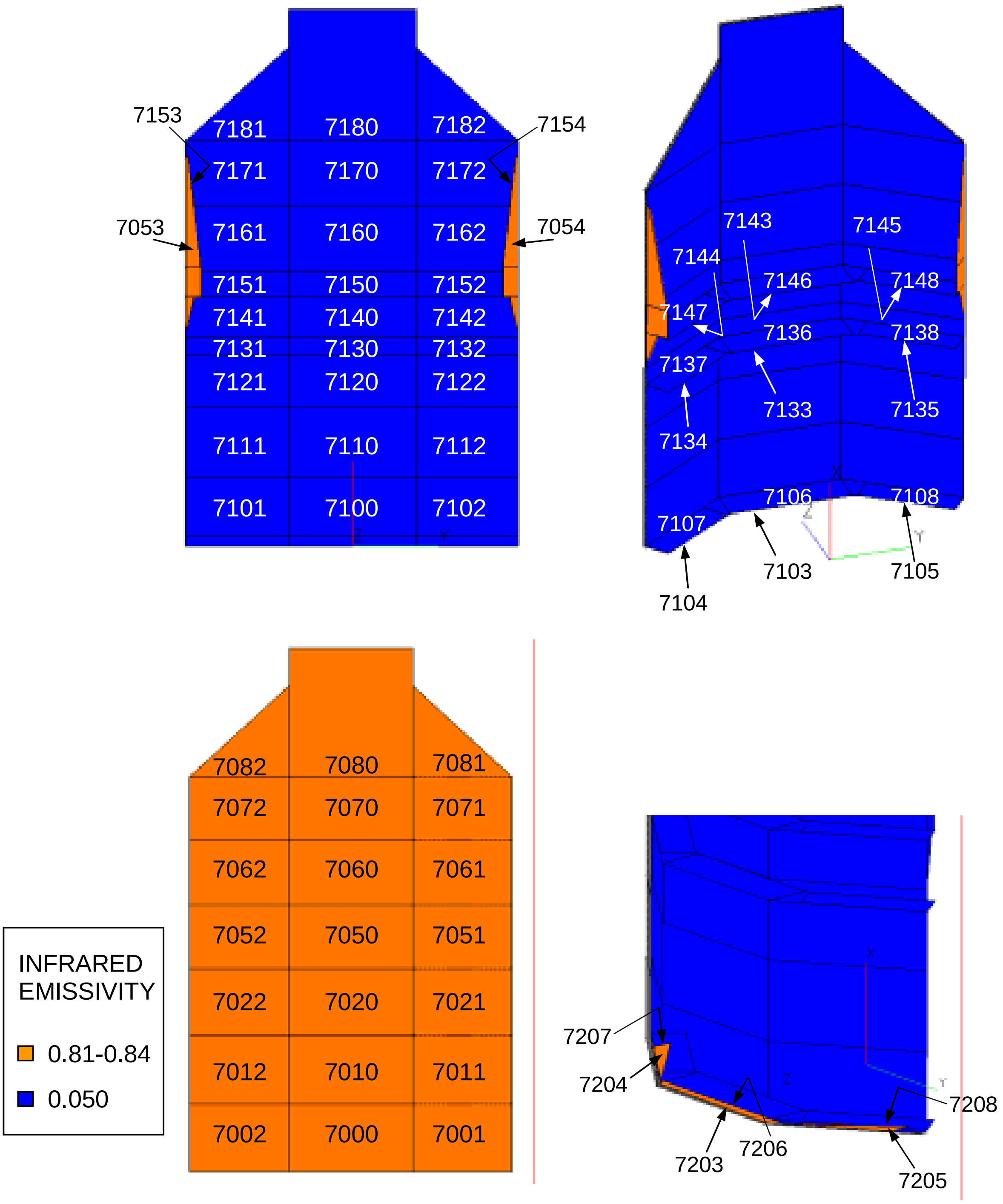


Figure 5.8-1: HSS Nodal Break-Down (upper: MLI nodes, lower: structural nodes)

Item	**Node**	**Material / Components**	**Mass**	**Size**	**Unit Level Requirement**	**Solar Absorpt.**	**IR Emiss.**	**Remark**
Solar Array Panels	7000-7022	Solar Cells with cover glass and harness	1.6 kg/m²			α=0.915 [RD 18]	0.81 [RD 18]	
		CFRP skins (M55J) *	0.83 kg/m²	2 x 0.3 mm thick				
		Adhesive for HC	0.3 kg/m²			-1200 W during Operation		
		Al Honeycomb (16 kg/m³)	0.8 kg/m²	50 mm thick				
		GFRP struts to CVV		A/L = 2.515 mm GFRP in total	R-SS-0330 [RD 25]			[RD 37],
		M55J CFRP struts with Ti end fittings (Ti6AlV4) to SVM		A/L = 1.293 mm M55J with A/L =12.9 mm Ti in serial				[RD 38]
		Ti tubes to SVM		0.04 W/K				
		Power harness to SVM		34.5 mm² Copper, 0.5 m length				[RD 37]
Solar Array Panels MLI	7100-7132	22 layers (4x5+2)	0.65 kg/m^2		R-EXM-430 [RD 28]	α=0.13	0.05	
Solar Array Stiffening Frame MLI upper	7133-7138	22 layers (4x5+2)	0.65 kg/m^2		R-EXM-430 [RD 28]	α=0.13	0.05	
Solar Array Stiffening Frame MLI lower	7103-7108	22 layers (4x5+2)	0.65 kg/m^2		R-EXM-430 [RD 28]	α=0.13	0.05	
Solar Array-SVM Closure MLI	7203-7208	22 layers (4x5+2)	0.65 kg/m^2		R-EXM-430 [RD 28]	α=0.13 α=0.8	0.05 0.8	+x side -x side
Sunshade Panels	7050-7082	OSR inclusive Adhesive	1.0 kg/m^2			α=0.20	0.84	EOL
		CFRP skins (M55J) *	0.83 kg/m²	2 x 0.2 mm thick		α=0.10	0.84	BOL
		Al Honeycomb (16 kg/m³)	0.8 kg/m²	50 mm thick				
		GFRP blades to Solar Array		A/L = (10)x16 x 7.86 mm				
		GFRP struts to CVV		A/L = 2.394 mm GFRP in total	R-SS-0330 [RD 25]			
Sunshade +Y Stiffen. Rib	7054					α=0.92	0.8	
Sunshade -Y Stiffen. Rib	7053					α=0.92	0.8	
Sunshade Panels MLI	7140-7142, 7150-7182	20 layers (3x6+1)	0.65 kg/m^2		R-EXM-330 [RD 28]	α=0.13	0.05	
Sunshade +Y Rib MLI	7154	20 layers (3x6+1)	0.65 kg/m^2		R-EXM-330 [RD 28]	α=0.13	0.05	
Sunshade -Y Rib MLI	7153	20 layers (3x6+1)	0.65 kg/m^2		R-EXM-330 [RD 28]	α=0.13	0.05	
Sunshade Stiff Frame MLI	7143-7148	20 layers (3x6+1)	0.65 kg/m^2			α=0.13	0.05	

Table 5.8-1: HSS related Items

5.9 SVM with Struts and SVM Thermal Shield

To calculate the radiative couplings of the HERSCHEL CVV/SVM GFRP struts to their environment all 24 struts have been modelled in the ESARAD geometry model with an IR emissivity of 0.03 (e.g. one or a few layer MLI). Each strut has been subdivided into three nodes. The struts and the obtained radiative couplings have been implemented in the H-EPLM ESATAN TMM. The relevant length for the thermal analysis is the total GFRP strut length minus the length of the sections where GFRP tube and the titanium end fitting overlap. The thermally relevant dimensions of the struts are summarized in Table 5.9-1.

The SVM Shield is subdivided into 3 nodes and the MLI on top of the SVM Shield is subdivided accordingly, see Figure 5.9-1. The struts supporting the SVM Thermal Shield are implemented by conductive couplings between SVM and SVM Thermal Shield.

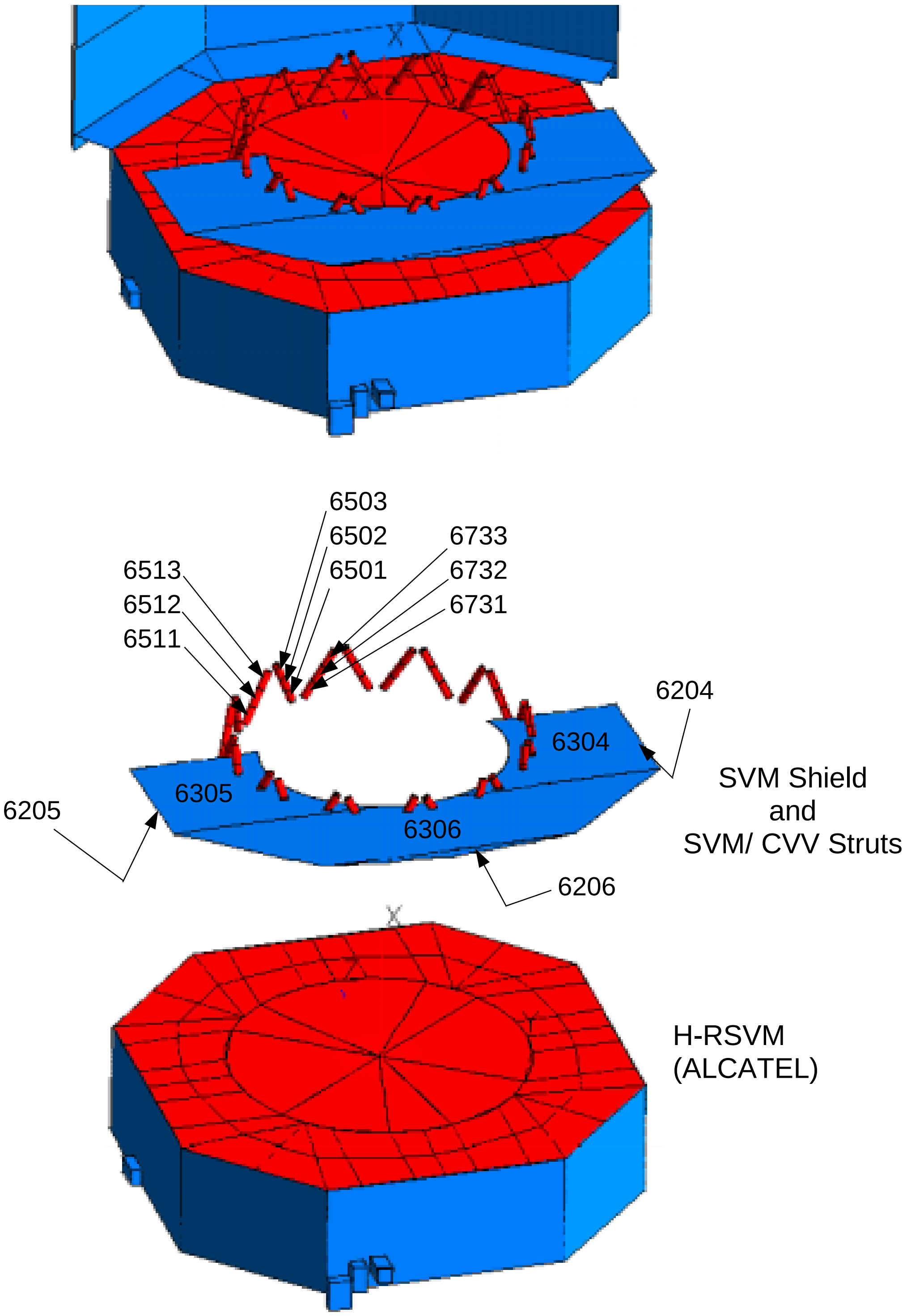


Figure 5.9-1: H-RSVM, SVM Thermal Shield and SVM/CVV Struts

Item	**Node**	**Material / Components**	**Mass**	**Size**	**Unit Level Requirement**	**Solar Absor.**	**IR Emiss.**	**Remark**
SVM Module	60XX,61XX 6020-6024 6101-6106	H-RSVM model, Alcatel responsibility Boundary Nodes (conductive) SVM top MLI				α=0.15	0.05	AD 07/08
SVM/CVV struts	6501-6733	GFRP strut tubes Ti fittings for GFRP tubes		A/L = 14.04 mm GFRP (24x D=35x2.1 mm, l=371mm)	R-SS-0330 [RD 25]			[RD 37], [RD 38
SVM Thermal Shield	6204-6206	CFRP T300 face sheets, VDA Kapton Foil on -X side (90% specularity) Al Honeycomb (32 kg/m^3)		2 x 0.5 mm thick 19 mm thick	R-STS-0180 [RD 26] R-STS-0190 [RD 26]	α=0.3	0.05	
		GFRP strut tubes to SVM structure Ti fittings for GFRP tubes		A/L = 2.636 mm GFRP	R-STS-0230 [RD 26]		0.05	[RD 37], [RD 38
SVM Thermal Shield MLI	6304, 6305 6306	20 layers (3x6+1)		0.99 m^2 (+Y/-Z) 0.99 m^2 (-Y/-Z) 2.04 m^2 (-Z)	R-EXM-630 [RD 28]	α=0.13	0.05	

Table 5.9-1: SVM and SVM Shield related Items

6 Material Properties

Note: All material properties tested on Herschel samples and components are compiled in [RD 35]. All other references used for material properties are listed in Section 6.6 of this chapter (i.e. not in Section 2).

6.1 MLI Thermo-Optical Properties and Performance Data

Internal MLI

The heat flux approximations and the thermal performance parameters derived in [RD 36] are compiled in Table 6.1-1 for the "Herschel-type" MLI. This MLI is used for the Thermal Shields MLI. The corresponding values for the "ISO-type" MLI are taken from /1/ and are summarized in Table 6.1-2. The ISO MLI data are used for the HTT and HOT MLI.

The heat fluxes are calculated for different boundary temperatures T_H and T_C. Herewith T_H corresponds to the temperature of the outermost MLI blanket layer while T_C corresponds to the thermal shield temperature the MLI blanket is attached to.

	$q = (a (T_H + T_C)/2 + b) (T_H – T_C) + \varepsilon \sigma ((T_H^4 – T_C^4)$		
	a	b	ε
10-layer MLI	8.720E-06	2.353E-05	0.00395
20-layer MLI	4.360E-06	1.177E-05	0.001975

Table 6.1-1: Derived MLI Performance Data for Herschel Type MLI

	$q = h (T_H – T_C) + \varepsilon \sigma ((T_H^4 – T_C^4)$	
	h (W/m²K)	ε
10-layer "ISO-type" MLI	3.50E-04	0.0030

T_H = "hot" temperature of outermost blanket layer
T_C = "cold" temperature of innermost blanket layer = identical to thermal shield temperature

Table 6.1-2: Derived MLI Performance Data for ISO Type MLI /1/

Degradation factors of integrated MLI have been evaluated in detail for the different MLI sections. The derivation of those factors is also described in [RD 36]. It should be noted that worst-case assumptions have been used for the individual contributions to the total degradation factor, leading to a strictly conservative MLI performance presentation in the TMM. An overview of all CVV internal MLI performance data used in the TMM is compiled in Table 6.1-3.

MLI on	Layers	radiative emissivity (ε_{rad})	linear conductance H [W/m^{2}K]	Integration Factor		emissivity of ext. layer (ε_{ext})	specul. of ext. layer (ρ_{ext})
				Orbit	Ground		
HTT	10	0.003	3.5 E-4	2	2	0.05	0
HOT	10	0.003	3.5 E-4	1	1	0.05	0
TS 1 upper bulk	10	0.00395	H(T) *	1.86	2.57	0.05	0
TS 1 upper cylinder	10	0.00395	H(T) *	2.60	4.05	0.05	0
TS 1 lower cylinder	10	0.00395	H(T) *	1.50	1.99	0.05	0
TS 1 lower bulk	10	0.00395	H(T) *	2.43	2.75	0.05	0
TS 2 upper bulk	20	0.001975	H(T) *	1.66	1.66	0.05	0
TS 2 upper cylinder	20	0.001975	H(T) *	2.05	2.03	0.05	0
TS 2 lower cylinder	20	0.001975	H(T) *	1.42	1.43	0.05	0
TS 2 lower bulk	20	0.001975	H(T) *	1.83	1.80	0.05	0
TS 3 upper bulk	20	0.001975	H(T) *	1.64	1.63	0.05	0
TS 3 upper cylinder	20	0.001975	H(T) *	2.09	2.05	0.05	0
TS 3 lower cylinder	20	0.001975	H(T) *	1.55	1.53	0.05	0
TS 2 lower bulk	20	0.001975	H(T) *	1.60	1.58	0.05	0

*) see Table 6.1-1

Table 6.1-3: Overview on CVV Internal MLI Performance Data

External MLI

To calculate the MLI performance at higher temperature the approach proposed by Doenecke /12/ is used. This approach is valid for a temperature range between 130 K and 410 K and features a calculation procedure for an effective MLI emissivity ε_{eff}. No linear component is foreseen in this approach. This calculation procedure has been taken for the HSS MLI and the SVM Thermal Shield MLI.

MLI on	Layers	radiative and effective emissivity (ε_{rad} and ε_{eff})	linear conductance H [W/m^{2}K]	emissivity of ext. layer (ε_{ext})	specul. of ext. layer (ρ_{ext})	Remark
CVV	25	ε_{rad} = 0.0022	1.093 E-3	0.05	0.8	Ref. /1,11/
Cryostat Baffle	25	ε_{rad} = 0.0022	1.093 E-3	0.05	0.8	Ref. /1,11/
LOU	20	ε_{eff} = 0.02	0	0.05	0.8	
	20	ε_{eff} = 0.02	0	0.15	0.7	Baseplate
Sunshade	20	ε_{eff} = 0.015	0	0.05	0.8	Ref. /12/
Solar Array	22	ε_{eff} = 0.012	0	0.05	0.8	Ref. /12/
SVM Shield +X	20	ε_{eff} = 0.015	0	0.05	0.8	
SVM Shield -X	1	n.a.	n.a.	0.05	0.9	Ref. /10/
SVM Struts	1	n.a.	n.a.	0.03	0	
SVM Top	n.a.	n.a.	n.a.	0.05	0	AD 07 & 08
Telescope, Orbit	n.a.	ε_{eff} = 0.01	n.a.	0.02	0	RD 29
Decontamination	n.a.	ε_{eff} = 0.025	n.a.	0.05	0	

Table 6.1-4: Overview on CVV External MLI Performance Data

6.2 Thermal Conductivity Data

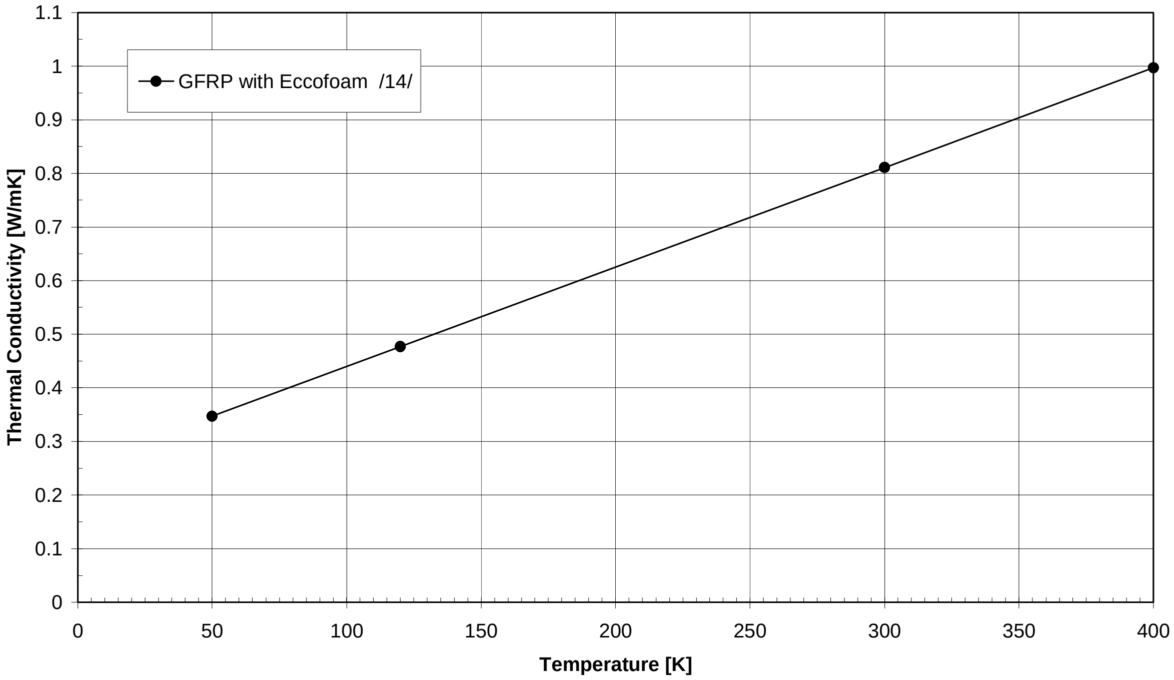


Figure 6.2-1: Thermal Conductivity of S-Glass GFRP Struts

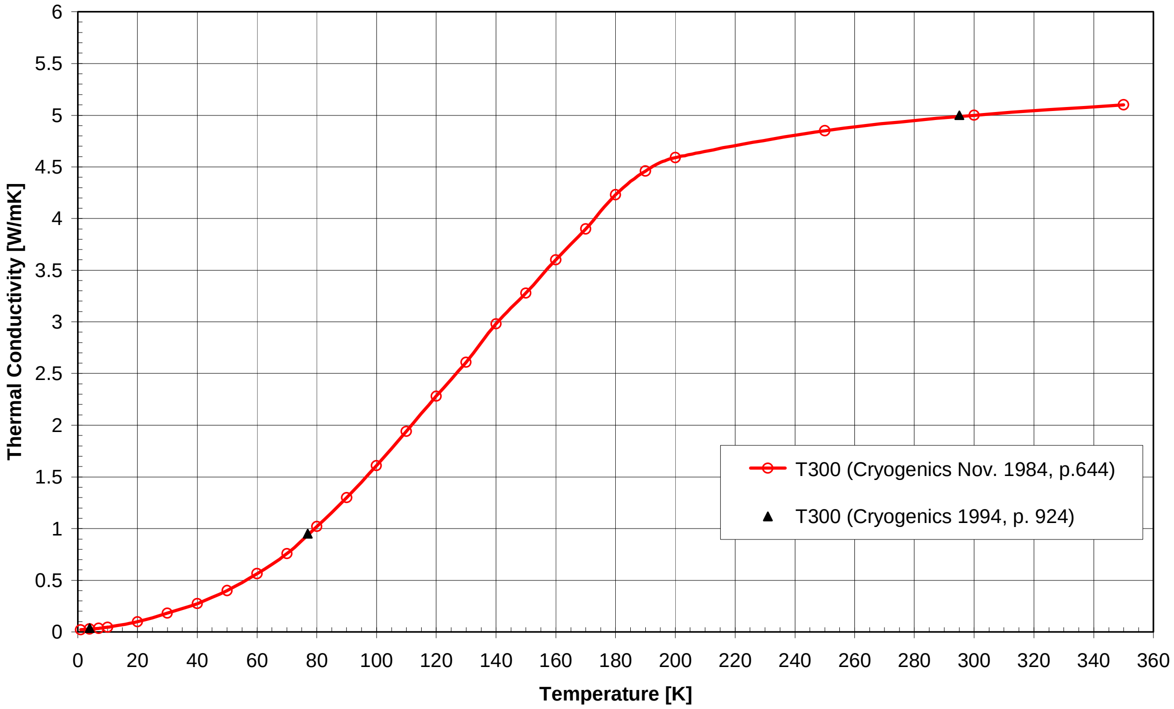


Figure 6.2-2: Thermal Conductivity of CFRP T300 Struts

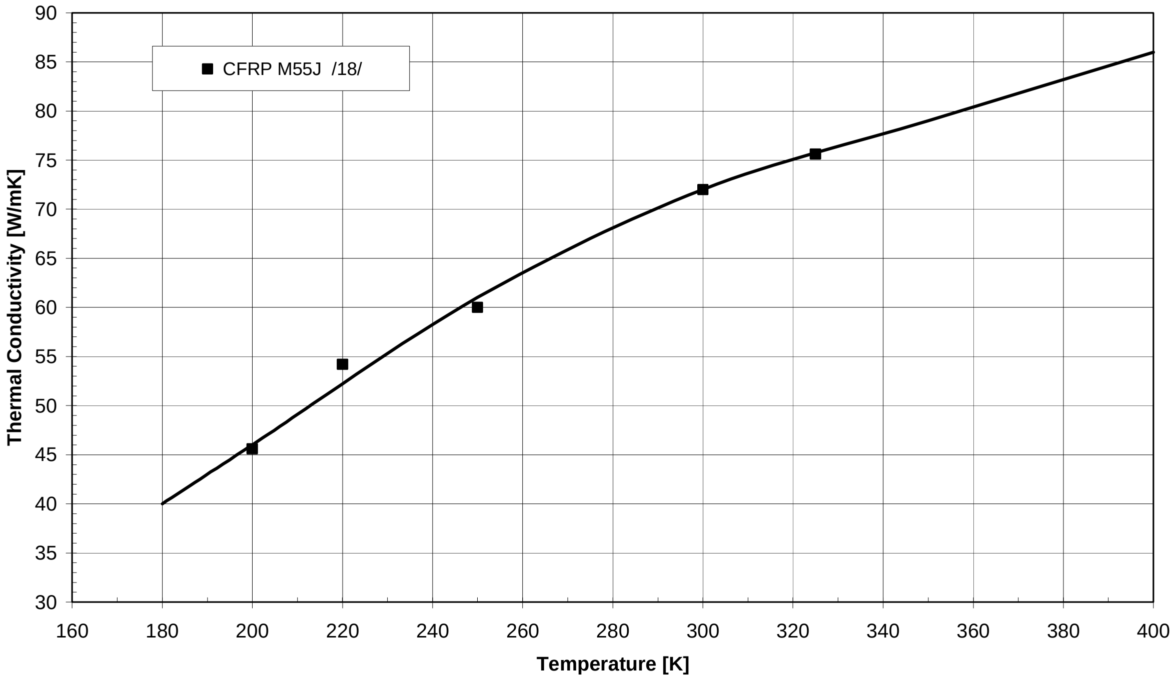


Figure 6.2-3: Thermal Conductivity of CFRP M55J Struts

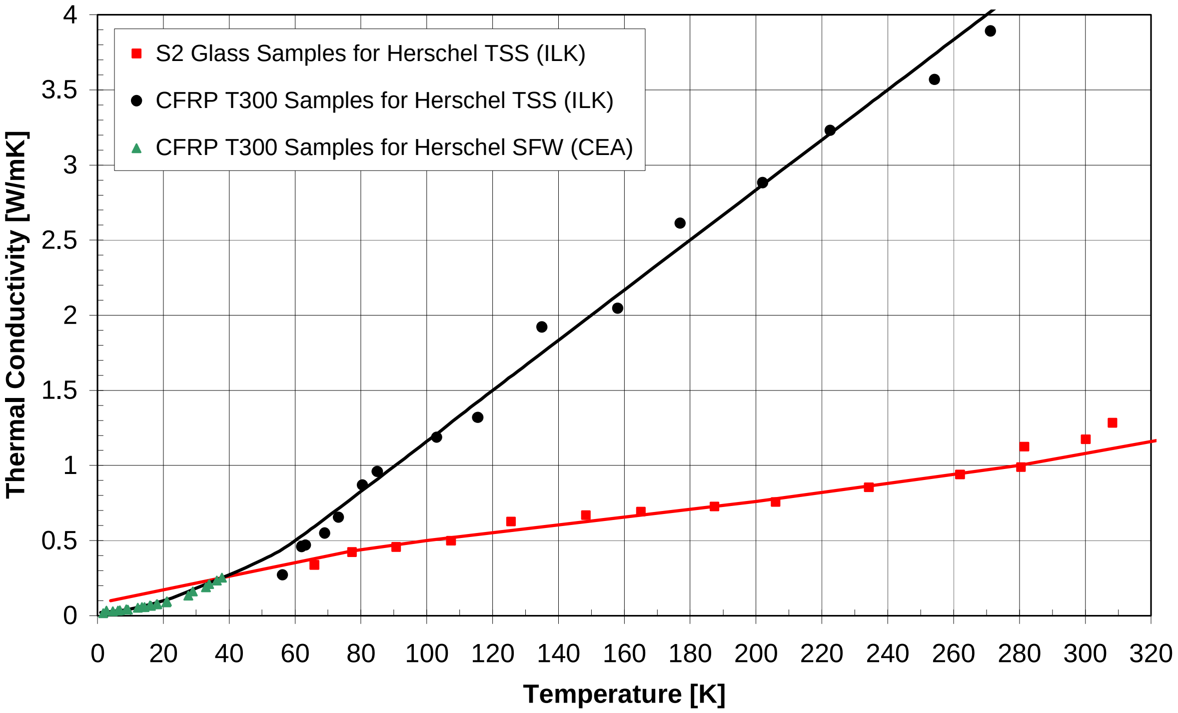


Figure 6.2-4: Thermal Conductivity of CFRP T300 and GFRP (S-glass) Tank Suspensions [RD 35]

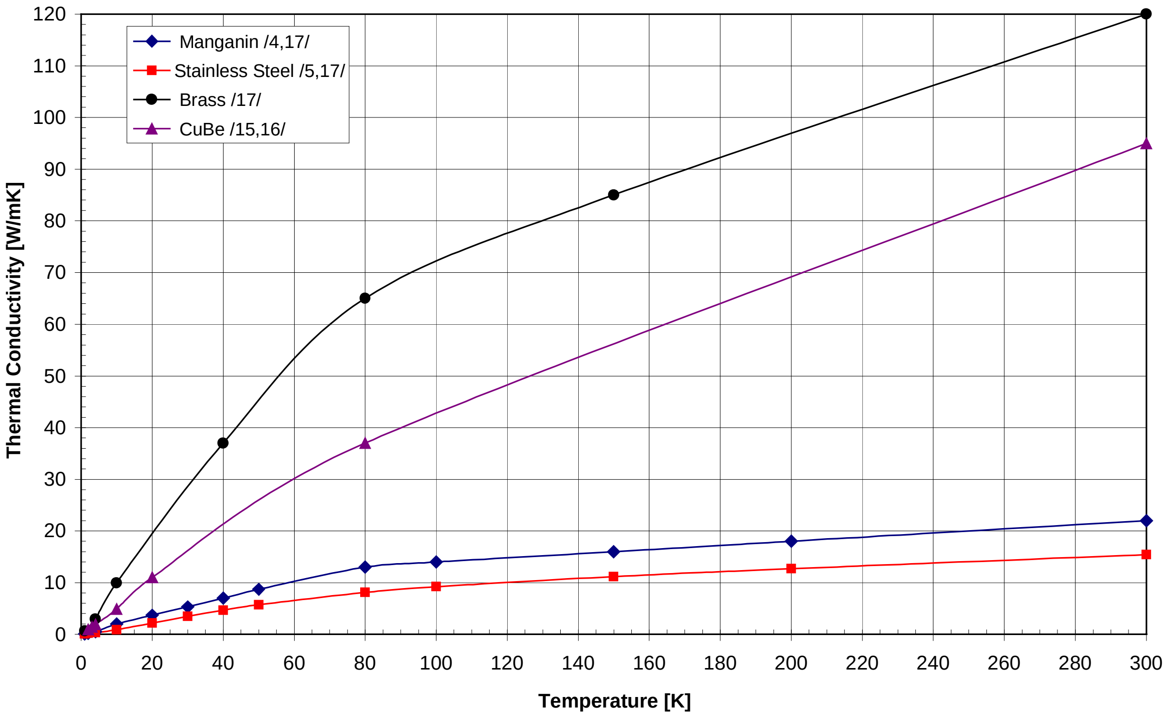


Figure 6.2-5: Thermal Conductivity of Harness Wires

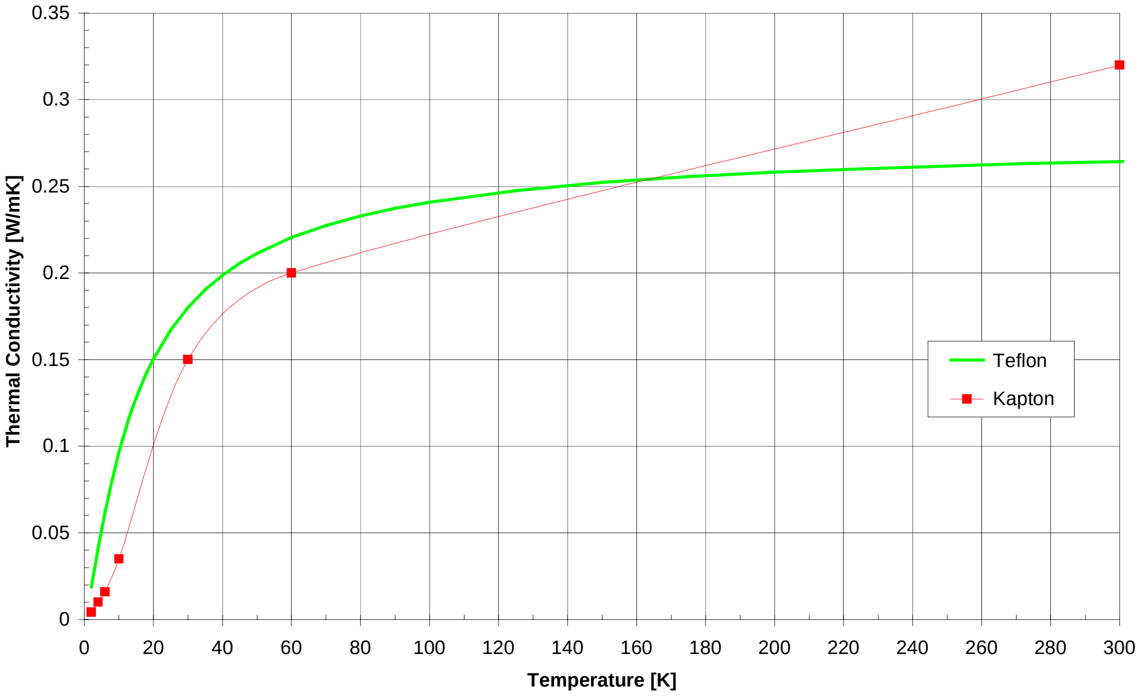


Figure 6.2-6: Thermal Conductivity of Harness Wire Insulation Materials /14/

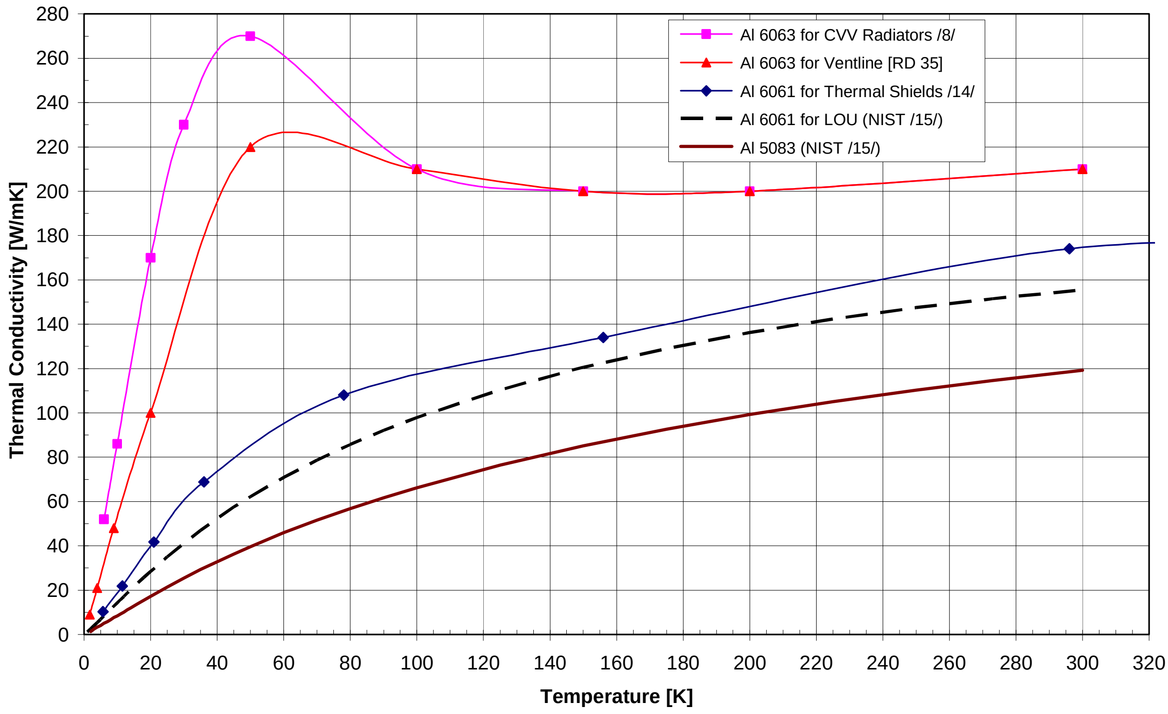


Figure 6.2-7: Thermal Conductivity of Aluminium Alloys

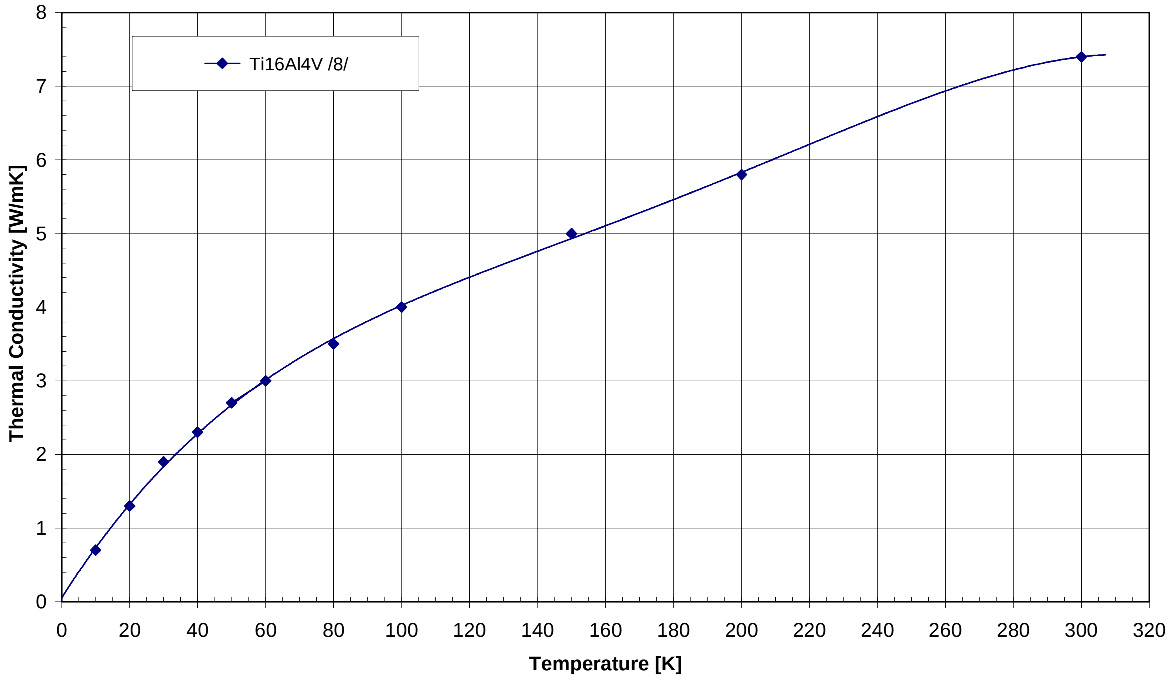


Figure 6.2-8: Thermal Conductivity of Titanium Alloy Ti6Al4V

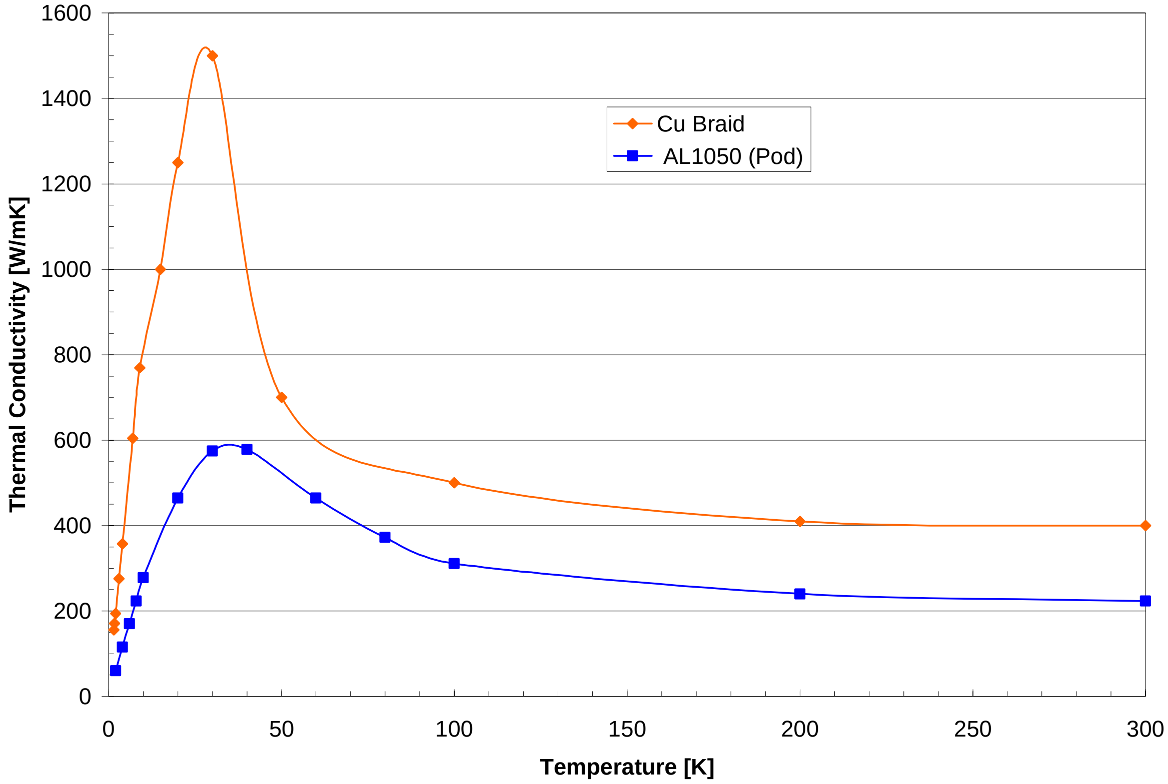


Figure 6.2-9: Thermal Conductivity of Thermal Link Materials [RD 35]

6.3 Thermal Contact Conductance Data

The thermal contact conductance data given in Figure 6.3-1 are related to 1 kN. For calculating the total contact conductance of an interface the following contact forces are applied:

- 2000 N for each M4 bolt with Invar washer
- 3000 N for each M5 bolt with Invar washer
- 10000 N for each M8 bolt with Invar washer

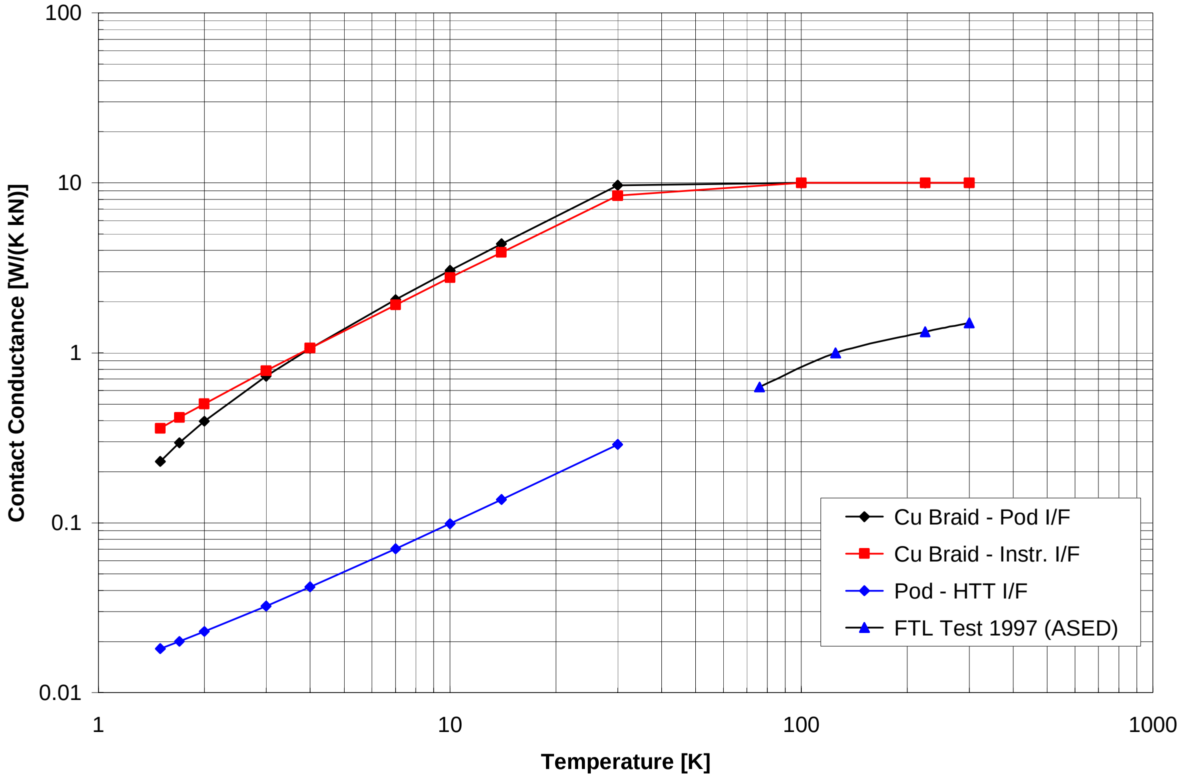


Figure 6.3-1: Thermal Contact Conductance of Thermal Link Interfaces [RD 35]

6.4 Specific Heat Capacity Data

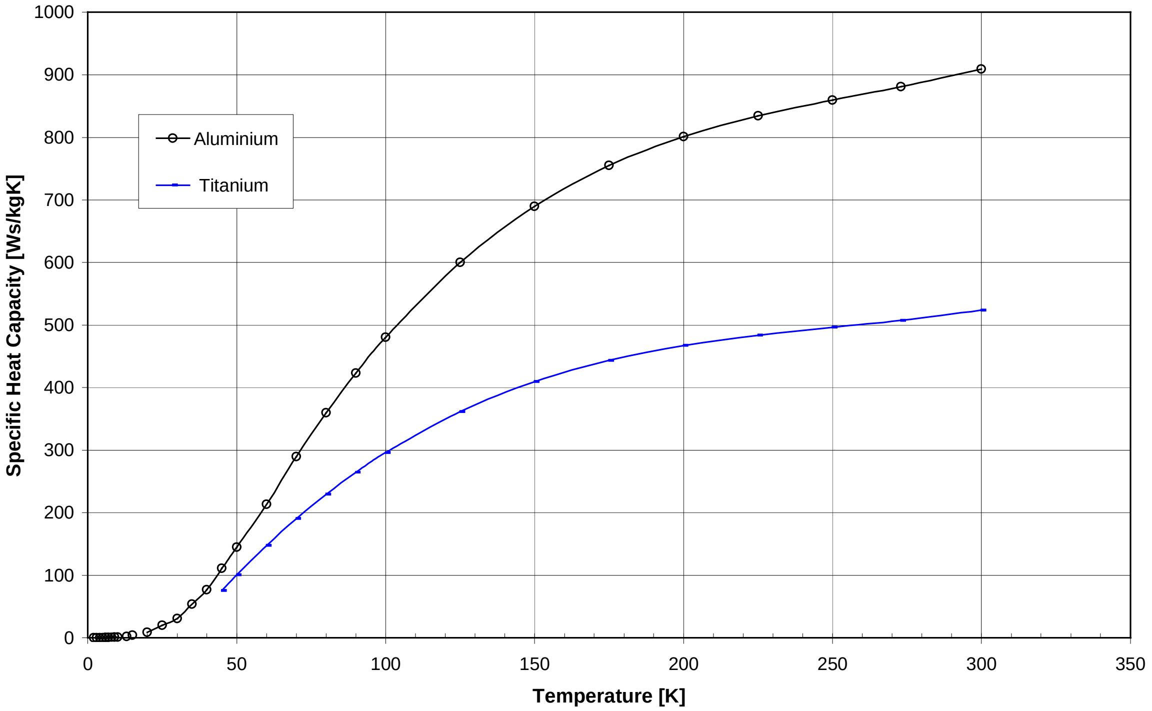


Figure 6.4-1: Specific Heat Capacity of Aluminium and Titanium /14/

6.5 Helium Properties

For the heat of vapourization of Helium different values are found in literature, see Figure 6.5-1. For the TMM calculations the data reported in Ref. /2/ are used.

The specific heat of the gas is 5.1966 kJ/kg/K (almost constant versus temperature).

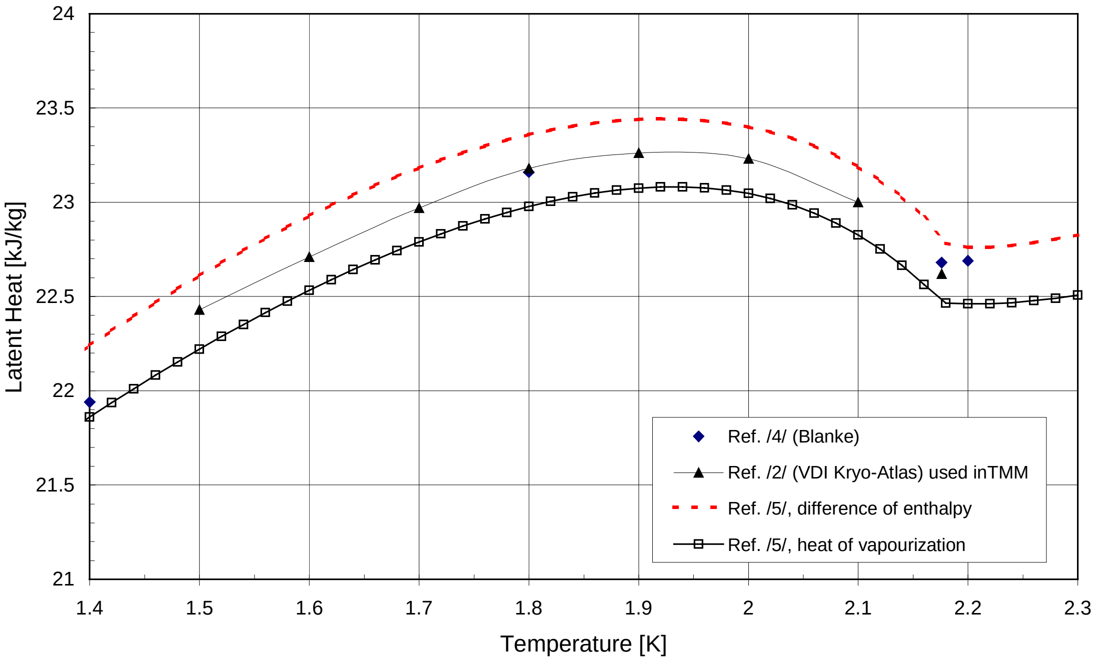


Figure 6.5-1: Heat of Vapourization of Helium 4

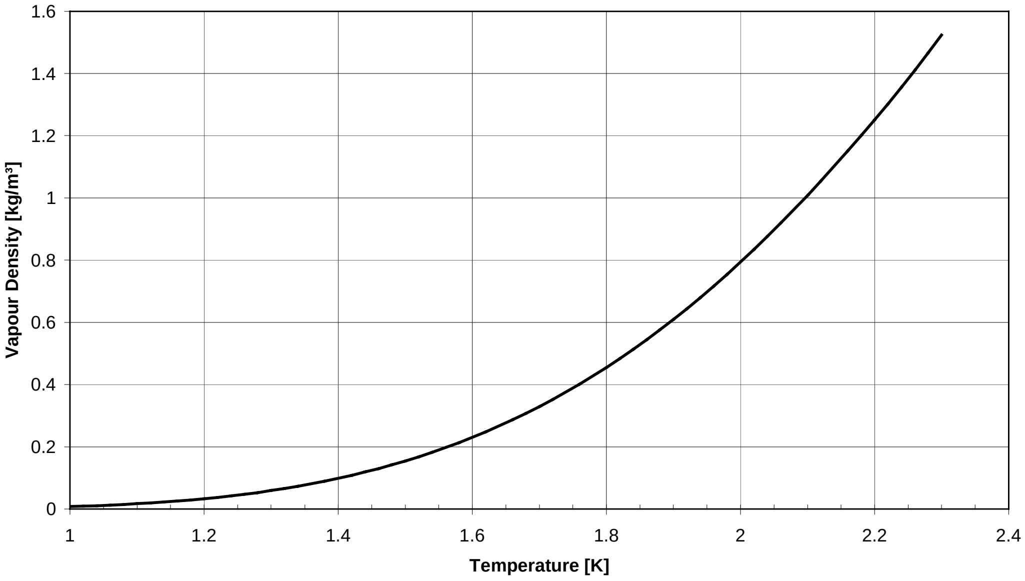


Figure 6.5-2: Vapour Density of Helium (Ref. /5/)

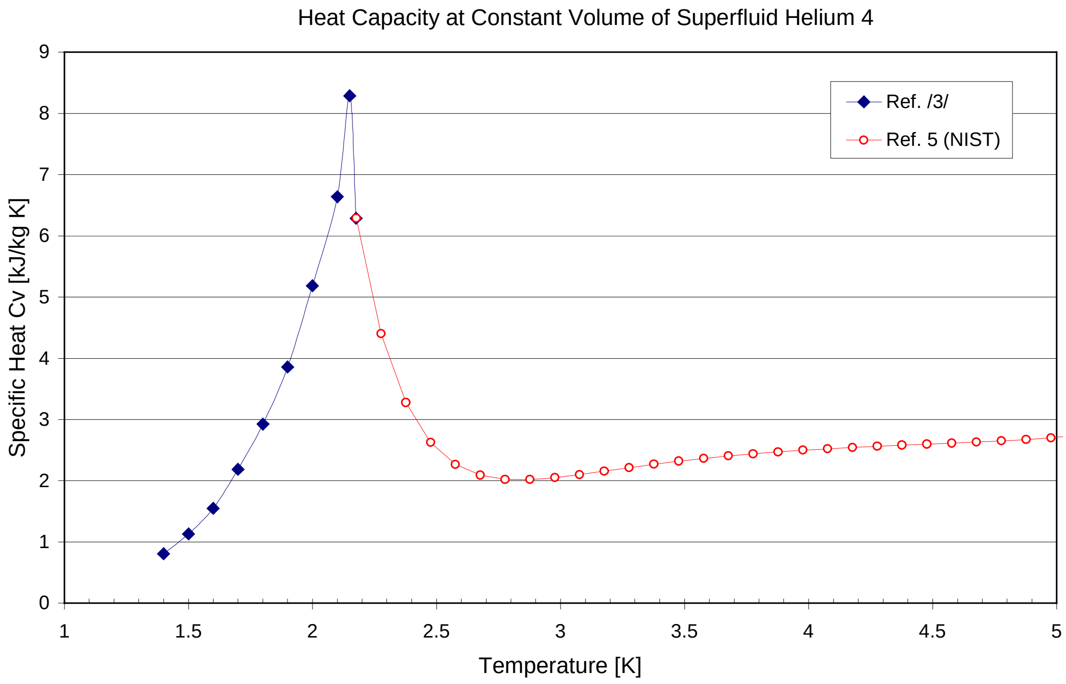


Figure 6.5-3: Volume Specific Heat Capacity of Liquid He on Saturation Line

6.6 References for Material Properties

/1/ Evaluation of LINDE/ESTEC-MLI Measurements and Transformation to the ISO Cryostat MLI Design, Doc.No.: ISO.TN-B1430.007, dated 12.07.88

/2/ VDI Kryoatlas BW 2407

/3/ Thermophysical Properties of Helium from 2 to 1500K with pressures to 1000 Atm (National Bureau of Standards TN 631)

/4/ W. Blanke: Thermophysikalische Stoffdaten, Springer 1989

/5/ NIST Standard Reference Database 12: NIST Thermophysical Properties of Pure Fluids, Version 3.0.

/6/ ASPI fax AS-FAX SE/SP/IS 2244/89, dated 30.01.89

/7/ Hartwig & Knaak, Cryogenics, Nov. 84, p.645

/8/ Touloukian: Thermophysical Properties of Matter, 1972

/9/ MLI Test Report – Linde, Doc.No.: ISO-TR-C130.001, dated 19.02.88

/10/ METOP Mechanical and Thermal Design Requirement Specification, Doc.No.; MO.RS.MMT.SY.0004, Issue 3, June 2000

/11/ Comparative Performance Measurements on MLI Test Samples with different Types of Foils and Studs, Test Report: YCV/BA/136, dated 07.03.88

/12/ Doenecke: Survey and Evaluation of Multilayer Insulation Heat Transfer Measurement, ICES July 1993

/13/ Reed and Golda: Cryogenic composite supports, Cryogenics 1997, p.233

/14/ ISO Thermal Mathematical Model, Version 7.12

/15/ NIST Data Base, http://cryogenics.nist.gov/NewFiles/material_properties.html

/16/ Data delivered by Th. Passvogel, ESA-FAX-PT-01750, dated 23.02.1996

/17/ Guy K. White: Experimental Techniques in Low Temperature Physics, Handbook on Materials for Superconductivity Machinery, 3rd Edition

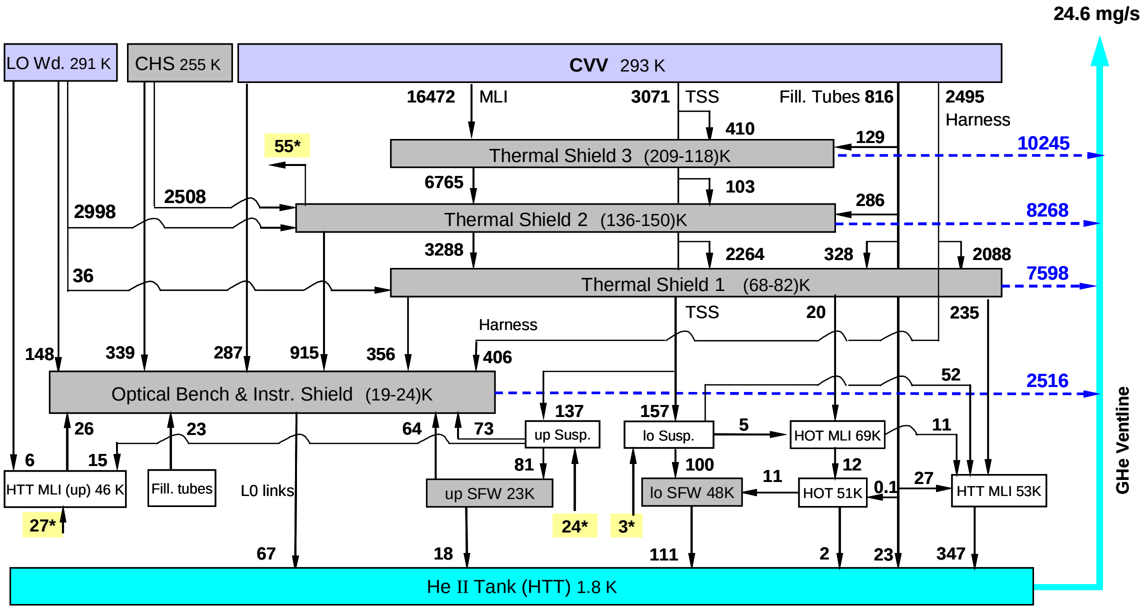
/18/ Thermomechanical Analysis, HP-2-ECAS-AN-0004, Issue 2, dated 28.11.03

7 Thermal Analysis Results

7.1 Operation On Ground

7.1.1 On-Ground Lifetime

A heat flow chart based on ground case analysis and showing the CVV internal main paths is shown in Fig. 7.1-1. The calculated temperatures of the different components as well as the GHe mass flow rate are included.



Only main paths are shown. All values are in [mW]

*) Heat flow from LOU Baffle (mounted on TS2)

Figure 7.1-1: CVV Heat Flow Chart for On-Ground Environment

In Table 7.1-1 the main results of a sensitivity analysis performed for ground case conditions are summarised. The uncertainties for the different items are assumed to be between ±20% for mechanical support structures and ±50% for MLI conductance. In Figure 7.1-2 the heat flow to HTT sensitivity is visualised.

Item			T, TS1 [K] [1021]		T, TS2 [K] [2021]		T, TS3 [K] [3021]		T, HOB [K] [375]		M $_{He}$ [mg/s]		Heat to HTT [mW]	
			+	-	+	-	+	-	+	-	+	-	+	-
Reference			**75.5**		**144**		**218**		**21.59**		**24.615**		**571**	
HTT MLI conductance	k1	±50%	-3.01	8.40	-2.32	6.22	-1.41	3.72	-1.27	4.17	0.379	-1.000	9	-23
Thermal Shield MLI conduct.	k2	±50%	1.87	-5.46	3.33	-10.15	3.23	-13.81	0.24	-0.50	1.387	-3.794	32	-88
TS 1 MLI cond.	k2a	±50%	0.51	-2.07	-1.30	5.11	-0.77	2.97	-0.16	0.71	0.191	-0.735	4	-17
TS 2 MLI cond.	k2b	±50%	0.54	-1.91	2.01	-7.24	-1.65	5.77	0.18	-0.61	0.473	-1.619	11	-38
TS 3 MLI cond.	k2c	±50%	0.73	-2.58	2.53	-9.13	5.67	-21.89	0.21	-0.67	0.646	-2.201	15	-51
HTT center + corner struts (T300)	k3	±20%	-0.43	0.53	-0.33	0.40	-0.20	0.24	-0.20	0.24	0.054	-0.065	1	-2
Inner tank susp. (T300)	k4	±20%	-0.81	0.89	-0.64	0.71	-0.39	0.43	-0.21	0.24	0.104	-0.115	2	-3
TS1/2 tank susp. (T300)	k5	±20%	0.29	-0.34	-1.36	1.56	-0.90	1.02	-0.21	0.25	0.224	-0.255	5	-6
TS2/3 tank susp. (GFRP)	k6	±20%	0.26	-0.29	0.63	-0.69	-0.72	0.79	0.01	-0.01	0.233	-0.254	5	-6
Outer tank susp. (GFRP)	k7	±20%	0.17	-0.19	0.56	-0.61	1.07	-1.16	0.04	-0.04	0.152	-0.163	4	-4
Int. harness cross-section	k8	±15%	0.64	-0.67	-0.22	0.23	-0.53	0.53	0.14	-0.13	0.415	-0.422	10	-10
Int. harness length	k9	±15%	-0.67	0.64	0.23	-0.22	0.53	-0.53	-0.13	0.14	-0.422	0.415	-10	10
Int. harness dissipation	k10	±20%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.000	0.000	0	0
He II latent heat	k11	±1%	0.29	-0.30	0.24	-0.24	0.15	-0.15	0.13	-0.13	-0.044	0.045	5	-5
Harness anchoring on TS1	k17	±90%	0.02	-0.34	0.00	0.01	-0.01	0.18	-0.01	0.19	0.01	-0.173	0	-4
Harness anchoring on OBP	k18	±90%	0.00	0.01	0.00	0.01	0.00	0.01	0.02	-0.06	0.00	-0.001	0	0
Sum of mean root square			**+8.7**	**-6.4**	**+7.3**	**-11**	**+5**	**-14**	**+4.2**	**-1.43**	**+1.598**	**-3.991**	**+37**	**-93**

Values of k2a, k2b, k2c, k17, k18 (written in blue colour) are not included in sum of mean root square

Note: ± 50% means 1.5 x nominal value for + 50%
0.5 x nominal values for -50%

Table 7.1-1: Sensitivities for Operation on Ground

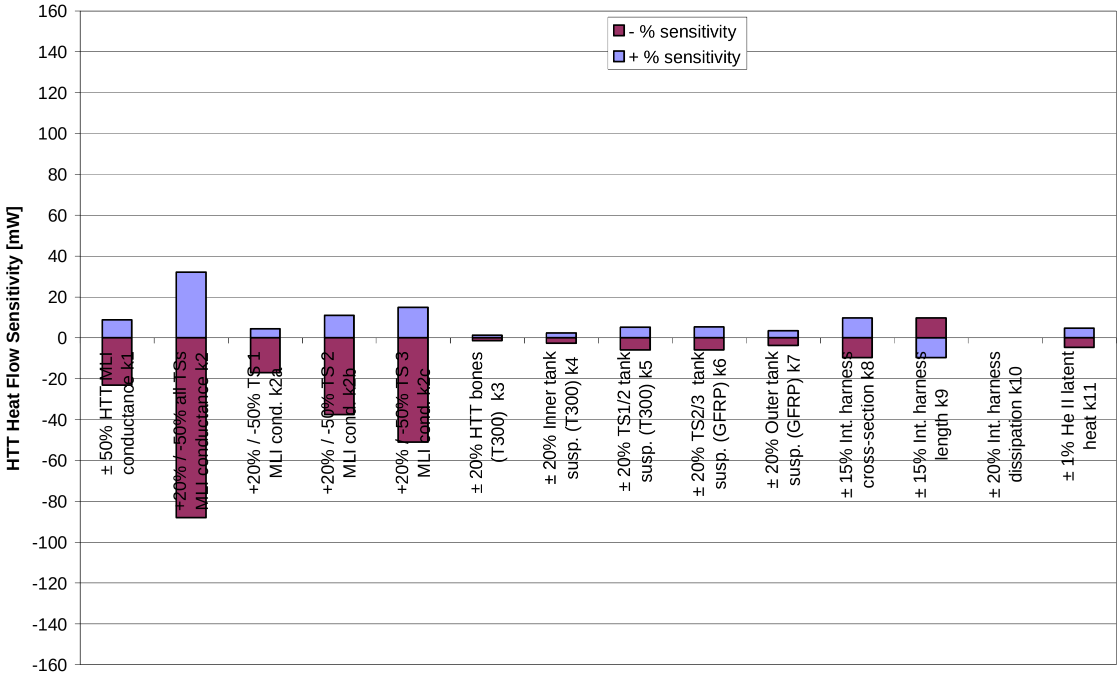


Figure 7.1-2: HTT Heat Flow Sensitivity for Operation on Ground

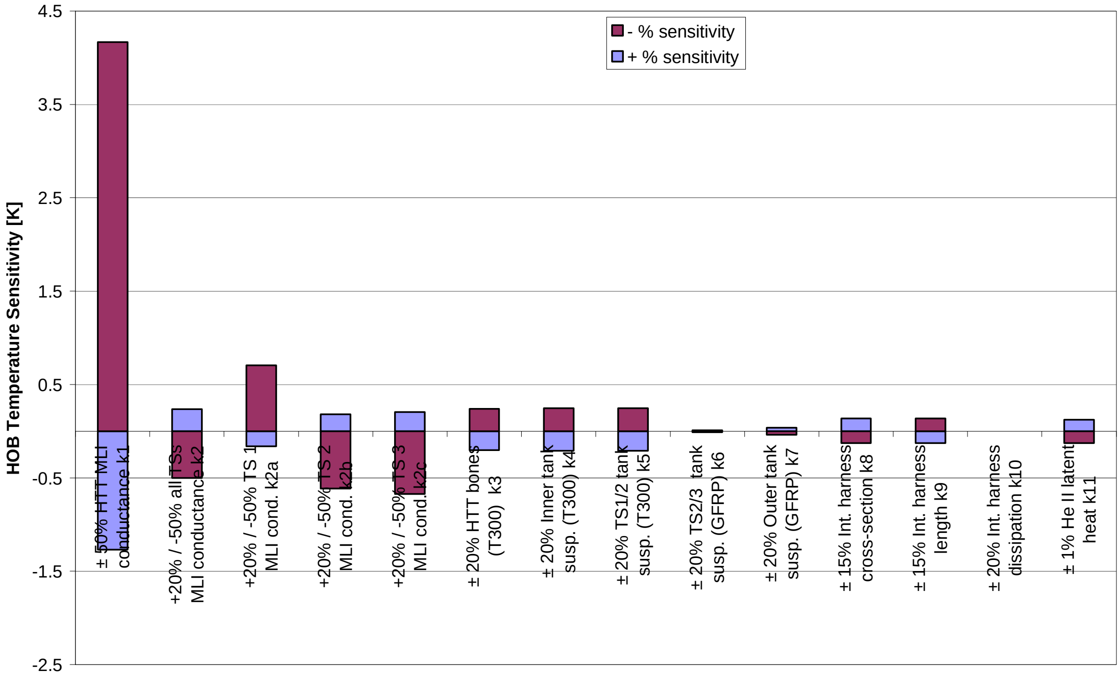


Figure 7.1-3: HOB Temperature Sensitivity for Operation on Ground

7.1.2 On-Ground Autonomy (closed HTT)

The parameter determining the length for the on-ground autonomy is the temperature of the He II in the main tank, which shall be below 2.1 K after 6 days.

The on-ground autonomy analysis is based on the following steady state start conditions (time t =0):

- System Pre-cooling with a He mass flow of 1000 mg/s

HOT He mass flow:	25 mg/s
Start temperature of HTT:	1.8 K
Temperature of HOT:	4.3 K (boundary until HOT is empty)
CVV temperature:	293 K (boundary)

For the transient HTT warm up two scenarios have been investigated: a constant HOT mass flow rate of 25 mg/s (adjusted by HOT heating) and a free floating mass flow rate determined by the parasitic heat load into the HOT only. The results shown in Figure 7.1-4 reveal that for the 25 mg/s scenario the HTT is below 2.1 K after 6 days, for the floating mass flow scenario the HTT exceeds 2.1 K after about 116 hours (4.8 days).

The bend in the 25 mg/s curve indicates that the HOT He reservoir of 8.75 kg is exhausted after 97 hours. In case of the floating mass flow 3.52 kg Helium are consumed after 6 days; i.e. 5.23 kg are still in the tank.

The mass flow evolution for a free floating mass flow due to parasitic heat into the HOT is shown in Figure 7.1-5. The HOT mass flow during 6 days launch autonomy is always less than 25 mg/s. This means, that the HOT tank need to be heated in order to achieve a constant HOT mass flow of 25 mg/s.

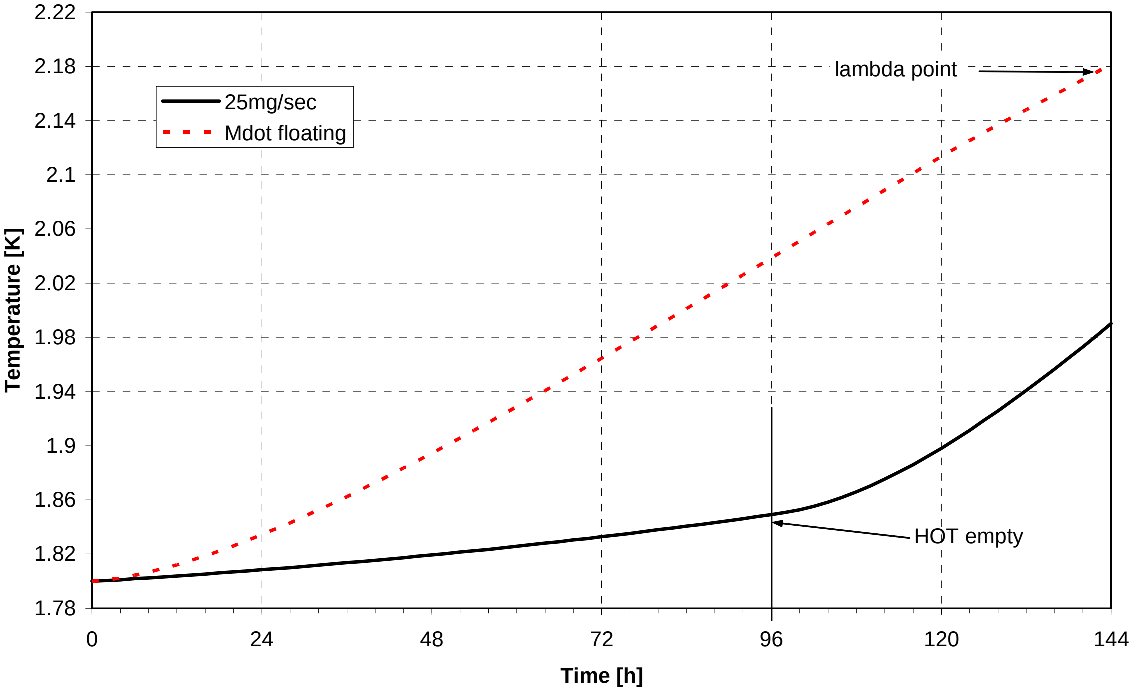


Figure 7.1-4: HTT Temperature Evolution for Different HOT Mass Flow Rates during Ground Autonomy

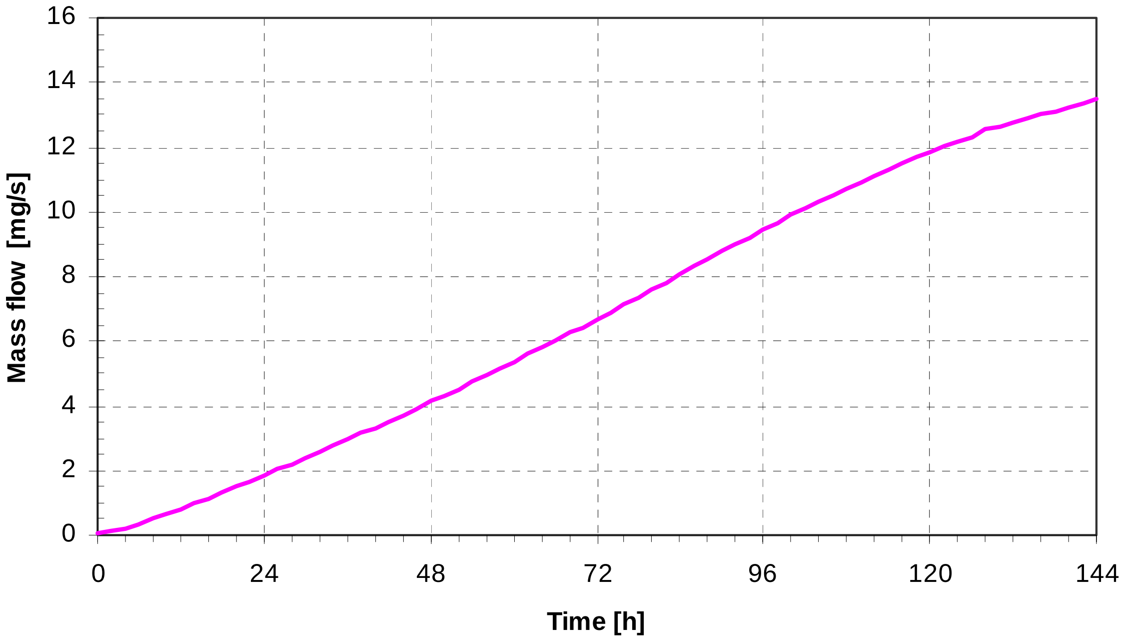


Figure 7.1-5: Floating HOT Mass Flow Rate due to Parasitic Heat Load only

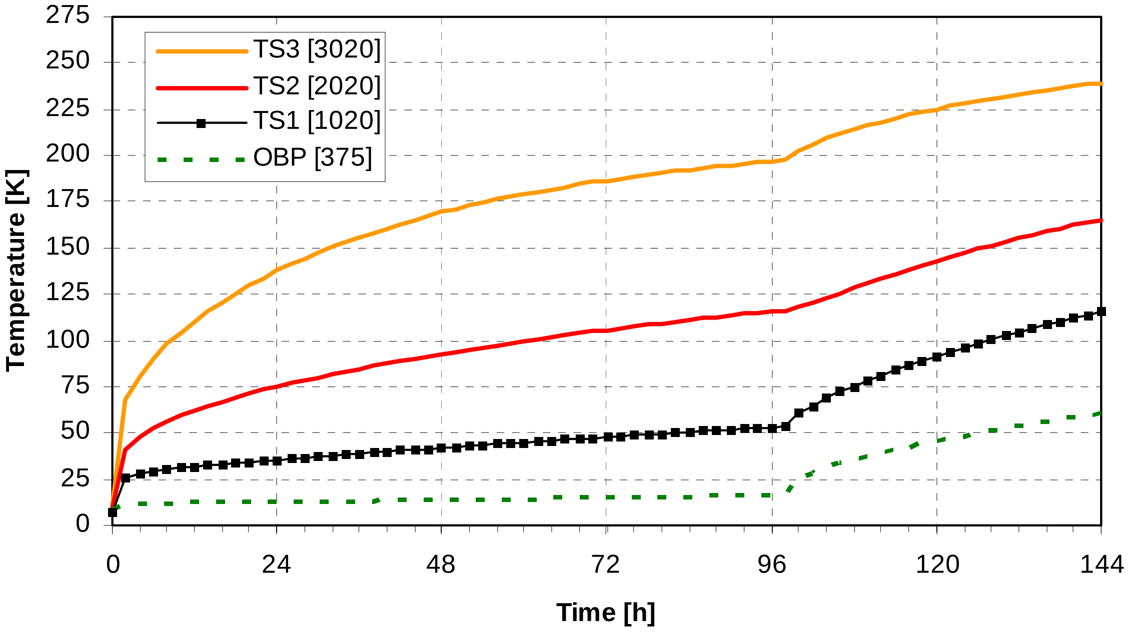


Figure 7.1-6: Thermal Shields Temperature Evolution during Ground Autonomy for 25 mg/s HOT Mass Flow Rate

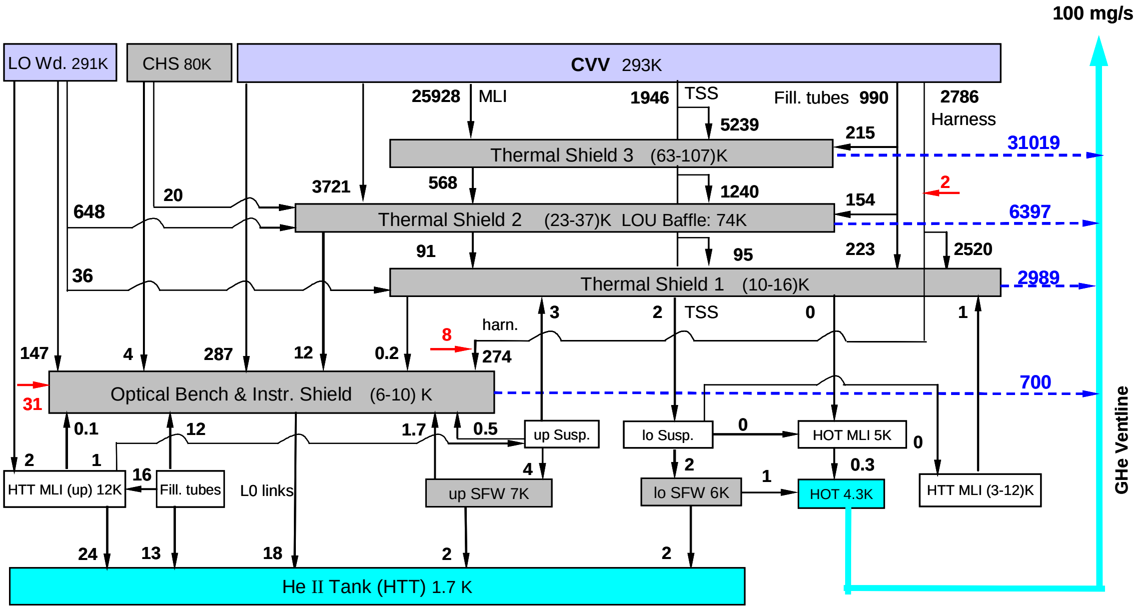
7.1.3 On-Ground Testing (IMT)

For the Integrated Module Test (IMT) with the CVV at 20°C the following conditions are assumed:

- HTT closed with start temperature:	1.7 K
- HOT He mass flow:	100 mg/s
- Temperature of HOT:	4.3 K (boundary)
- CVV temperature:	293 K (boundary)
- Cryo Cover cooled:	80 K (boundary)

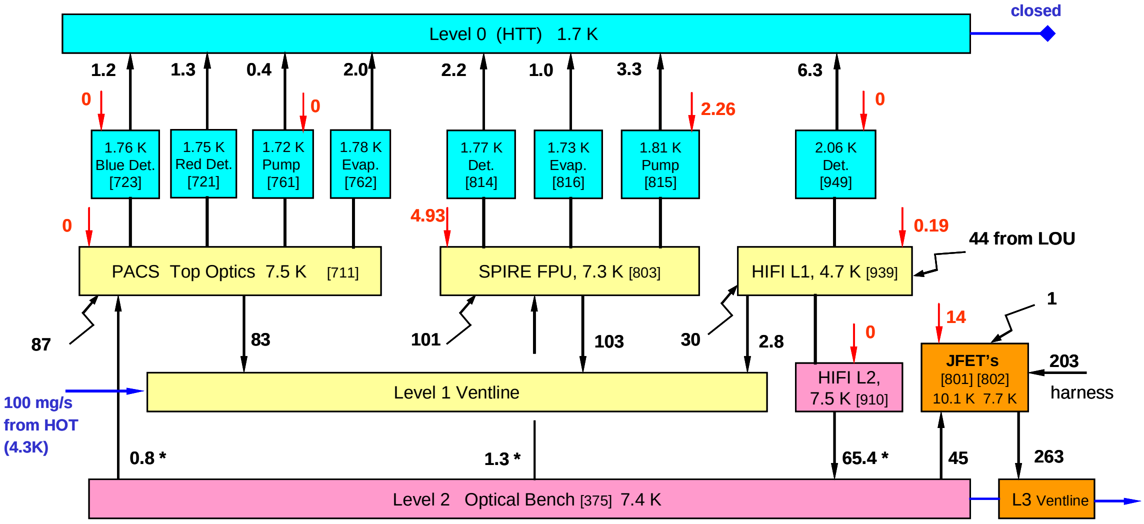
The corresponding I/F temperatures and heat flow charts for the CVV internal and for the OBA with SPIRE in Spectrometer Mode are shown in Figure 7.1-7 and Figure 7.1-8.

Transient calculations have been performed assuming the instrument in-orbit timeline (see section 7.4) also for the on-ground testing. The results are shown in Figure 7.1-9 until Figure 7.1-16.



Only main paths are shown. All values are in [mW]

Figure 7.1-7: CVV Heat Flow Chart for IMT (Spire Spectrometer Mode)



* feet & harness

Figure 7.1-8: OBA Heat Flow Chart for IMT (SPIRE Spectrometer Mode)

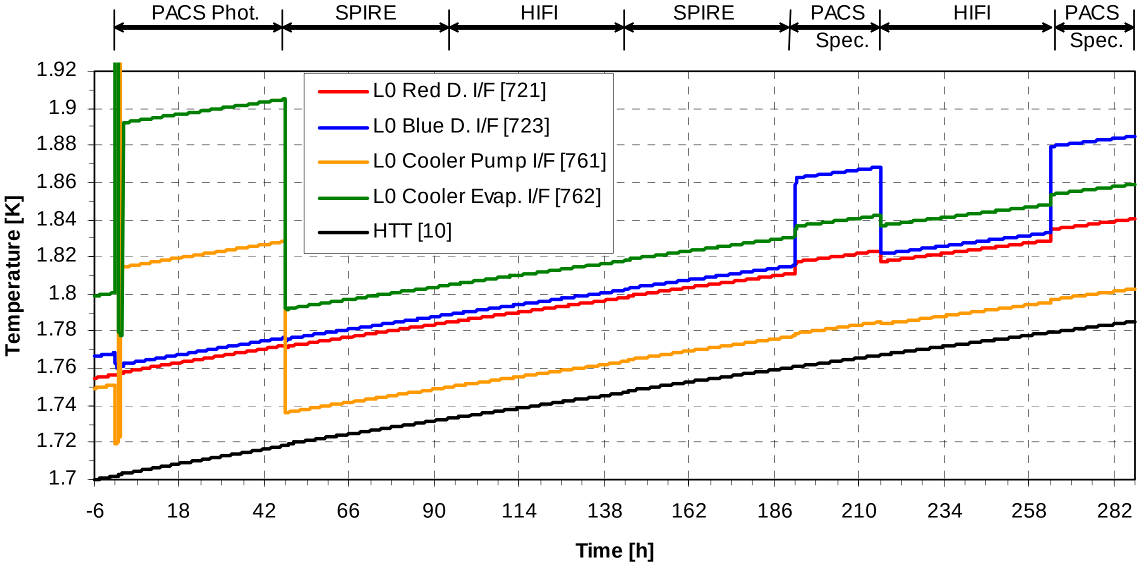


Figure 7.1-9: PACS L0 Interface Temperatures during IMT (based on orbit timeline)

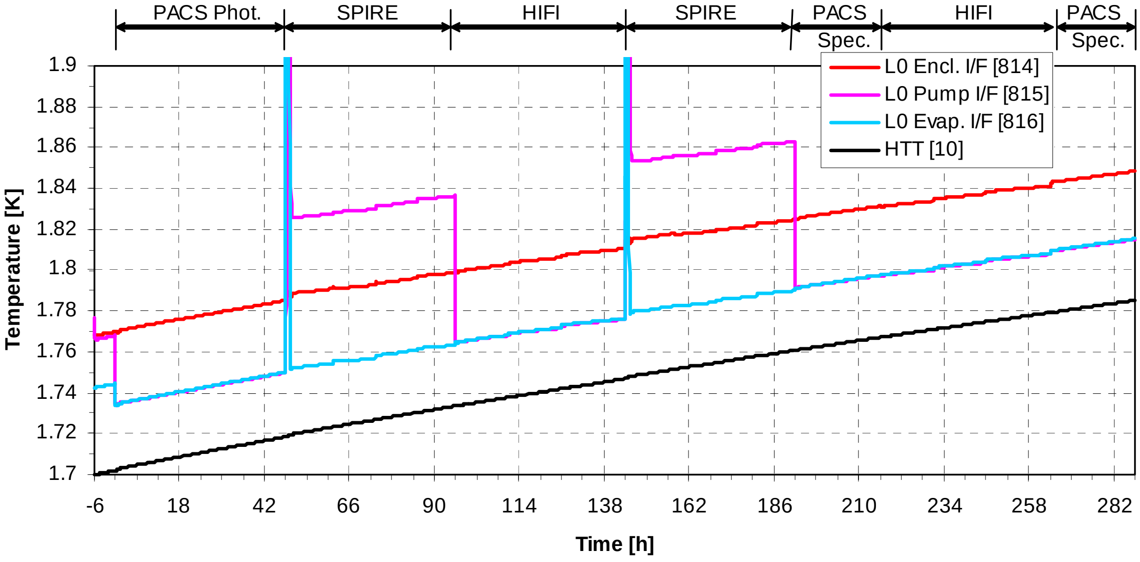


Figure 7.1-10: SPIRE L0 Interface Temperatures during IMT (based on orbit timeline)

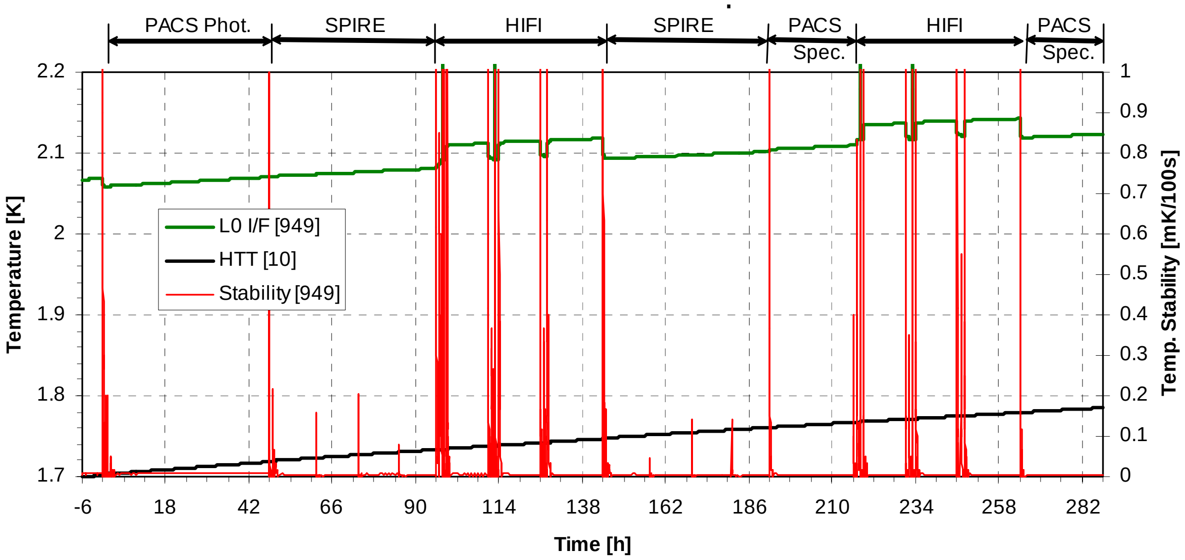


Figure 7.1-11: HIFI L0 Interface Temperatures during IMT (based on orbit timeline)

Note that the temperature change peaks of HIFI are caused by short heat peak phases due to dissipation switching.

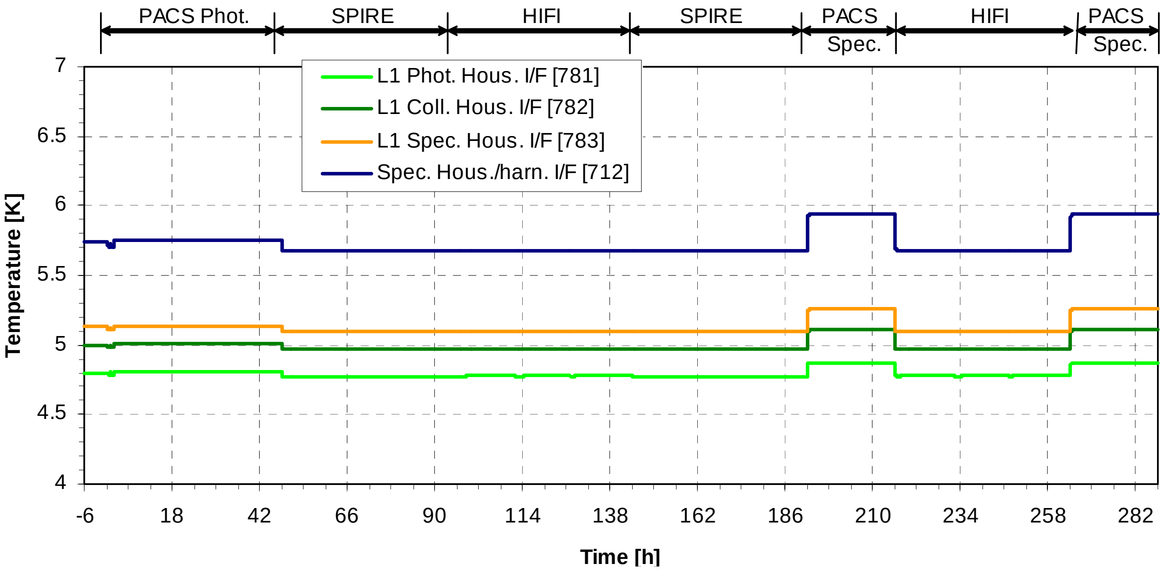


Figure 7.1-12: PACS L1 Interface Temperatures during IMT (based on orbit timeline)

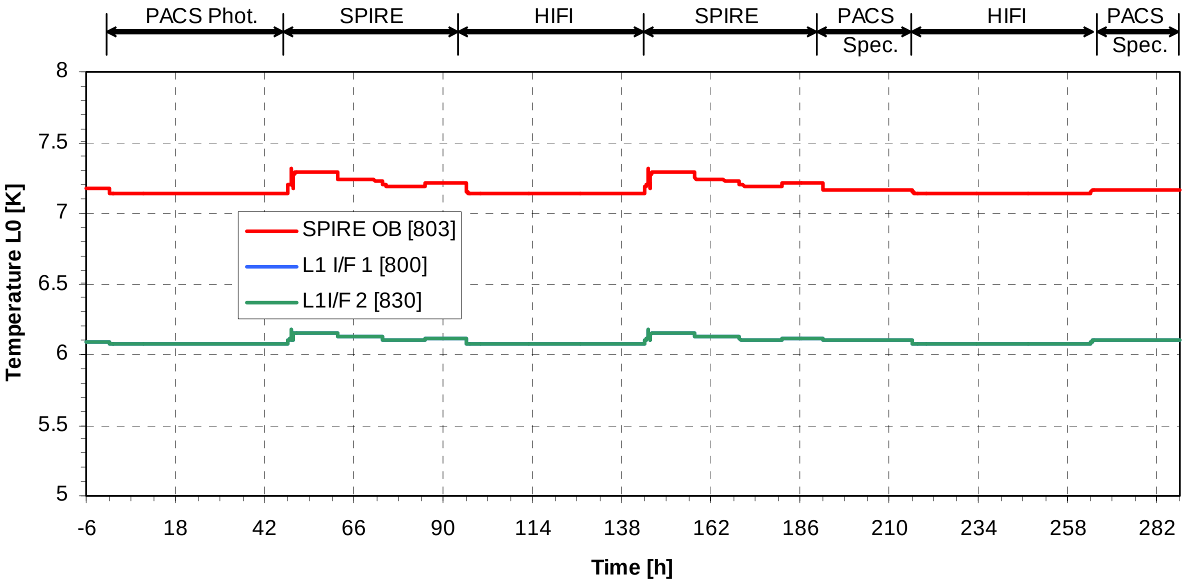


Figure 7.1-13: SPIRE L1 Interface Temperatures during IMT (based on orbit timeline)

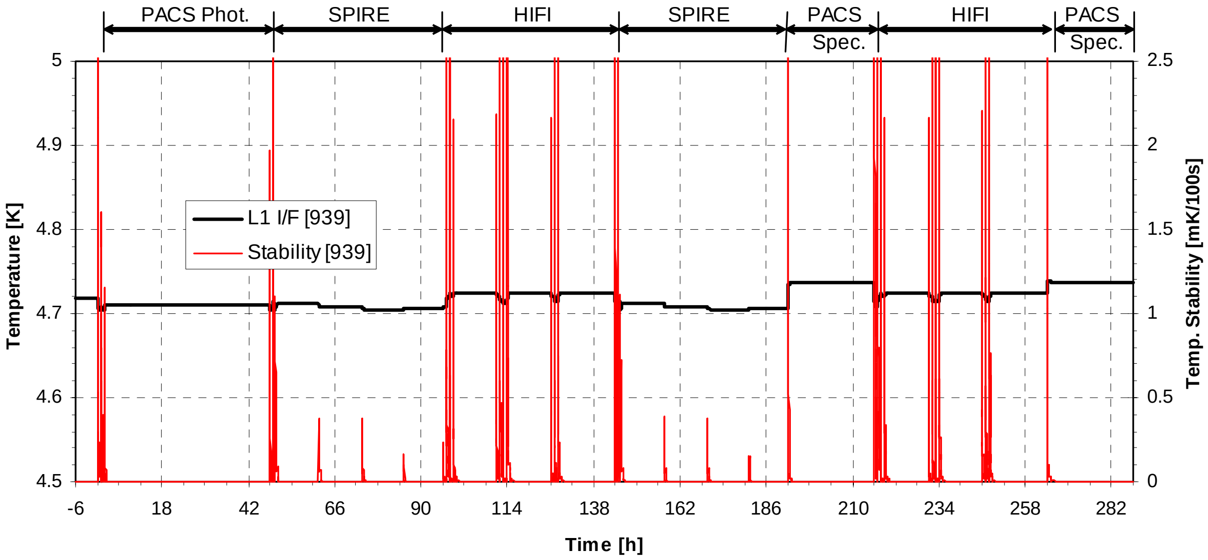


Figure 7.1-14: HIFI L1 Interface Temperature during IMT (based on orbit timeline)

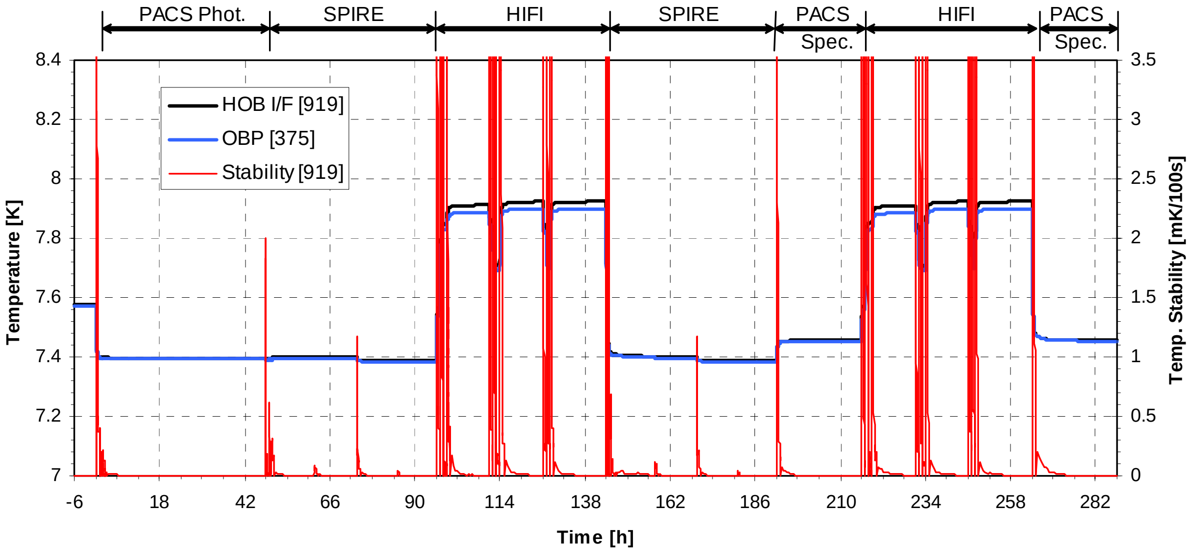


Figure 7.1-15: HIFI L2 and OBP Temperature during IMT (based on orbit timeline)

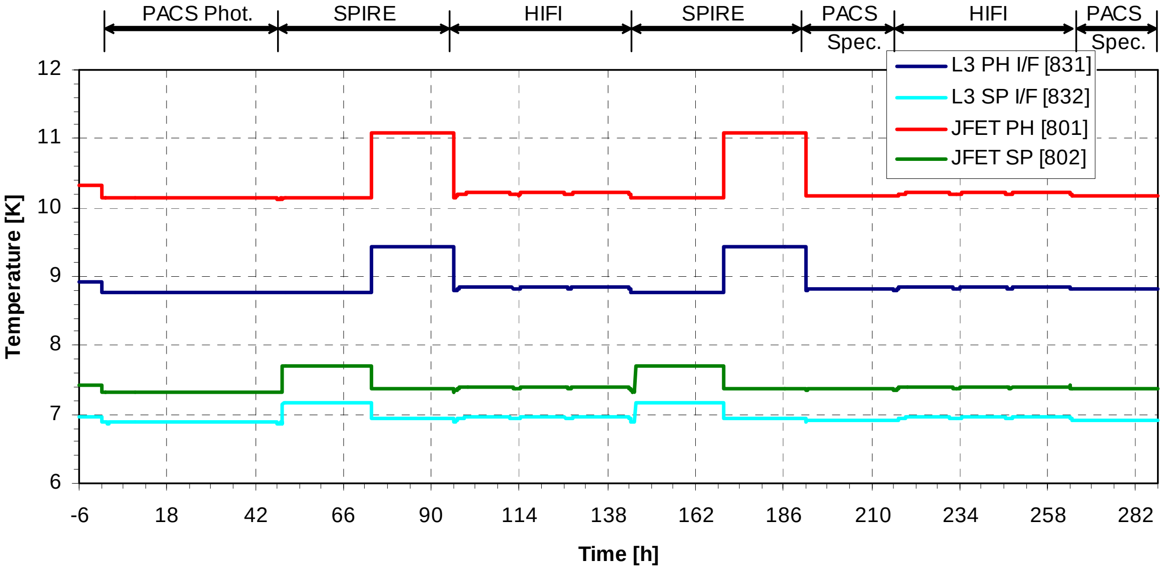


Figure 7.1-16: SPIRE L3 Temperatures during IMT (based on orbit timeline)

7.2 Pre-Launch and Early Orbit Phase

For the pre-launch and early orbit phase three scenarios have been investigated in accordance with the POC operations as discussed with Arianespace [RD 41]:

- nominal scenario with no launch delay:
  - Helium II top up completed 4 days before launch with a level of 98% and a temperature of 1.8K
  - Last HOT refill with Thermal Shields subcooling completed two days before launch
  - HOT depletion and heating to 40 K 3 hours before launch
- launch scenario with 25 hours launch delay:
  - Helium II top up completed 4 days before nominal launch with a level of 98% and a temperature of 1.8K
  - Last HOT refill with Thermal Shield subcooling completed two days before nominal launch
  - HOT depletion and heating to 40 K 3 hours before nominal launch
  - launch abort after HOT heating
  - 25 hours hold time with depleted HOT
- launch scenario with 25 hours launch delay (as above), but with degraded internal MLI performance (50% higher conductance, i.e. k1=1.5 and k2=1.5) and simultaneously 15% increased internal harness conductance (k8=1.15)

Critical areas that are exposed to an intensive solar as well as aero-thermal flux are investigated in RD 17. The cool-down of the HSS after fairing jettison has been assessed for an extreme S/C attitude, see also RD 17.

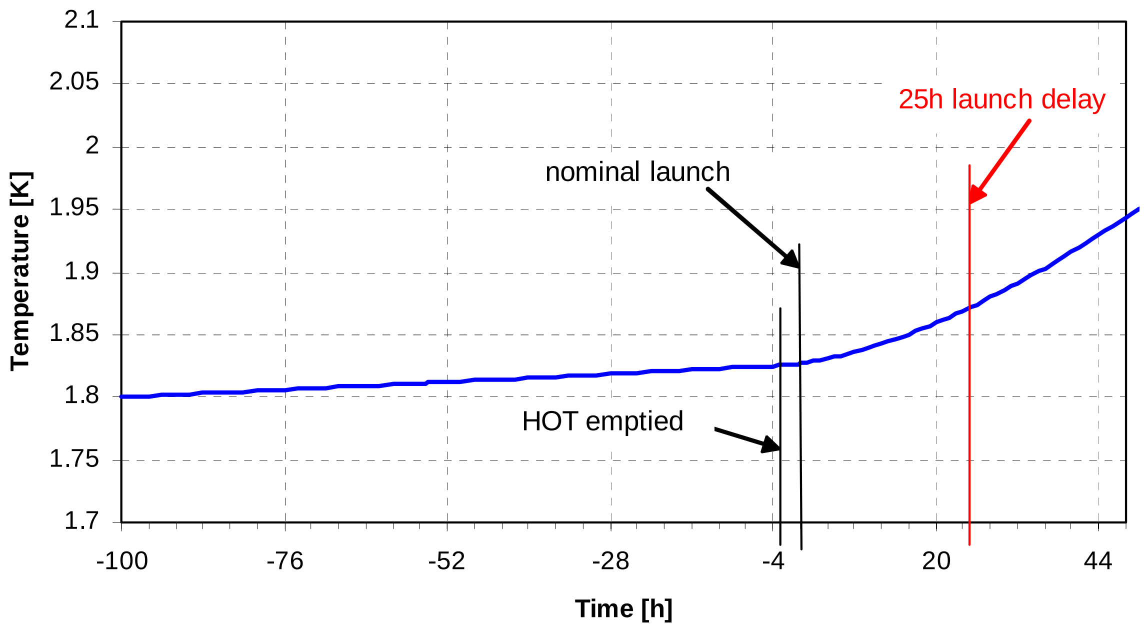


Figure 7.2-1: HTT Temperature Evolution During Pre-Launch Phase

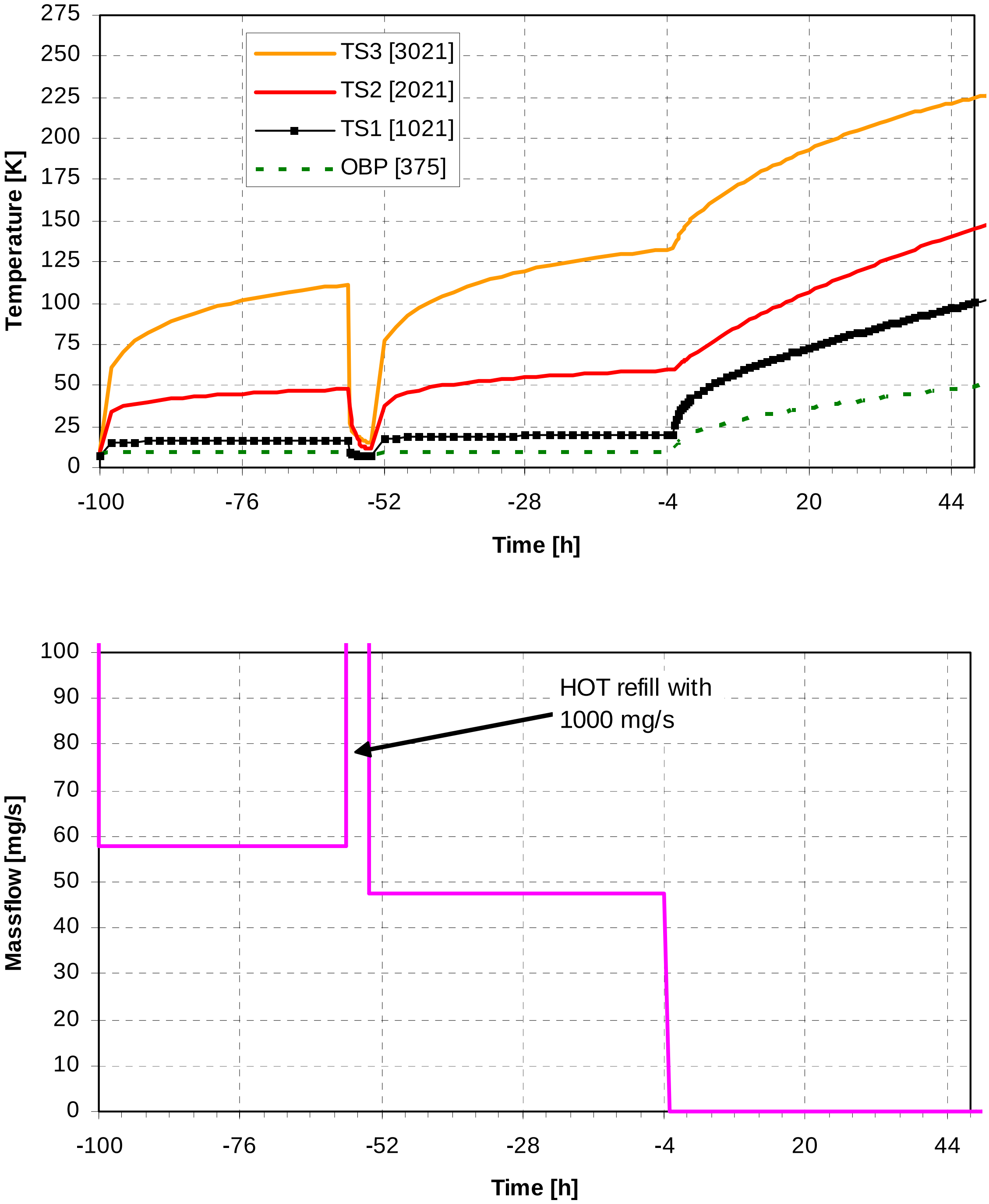


Figure 7.2-2: Thermal Shield Temperature Evolution During Pre-Launch Phase

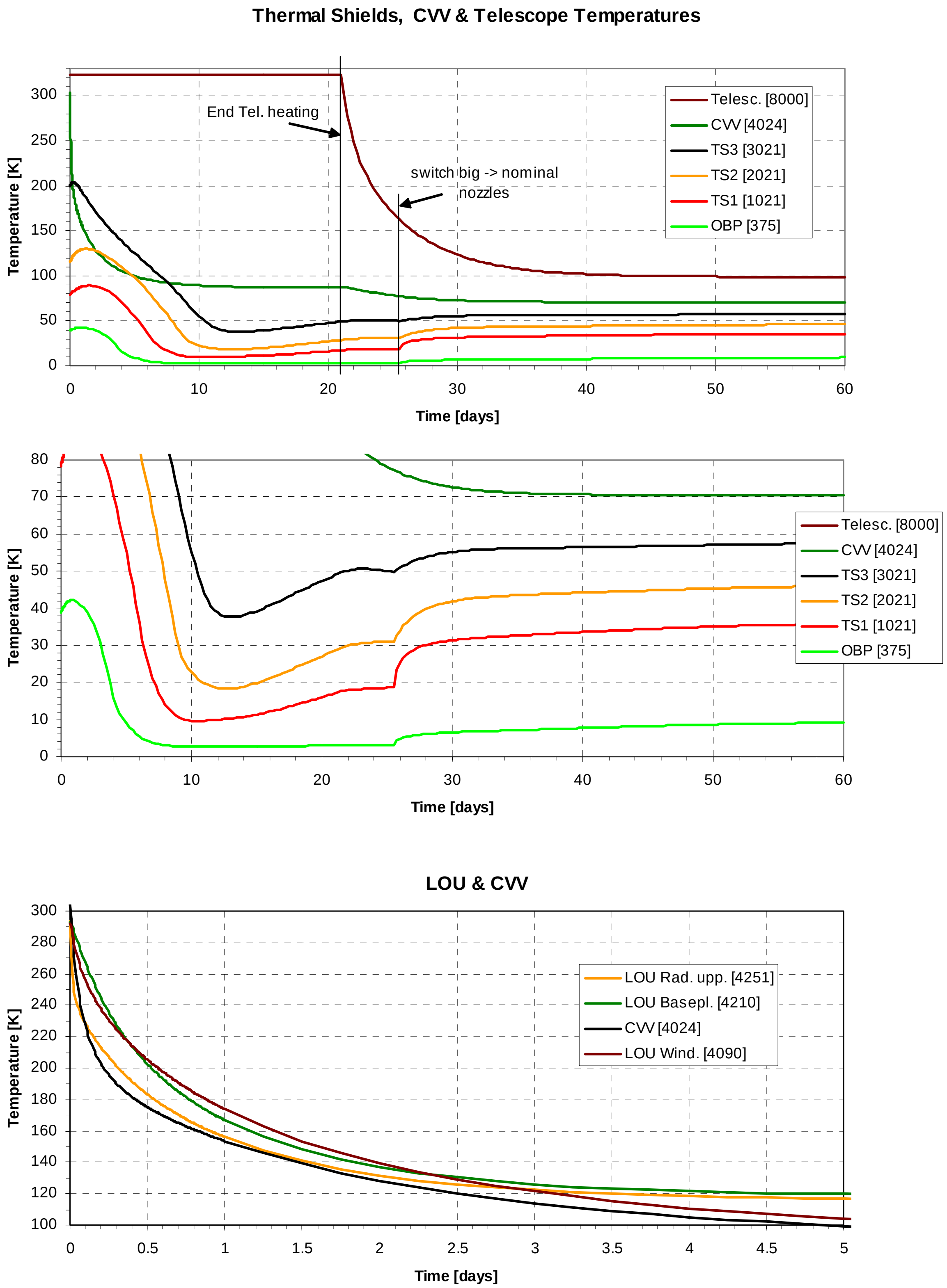


Figure 7.2-3: H-EPLM Temperatures During In-Orbit Cool-Down (25 h launch delay)

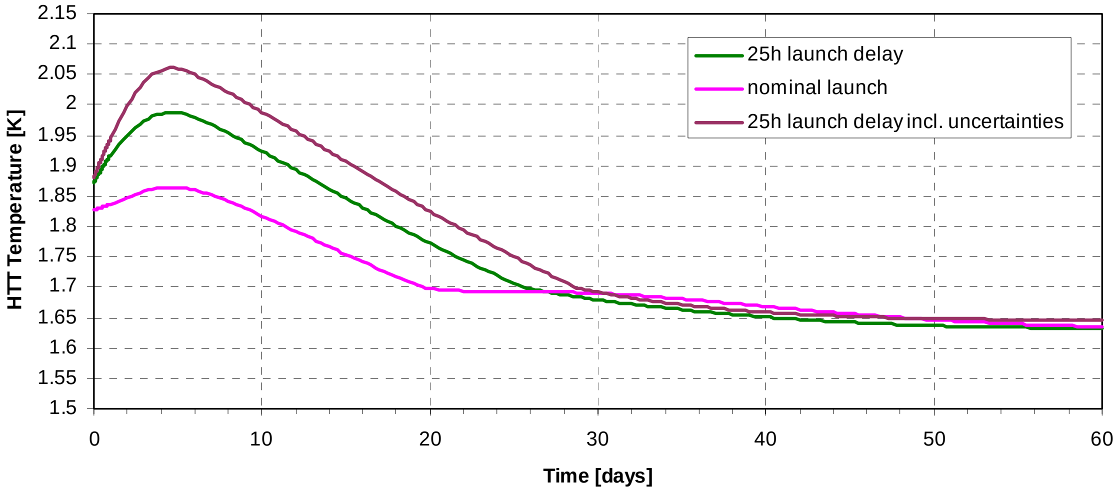


Figure 7.2-4: HTT Temperature During In-Orbit Cool-Down

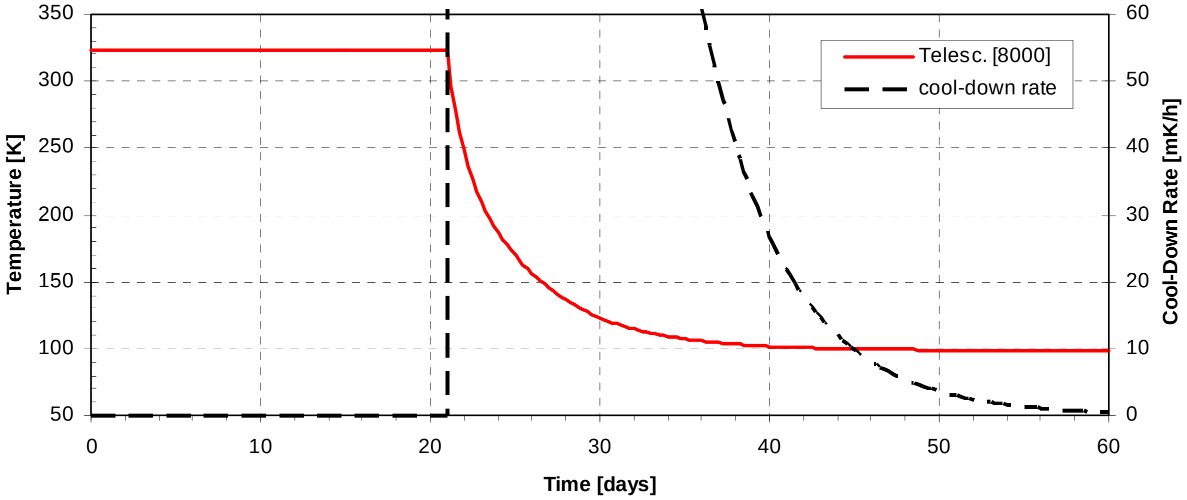
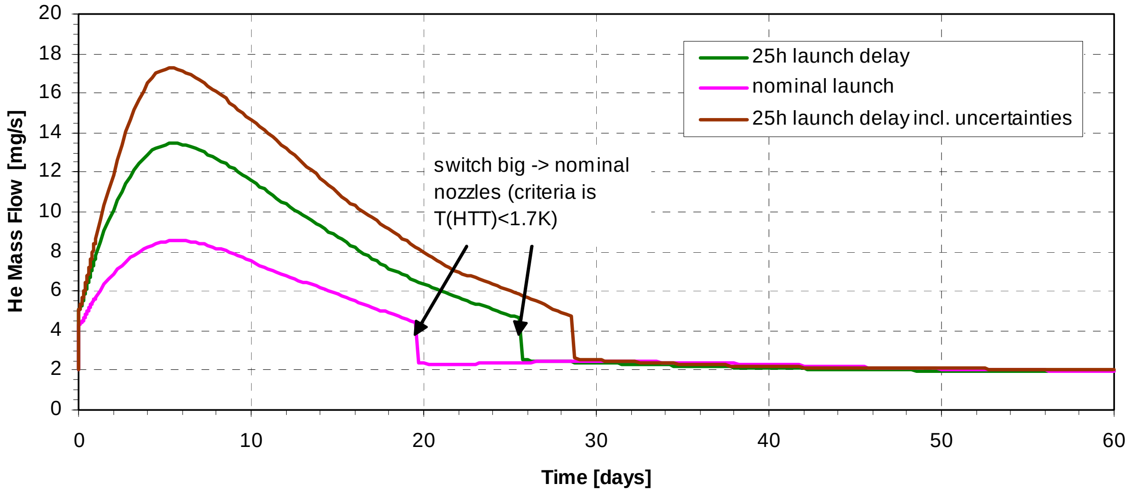


Figure 7.2-5: Telescope Cool-Down Rate after Decontamination (Cover still closed)

For the nominal scenario (without launch delay) the helium loss during the in-orbit cool-down phase in this case is 17.2 kg within the first 48 days, see Figure 7.2-6. This amount of Helium is taken for the lifetime analysis described in section 7.5. The HTT temperature increases from 1.827 K at launch (Figure 7.2-1) to a maximum of 1.865 K (Figure 7.2-4) during in-orbit cool down.

For the scenario with 25 hours launch delay the corresponding Helium consumption is about 23.2 kg within the first 40.5 days and the HTT temperature increases from 1.872 K at delayed launch to a maximum of 1.988 K during in-orbit cool down.

The launch delay scenario with uncertainties (degraded internal MLI and increased internal harness conductance) lead to a HTT temperature increase from 1.880 K at delayed launch to a maximum of 2.060 K during in-orbit cool down. The margin w.r.t. available Helium enthalpy until the maximum allowable HTT temperature of 2.1 K would be reached is 30% [RD 40], which is considered to be sufficient.



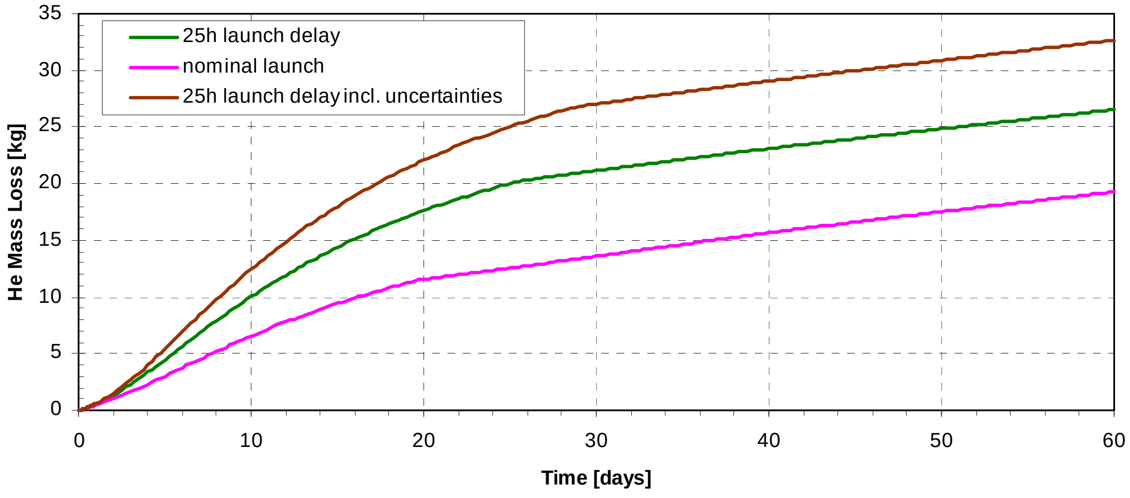


Figure 7.2-6: Helium Mass Flow and Mass Loss During In-Orbit Cool-Down

7.3 Spacecraft Operation in L2 Orbit

7.3.1 Steady State Analysis for Hot and Cold Case Conditions

Thermal analyses with implemented instrument models have been performed both for the hot and cold case thermal environment at L2.

The results are summarized in Table 7.3-1. The corresponding heat flow charts showing the CVV external main paths are shown in Figure 7.3-3 for the hot case environment and in Figure 7.3-4 for the cold case environment. The calculated temperatures of the relevant components are included. The internal heat flow chart for the hot case environment is shown in Figure 7.3-5.

	Solar constant	SAA around Y	OSR Solar absorpt.	T CVV	T HOB	T HTT	He Mass Flow
Hot case	1405 W/m² (WS)	0°	0.2 (EOL)	70.0 K	11.0 K	1.65 K	2.125 mg/s
Cold case	1287 W/m² (SS)	30°	0.1 (BOL)	66.7 K	10.9 K	1.63 K	1.970 mg/s
Safe Mode *	1287 W/m² (SS)	30°	0.1 (BOL)	63.8 K	9.2 K	1.59 K	1.624 mg/s
IID-A Average **	1352 W/m²	17.267°	0.15	68.6 K	14.8 K	1.65 K	2.267 mg/s

*) All dissipation set to zero
**) Instrument TMM's replaced by IID-A heat load allocations and HTT set to 1.65 K

Table 7.3-1: Analysis Results for Hot and Cold Case Environment

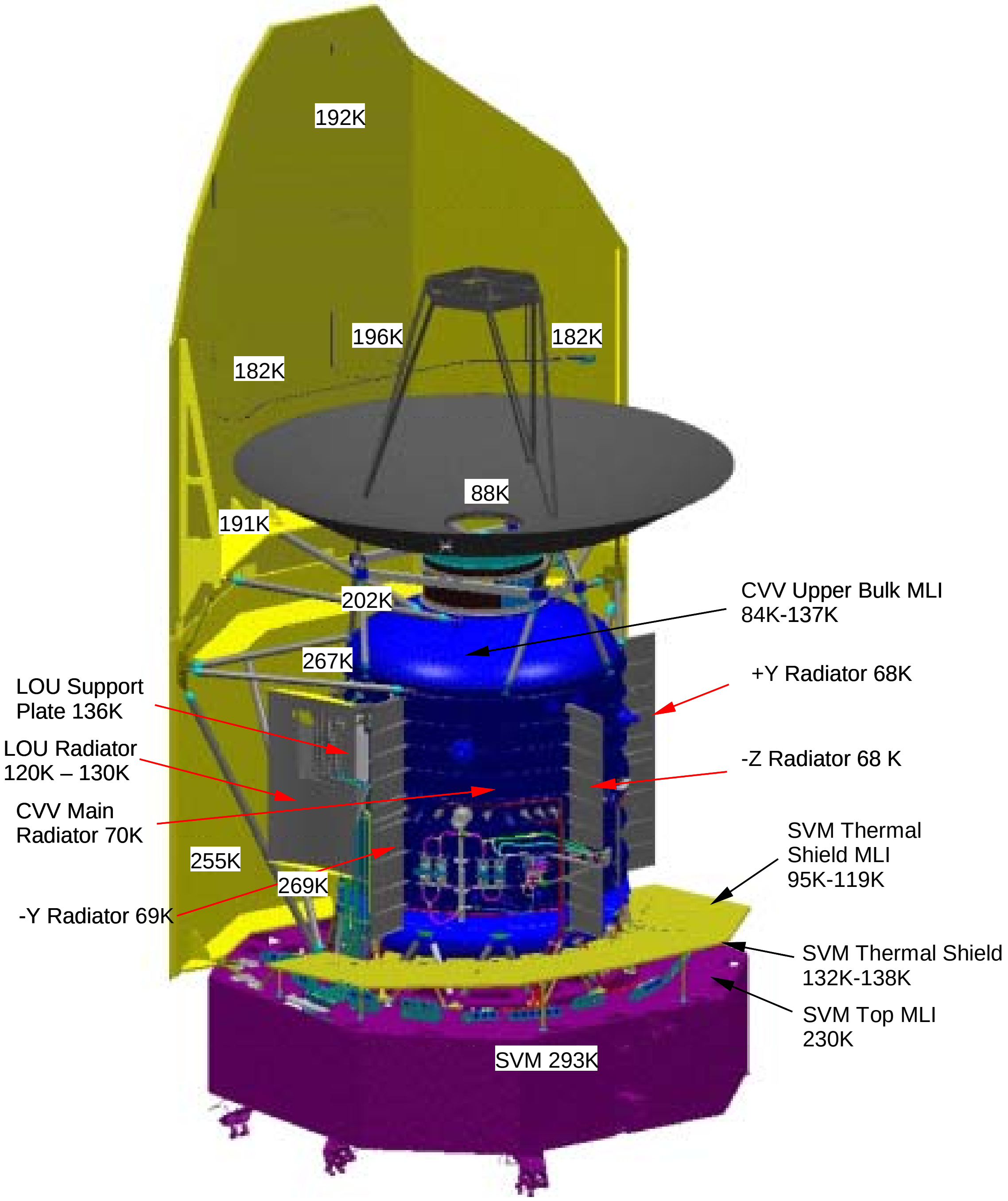


Figure 7.3-1: H-EPLM Temperature Distribution for Hot Case Environment at L2

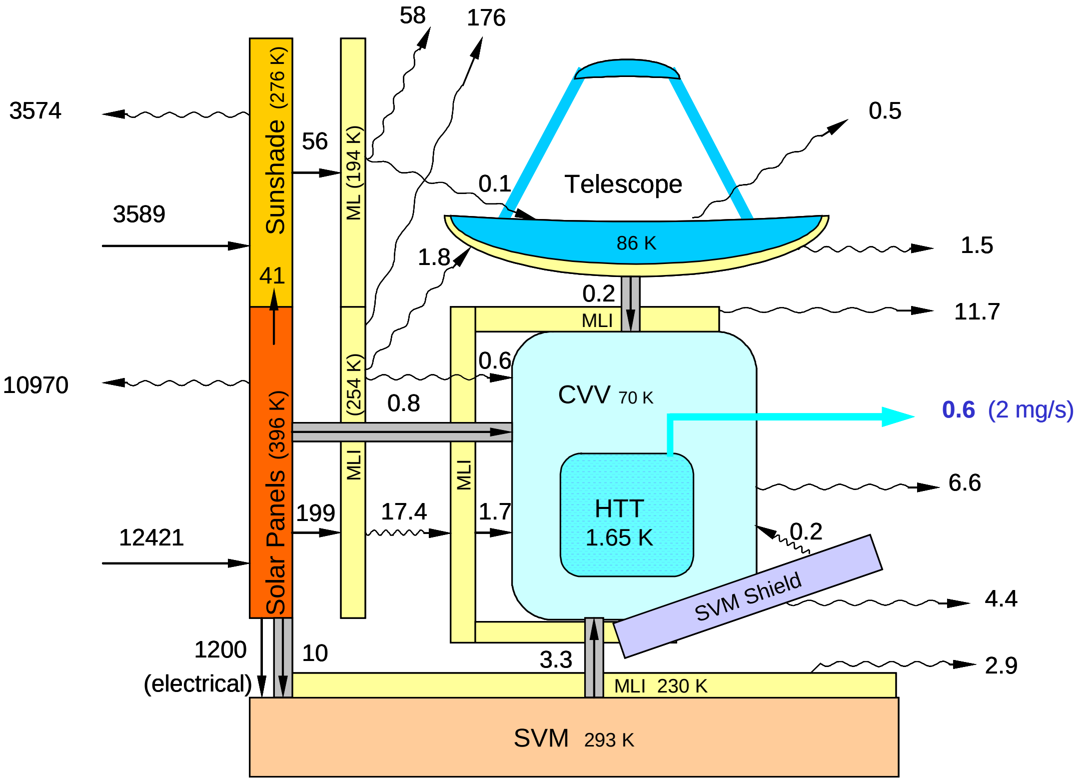
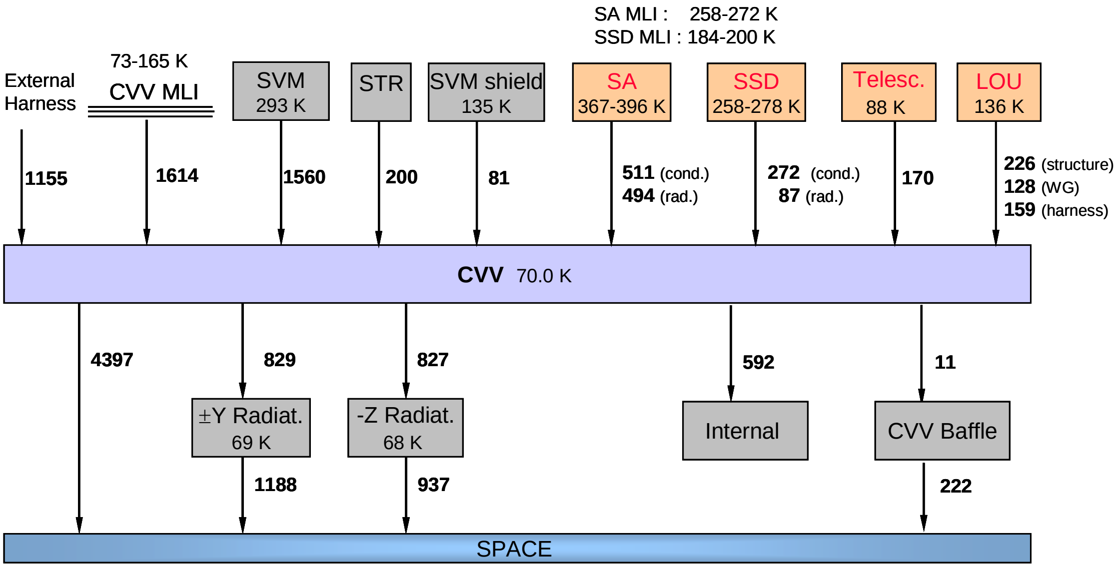


Figure 7.3-2: CVV External Heat Flow Chart in [W] (Hot Case)

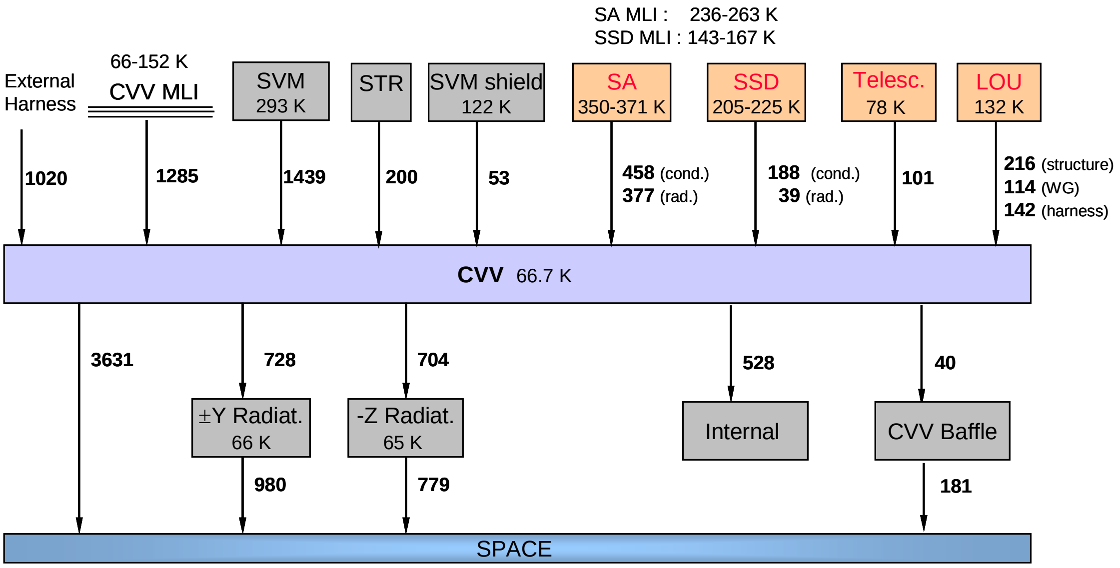
The maximum calculated thermal interface fluxes between SVM and Sunshield (=Solar Panels) are as follows. The max. allowed values as per [AD 07] are given in parenthesis:

Flux via CFRP struts:	4.0 W (<5 W required)
Flux via Sunshield brackets:	3.4 W (<10 W required)
Flux via harness:	2.9 W



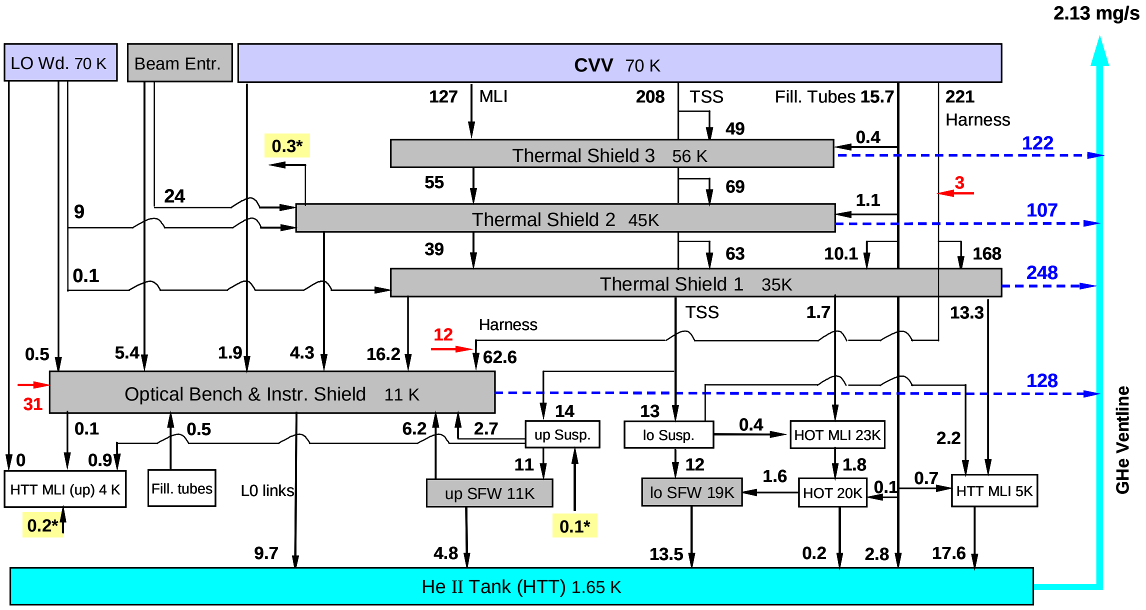
All values are in [mW]

Figure 7.3-3: CVV Heat Flow Chart for Hot Case Environment at L2



All values are in [mW]

Figure 7.3-4: CVV Heat Flow Chart for Cold Case Environment at L2



Only main paths are shown. All values are in [mW]

*) Heat flow from LOU Baffle (mounted on TS2)

Figure 7.3-5: HPLM internal Heat Flow Chart for Average Instrument Dissipation and Hot Case Environment at L2

7.3.2 Sensitivity Analysis for Lifetime and EPLM Temperatures

A comprehensive sensitivity analysis has been performed for In-Orbit operations. The results are listed in Table 7.3-2 and Table 7.3-3. The sensitivities for the lifetime, the CVV, HSS and Telescope temperatures are visualised in Figure 7.3-6 to Figure 7.3-12.

Item	Sensitivity		T, OBP [K]		M_{He} [mg/s]		Δ Lifetime [days]	
			+	**-**	**+**	**-**	**+**	**-**
Reference Case: see Figure 7.3-5			**11.01**		**2.125**		**-**	
HTT MLI conductance	k1	± 50%	-0.001	0.005	0.000	0.000	0	0
Thermal Shield MLI cond.	k2	+20/-50%	-0.006	0.020	0.017	-0.056	-11	39
TS 1 MLI cond.	k2a	+20/-50%	-0.003	0.013	0.003	-0.014	(-2)	(10)
TS 2 MLI cond.	k2b	+20/-50%	-0.001	0.002	0.005	-0.018	(-3)	(12)
TS 3 MLI cond.	k2c	+20/-50%	-0.002	0.007	0.009	-0.029	(-6)	(20)
HTT center and corner struts (T300)	k3	± 20%	-0.209	0.240	0.014	-0.016	-10	11
Inner tank susp. (T300)	k4	± 20%	-0.042	0.055	0.021	-0.022	-14	15
TS1/2 tank susp. (T300)	k5	± 20%	-0.029	0.034	0.023	-0.026	-16	18
TS2/3 tank susp. (GFRP)	k6	± 20%	-0.006	0.007	0.023	-0.027	-16	19
Outer tank susp. (GFRP)	k7	± 20%	-0.005	0.005	0.017	-0.021	-12	14
Int. Harness cross-section	k8	± 15%	0.293	-0.300	0.097	-0.100	-64	72
Int. Harness length	k9	± 15%	-0.300	0.293	-0.100	0.097	72	-64
Int. Harness dissipation	k10	± 20%	0.125	-0.126	0.013	-0.013	-9	9
He II latent heat	k11	± 1%	0.054	-0.055	-0.007	0.007	5	-5
Harness anchoring on TS1	k17	± 90%	-0.004	+0.072	+0.001	-0.019	-1	13
Harness anchoring on OBP	k18	± 90%	0.008	-0.04	0.000	-0.001	0	1
Sum of mean root square			**-0.496**	**0.502**	**0.146**	**-0.161**	**-96**	**115**

Note: Values in ( ) not taken for lifetime uncertainty

Table 7.3-2: In-Orbit Sensitivities due to Uncertainties of Physical Parameters inside CVV

Item	Sensitivity		T, CVV [K]		M $_{He}$ [mg/s]		Δ Lifetime [days]		Remark
			+	**-**	**+**	**-**	**+**	**-**	
Reference Case: see Figure 7.3-5			**70.0**		**2.125**		**-**		
CVV MLI conductance	k21	± 50%	1.61	-1.92	0.066	-0.077	-44	55	
Solar Array MLI conduct.	k22	± 50%	1.54	-2.16	0.065	-0.089	-43	64	
Sunshade MLI conduct.	k23	± 50%	0.23	-0.30	0.018	-0.024	-12	16	
SVM Shield MLI conduct.	k24	± 50%	0.06	-0.09	0.003	-0.004	-2	3	
CVV strut conductance	k25	± 20%	0.72	-0.73	0.029	-0.029	-20	20	
HSS strut conductance	k26	± 20%	0.35	-0.36	0.014	-0.014	-10	10	
Ext. Harness cross-section	k27	± 15%	0.39	-0.41	0.020	-0.020	-13	14	
Ext. Harness length	k28	± 15%	-0.41	0.39	-0.020	0.020	14	-13	
Ext. Harness dissipation	k29	± 20%	0.01	-0.02	0.001	-0.001	-1	1	
MLI IR specularity	k30	± 20%	-0.34	0.35	-0.015	0.015	10	-10	
Emissivity of radiator surfaces	k31	± 0.03	-0.38	0.39	-0.015	0.016	11	-11	see RD 35
Emissivity of Sunshade (OSR panels)	k32	± 0.03	-0.04	0.03	-0.002	0.002	2	-2	1)
Emissivity of Solar Array	k33	± 0.03	-0.19	0.19	-0.008	0.008	5	-6	1)
Absorptivity of Sunshade (OSR panels)	k34	± 0.03	0.15	-0.16	0.010	-0.010	-7	7	1)
Absorptivity of Solar Array	k35	± 0.03	0.19	-0.19	0.008	-0.008	-5	5	1)
Telescope emissivity (M1)	k36	±0.005	-0.1	0.1	-0.004	0.005	(2)	(-3)	*from issue 3*
LOU strut conductance	k38	± 20%	0.1		0.002	-0.002	(-1)	(1)	
Sum of mean root square			**2.25**	**-3.13**	**0.108**	**-0.130**	**-72**	**93**	

1) acc. to ECSS-E-30, Part 1A

Note: Values in ( ) not taken for lifetime uncertainty

Table 7.3-3: In-Orbit Sensitivities due to Uncertainties of Physical Parameters outside CVV

The case of 25 hours launch delay has also to be taken into account as uncertainty. As described in Section 7.2 the launch delay leads to a Helium consumption of 23.2 kg in 40.5days compared to 17.2 kg in 48 days for nominal launch. This leads to an additional helium loss of 6 kg and a corresponding lifetime loss of 7.5 days + 6 kg / (2.267 mg/s) = 38 days.

Item	Node	T, cold case [K]		T, hot case [K]	
SA MLI, center panel	[7100]	253	+19 / -32 a)	270	+20 / -34
SA MLI side panel	[7101]	241	+18 / -30 a)	258	+19 / -32
SSD MLI, center panel	[7160]	157	+11 / -18 a)	196	+15 / -25
SSD MLI side panel	[7161]	148	+10 / -16 a)	184	+14 / -23
Telescope	[8000]	78.3	+4 / -6 a)	87.8	+5 / -6
LOU support plate	[4200]	132	± 2 a)	136	± 3
Solar Array, center panel	[7000]	371		396	± 5
Solar Array, side panel	[7001]	352		376	± 5
SSD (OSR's), center panel	[7060]	219		276	± 11
SSD (OSR's), side panel	[7061]	205		258	± 11
SVM Thermal Shield	[6204]	122		135	± 3

a) sum of mean root square due to MLI sensitivity analysis (k21, k22, k23)

Table 7.3-4: EPLM Temperatures with uncertainties in L2 Orbit

In case the solar cells are in shunt mode and all absorbed solar energy is dumped in the Solar Array, the temperature of the center panel increases to 409 K (136°C). This has been calculated for LEOP and Winter Solstice.

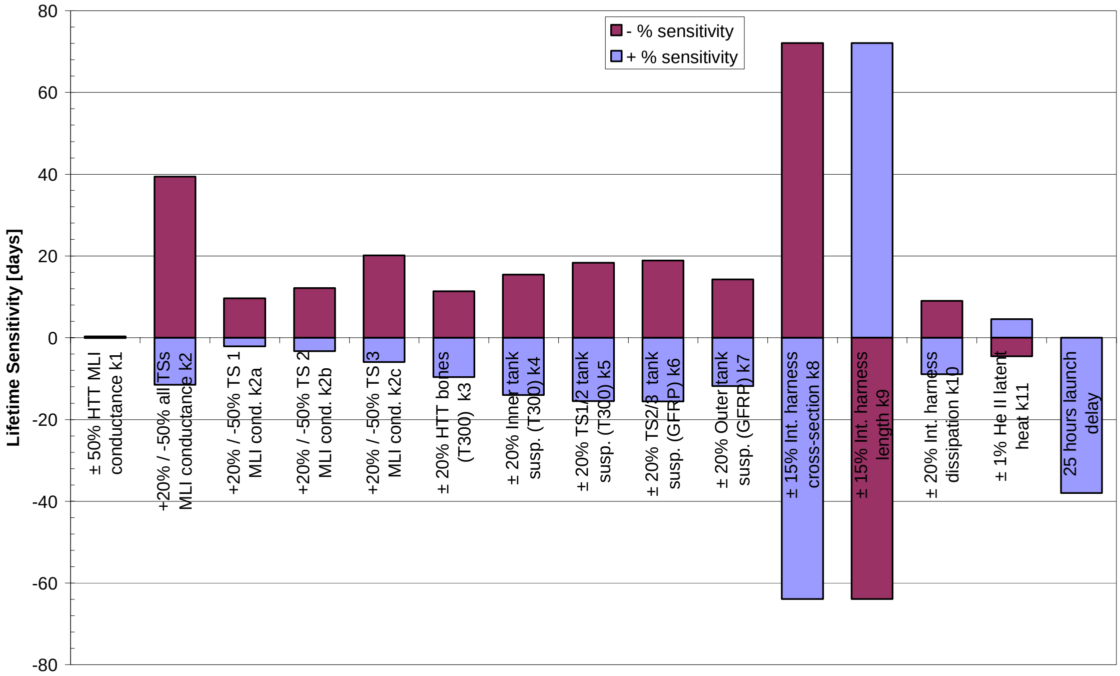


Figure 7.3-6: Lifetime Sensitivity for CVV Internal Parameter Variations

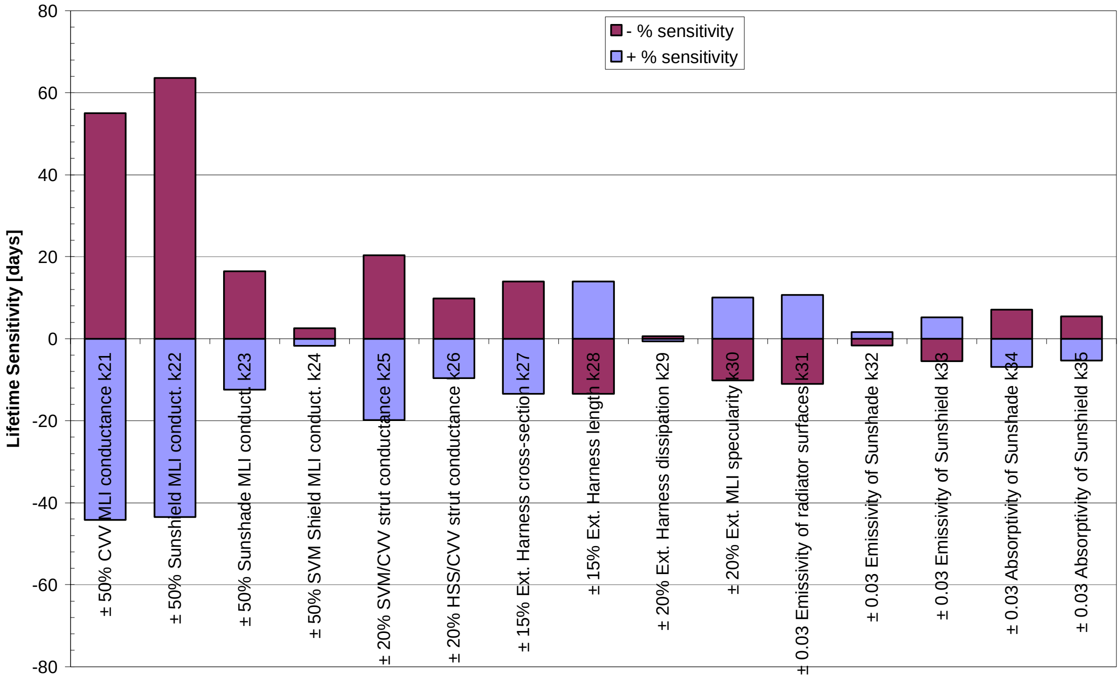


Figure 7.3-7: Lifetime Sensitivity for CVV External Parameter Variations

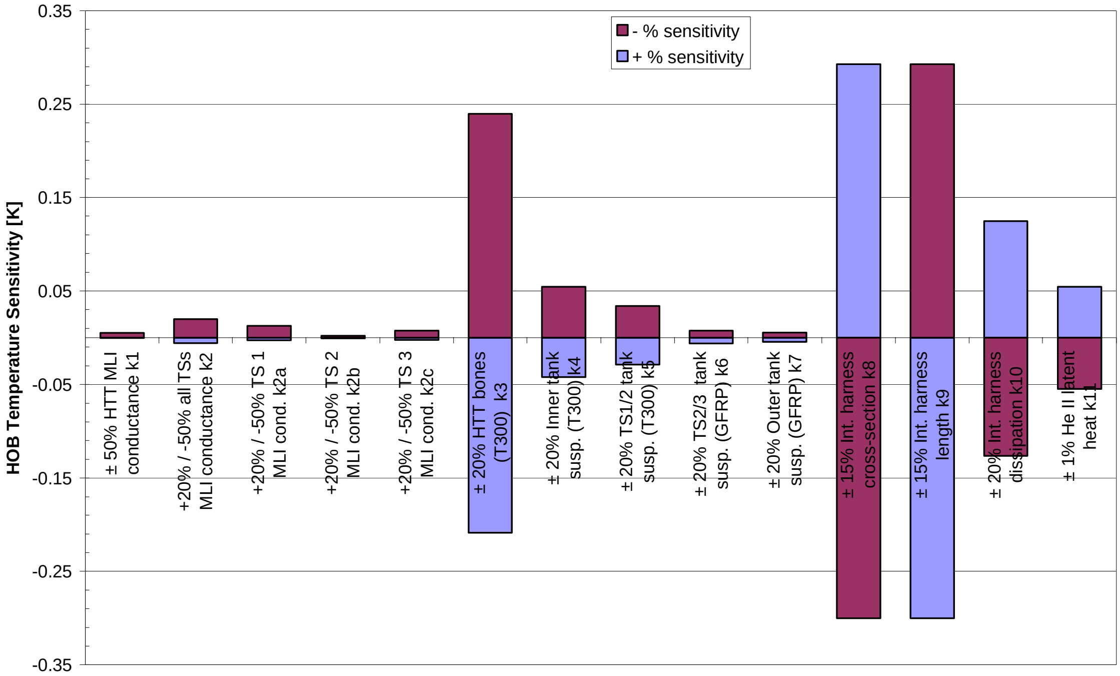


Figure 7.3-8: Sensitivity of HOB Temperature for Operation at L2

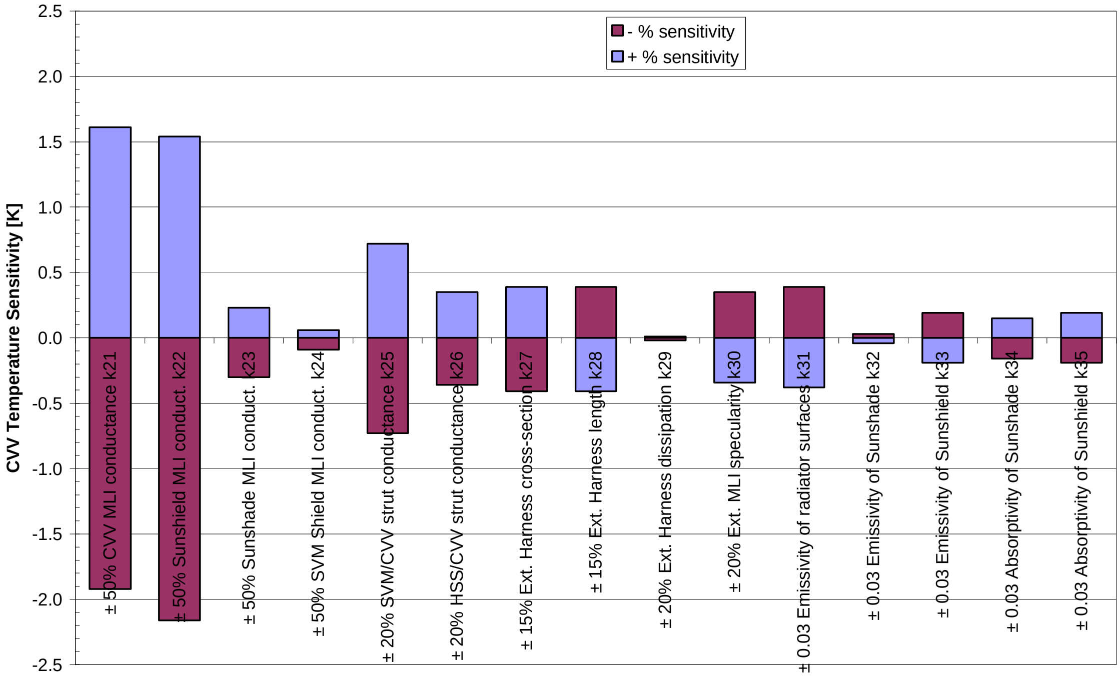


Figure 7.3-9: Sensitivity of CVV Temperature for Operation at L2

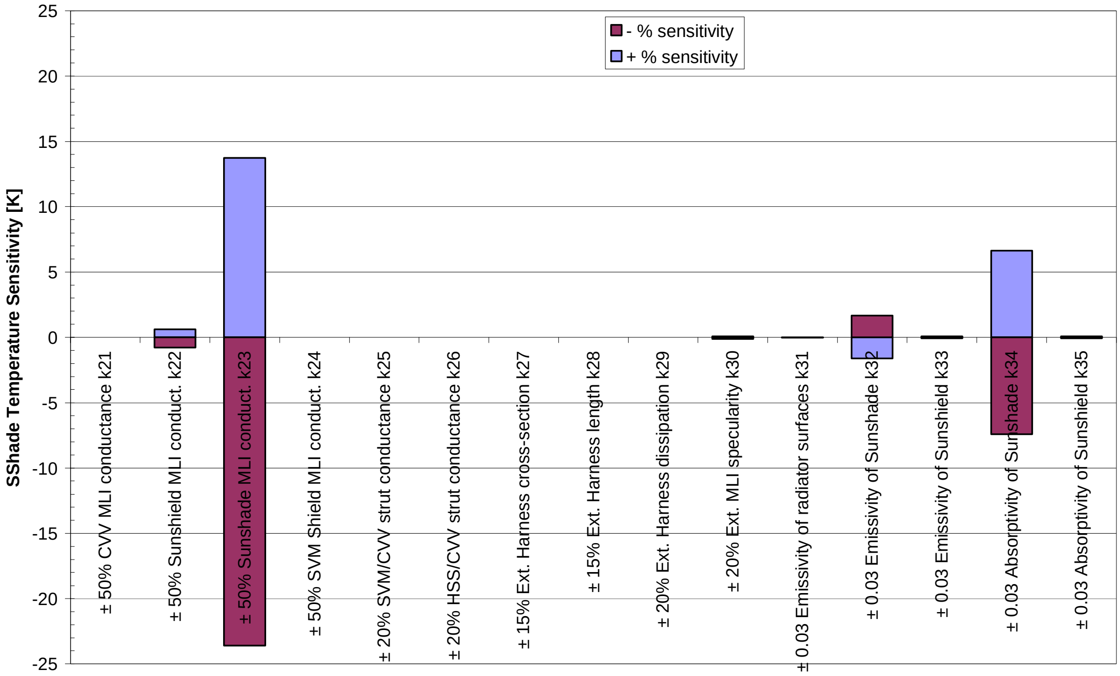


Figure 7.3-10: Sensitivity of Sunshade MLI Temperature for Operation at L2

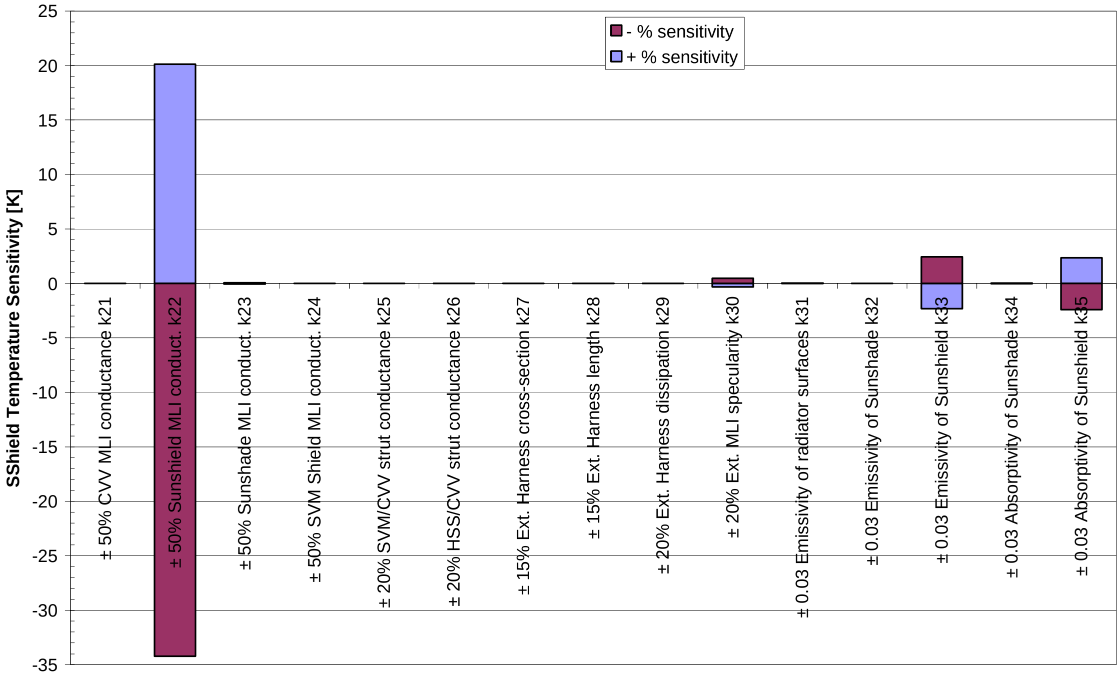


Figure 7.3-11: Sensitivity of Solar Array MLI Temperature for Operation at L2

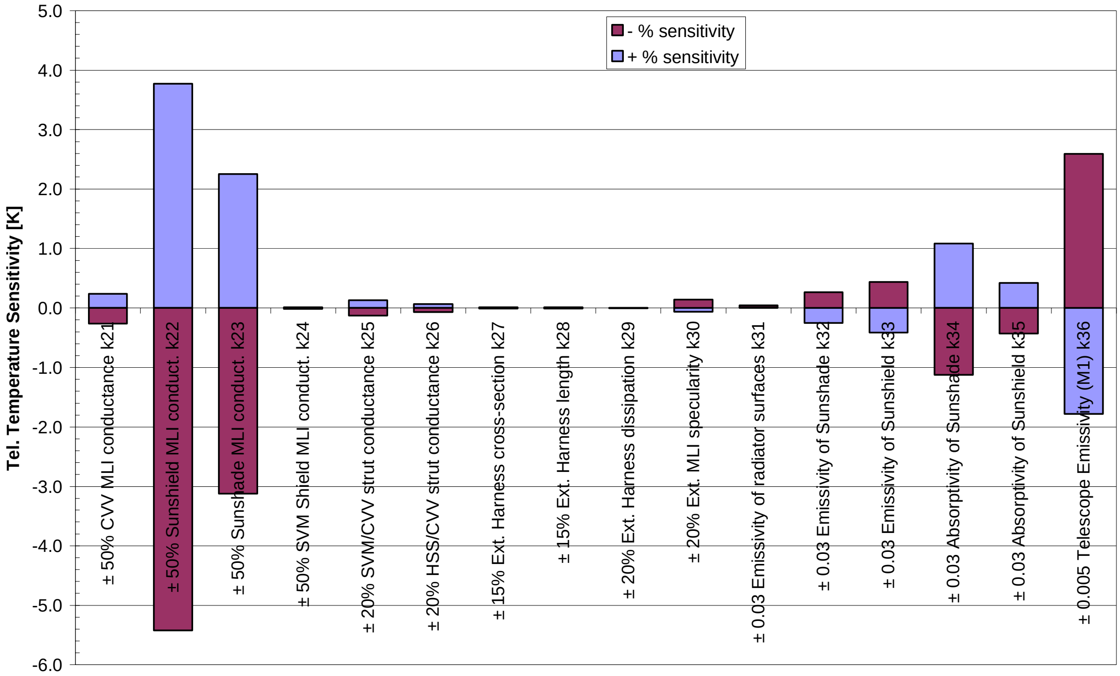


Figure 7.3-12: Sensitivity of Telescope Temperature for Operation at L2

7.3.3 Transient Spacecraft Operations

A transient analysis run has been performed for in-orbit rotation of the Herschel S/C by 30° around Y-axis. The transient cool-down curves of Telescope, LOU, CVV and HTT in this case are shown in the following figures.

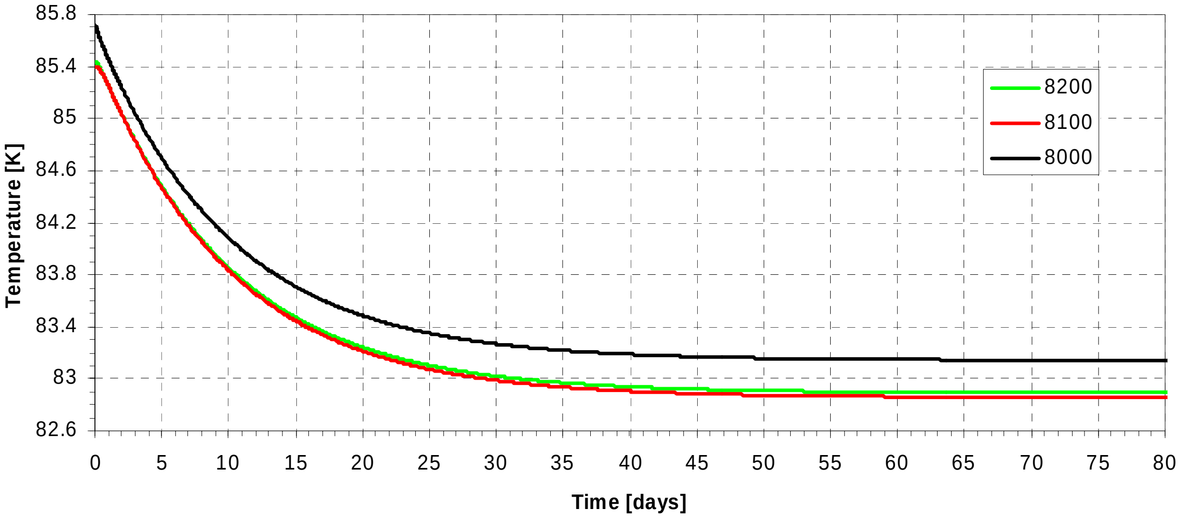


Figure 7.3-13: Transient Cool-Down of Telescope after S/C Rotation 30° around Y-Axis (Issue 3 status)

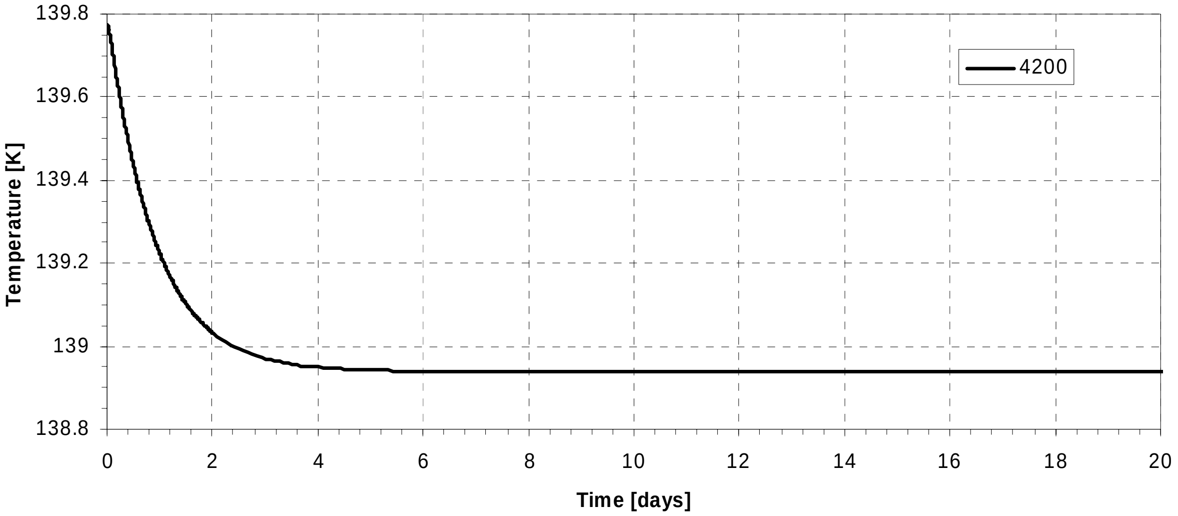


Figure 7.3-14: Transient Cool-Down of LOU Baseplate after S/C Rotation 30° around Y-Axis (Issue 3 status)

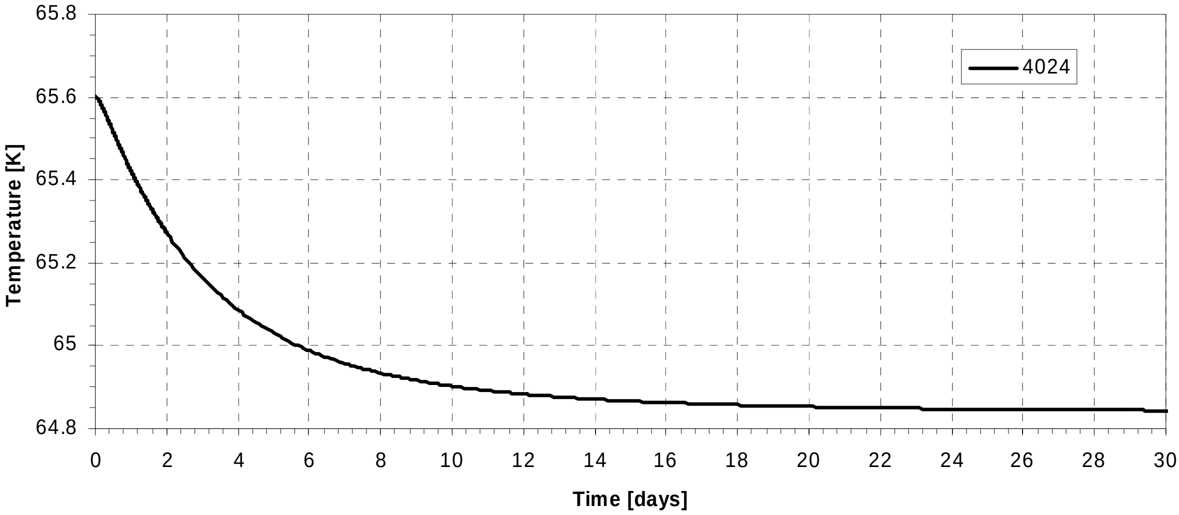


Figure 7.3-15: Transient Cool-Down of CVV after S/C Rotation 30° around Y-Axis (Issue 3 status)

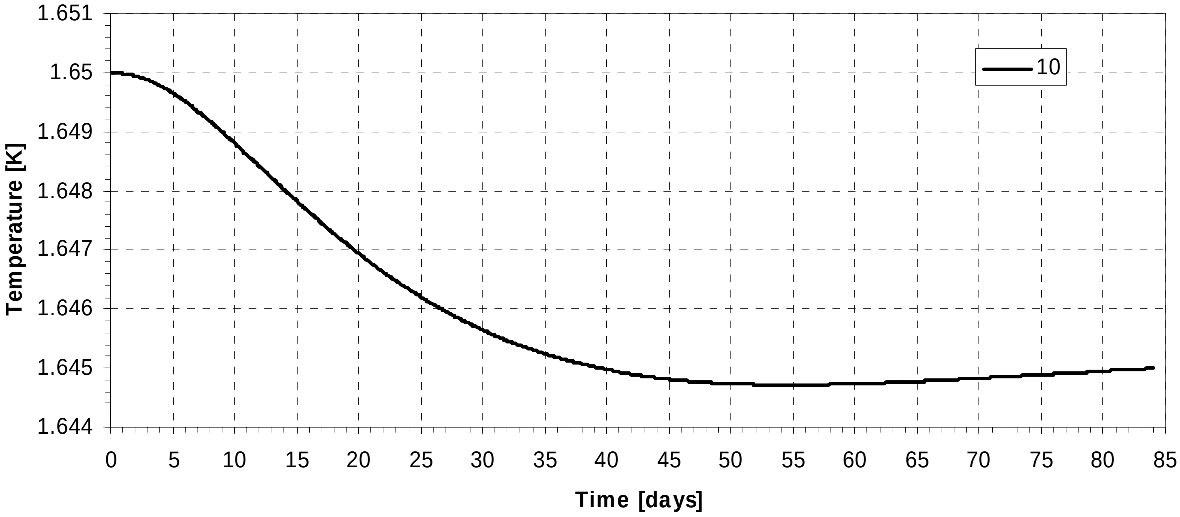


Figure 7.3-16: Transient Cool-Down of HTT after S/C Rotation 30° around Y-Axis (Issue 3 status)

7.4 Instrument Operation in L2 Orbit

The transient temperature and heat flow results for the instrument thermal interface nodes shown in this section are based on the following instrument timeline:

Start conditions (steady state):	Instruments average dissipation
PACS Photometer Mode (incl. sorption cooler cycle)	48 h
SPIRE	48 h
HIFI	48 h
SPIRE	48 h
PACS Spectrometer Mode (no sorption cooler cycle)	24 h
HIFI	48 h
PACS Spectrometer Mode (no sorption cooler cycle)	24 h

The analysis results shown in Section 7.4.1 till 7.4.4 are performed for hot case conditions with a remaining He II mass of 5 kg (EOL) at beginning of the simulation.

Please note that the L0 temperatures will have an uncertainty of about 60 mK (mean root square of 50 mK due to the uncertainty of the HTT temperature and 25 mK due to sensitivity analysis results obtained with Issue 2 TMM).

Further analyses have been performed to investigate the effect of cold case conditions at L2 and to compare the result at EOL with the performance of an almost full Helium tank (BOL). Those results are shown in Section 7.4.5.

7.4.1 PACS Interface Temperatures and Heat Flows

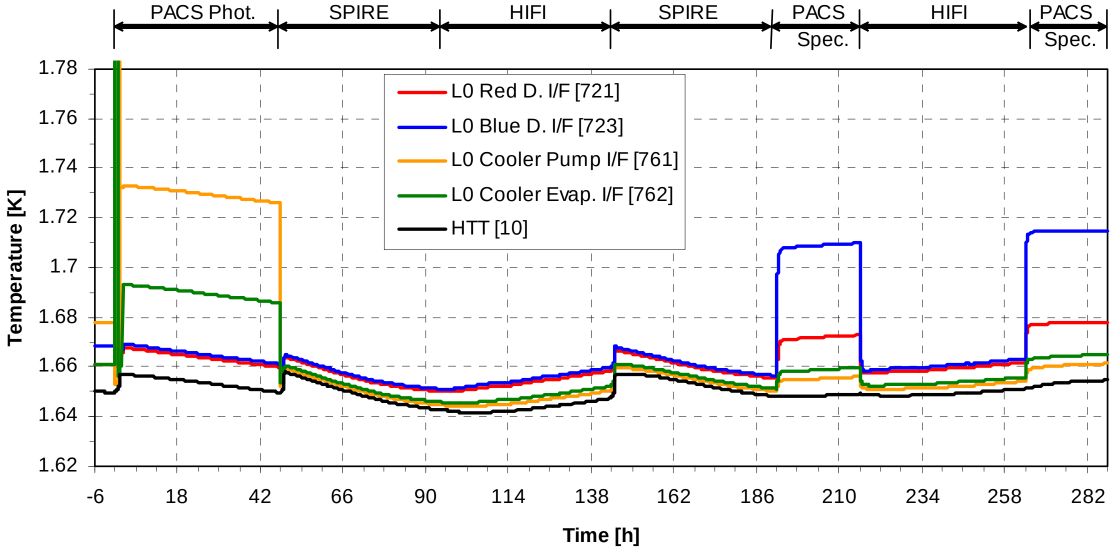


Figure 7.4-1: PACS L0 Interface Temperatures

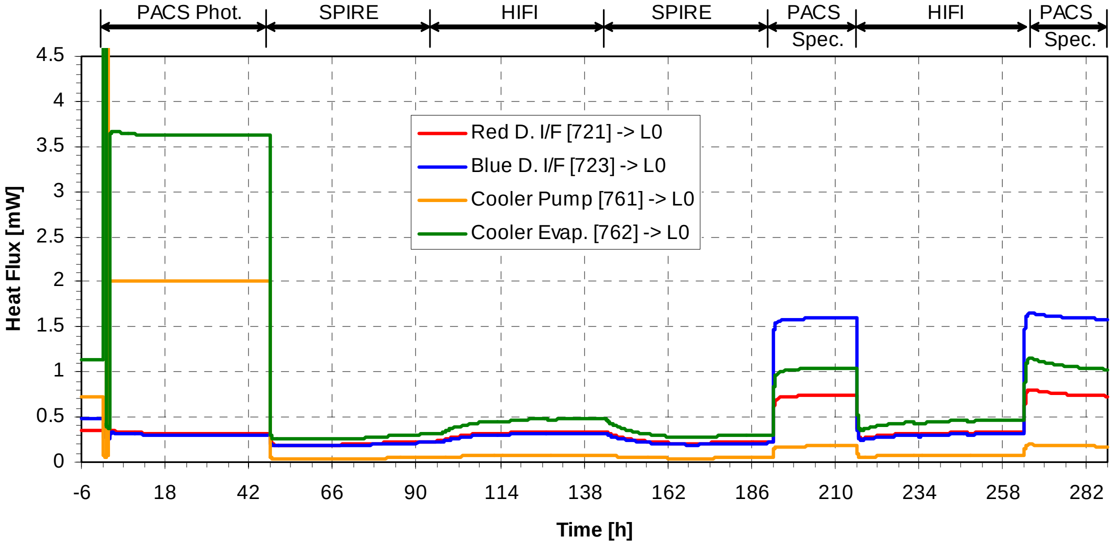


Figure 7.4-2: PACS L0 Interface Heat Flows

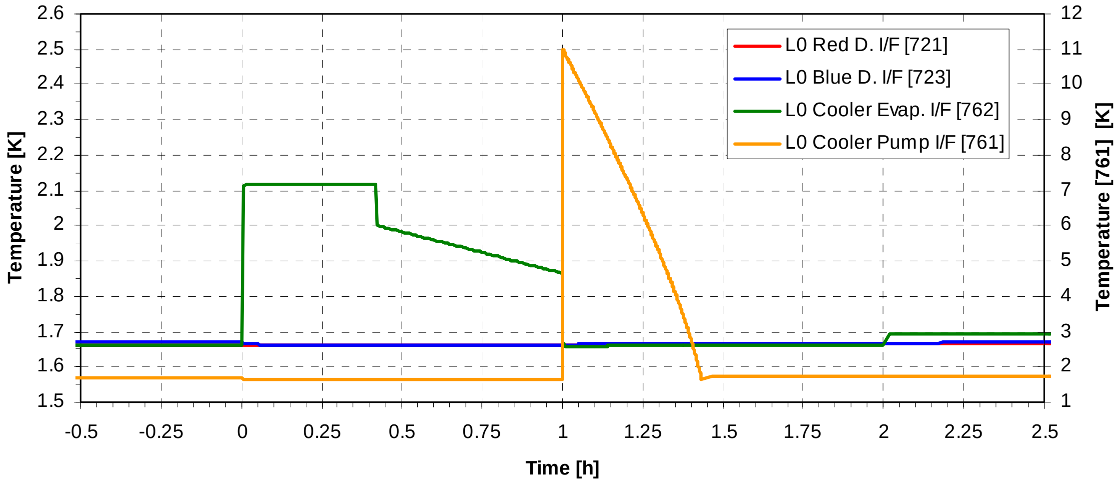


Figure 7.4-3: PACS L0 Interface Temperatures during Recycling

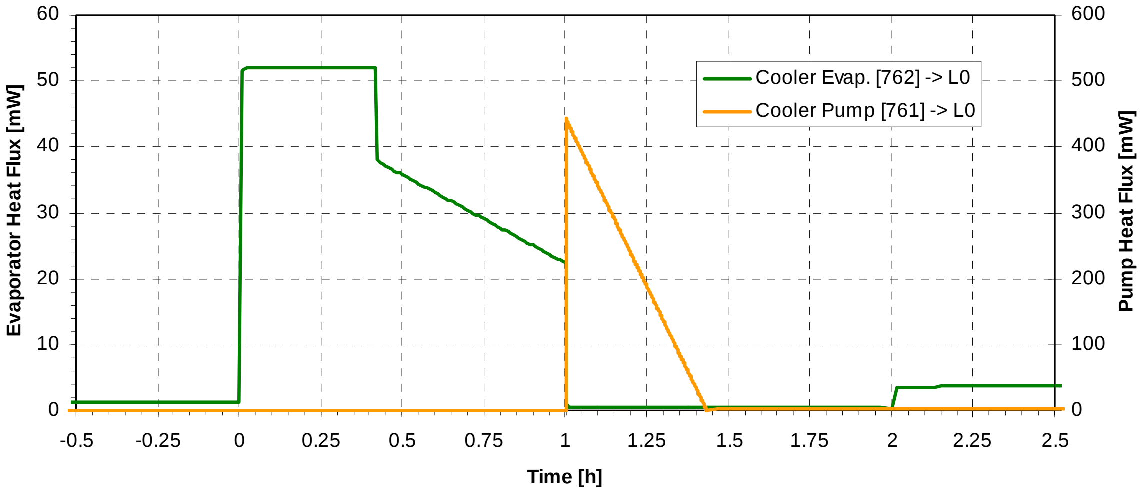


Figure 7.4-4: PACS L0 Interface Heat Flows during Recycling

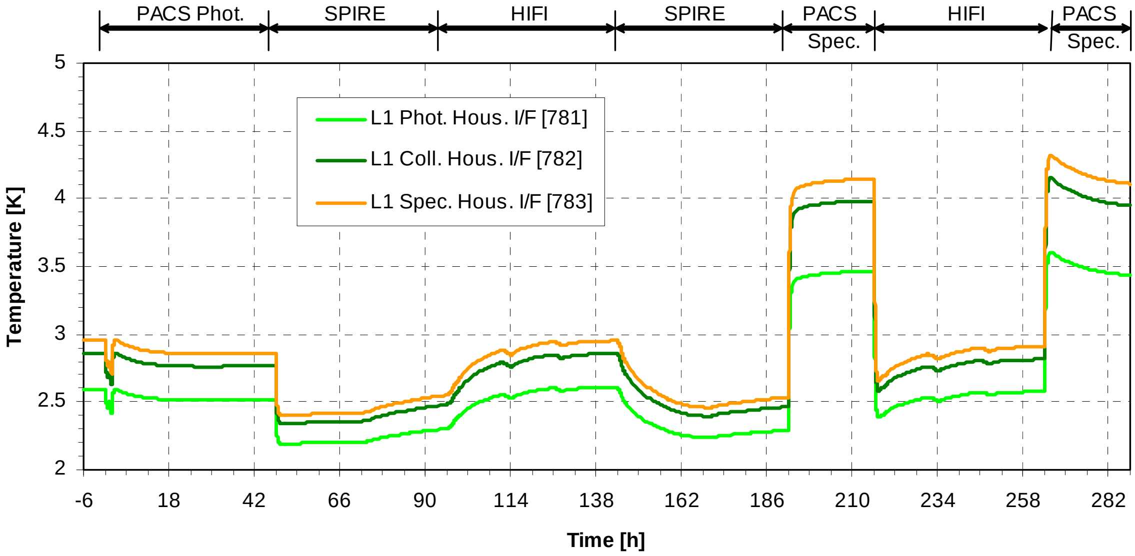


Figure 7.4-5: PACS L1 Interface Temperatures

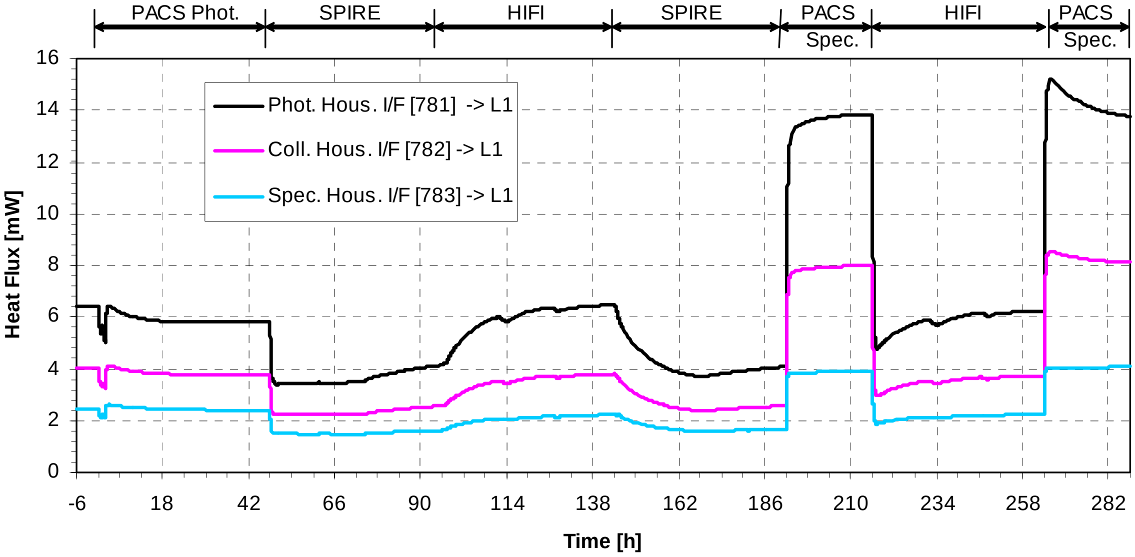


Figure 7.4-6: PACS L1 Interface Heat Flows

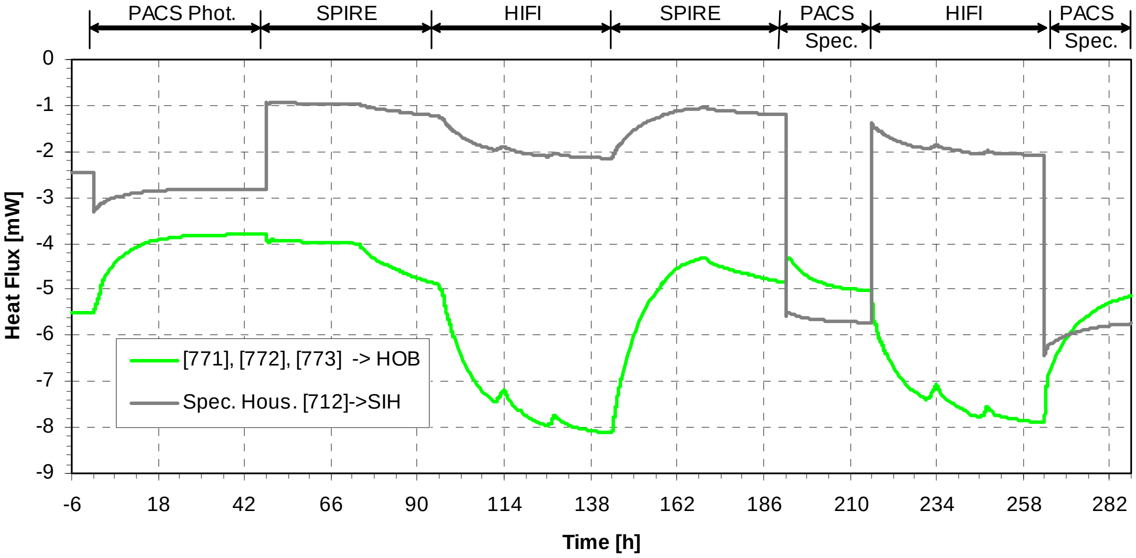


Figure 7.4-7: PACS L2 Interface Heat Flows

7.4.2 SPIRE Interface Temperatures and Heat Flows

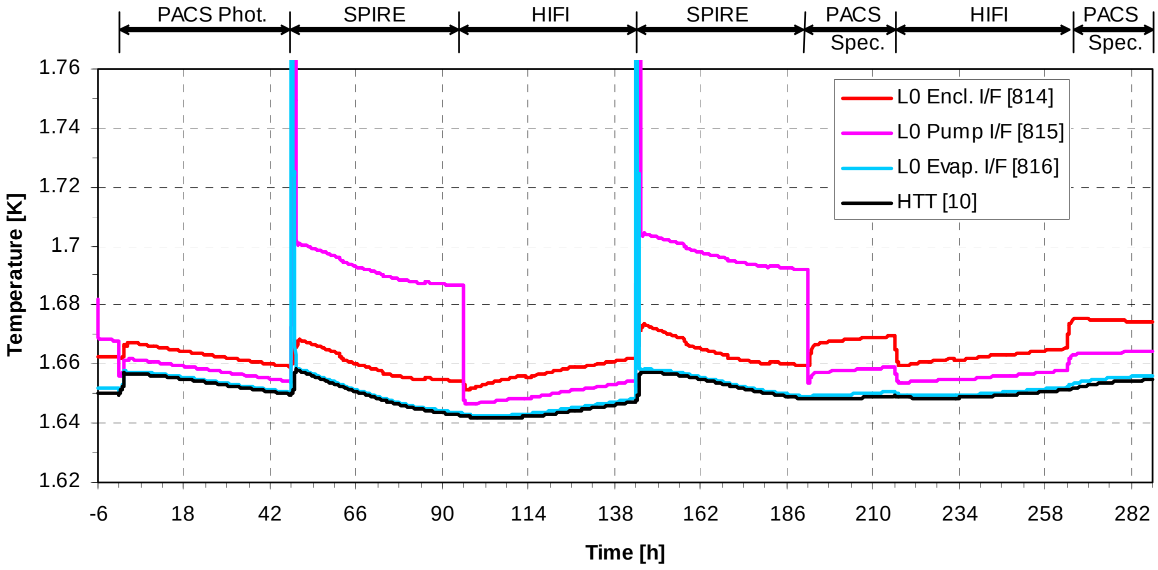


Figure 7.4-8: SPIRE L0 Interface Temperatures

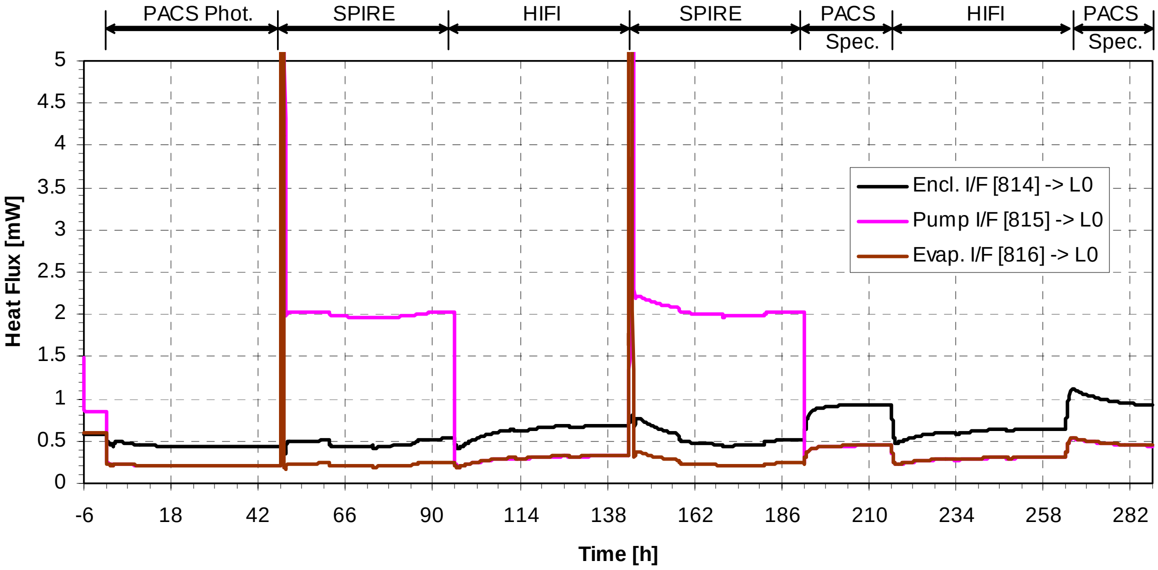


Figure 7.4-9: SPIRE L0 Interface Heat Flows

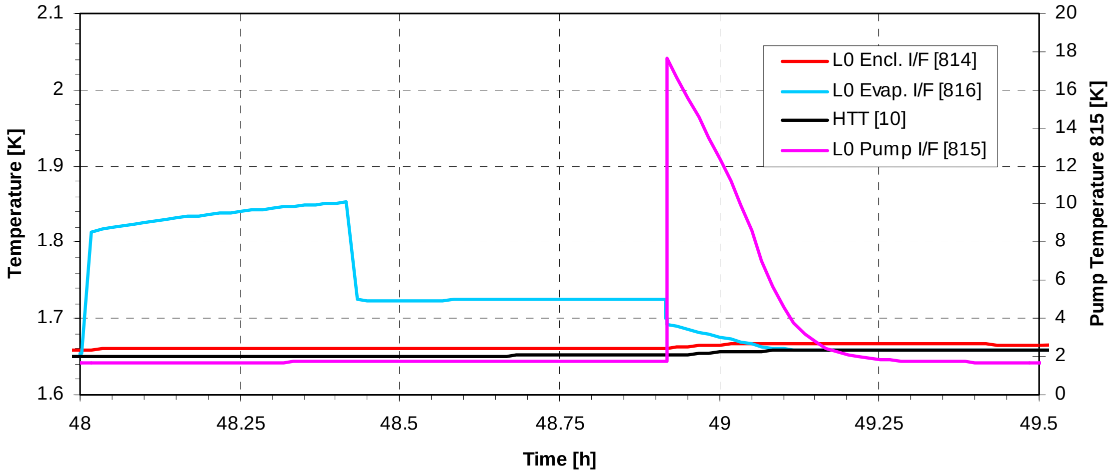


Figure 7.4-10: SPIRE L0 Interface Temperatures during Recycling

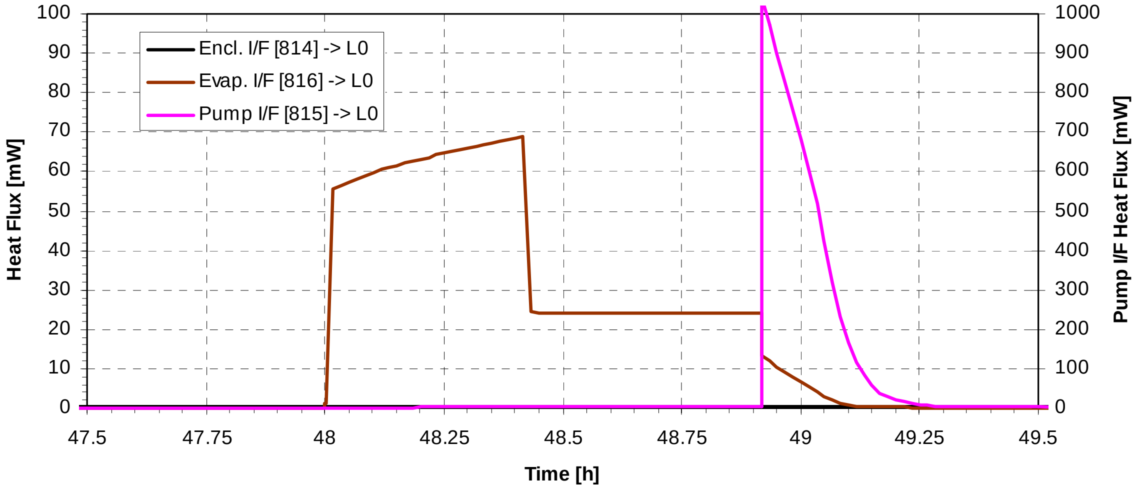


Figure 7.4-11: SPIRE L0 Interface Heat Flows during Recycling

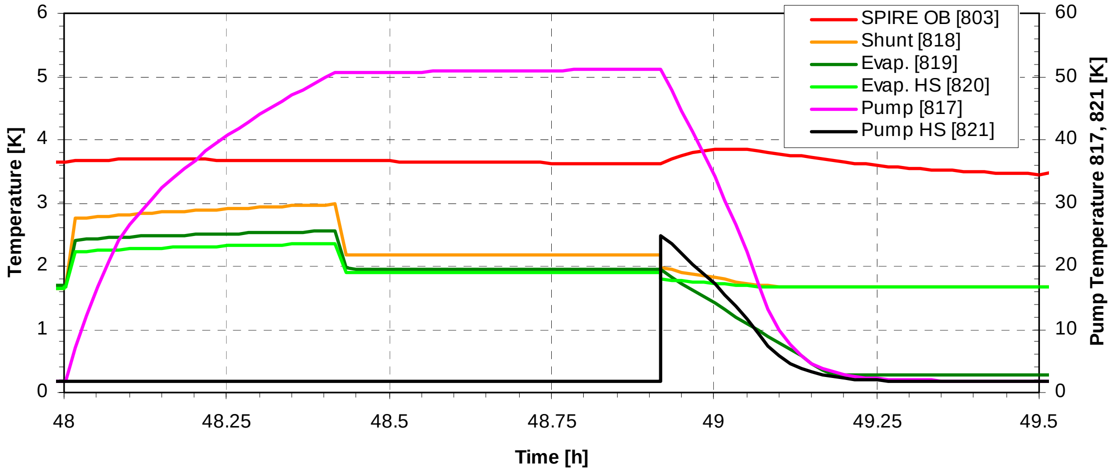


Figure 7.4-12: SPIRE Cooler Temperatures during Recycling (for information)

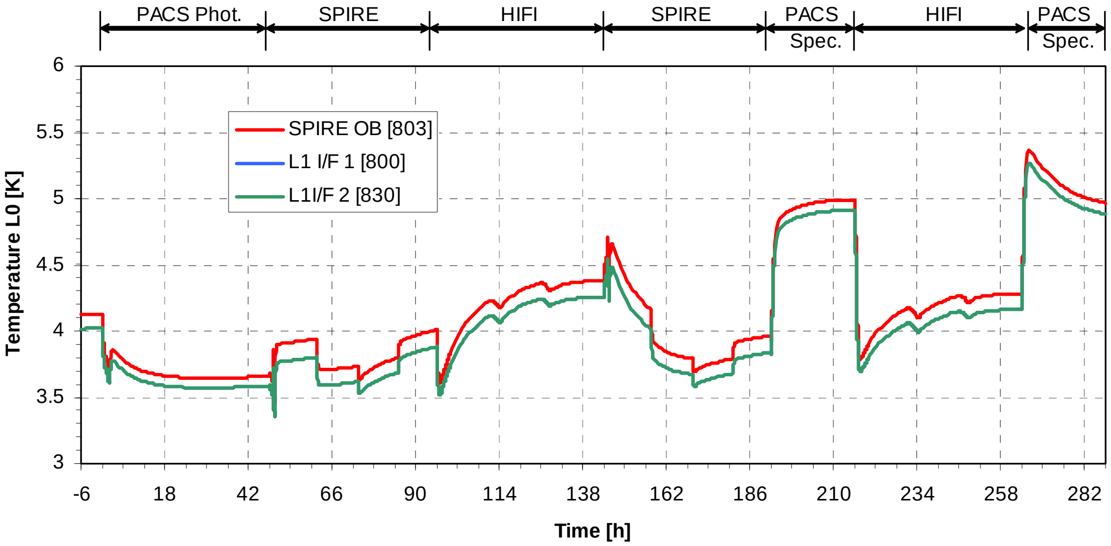


Figure 7.4-13: SPIRE L1 Interface Temperatures

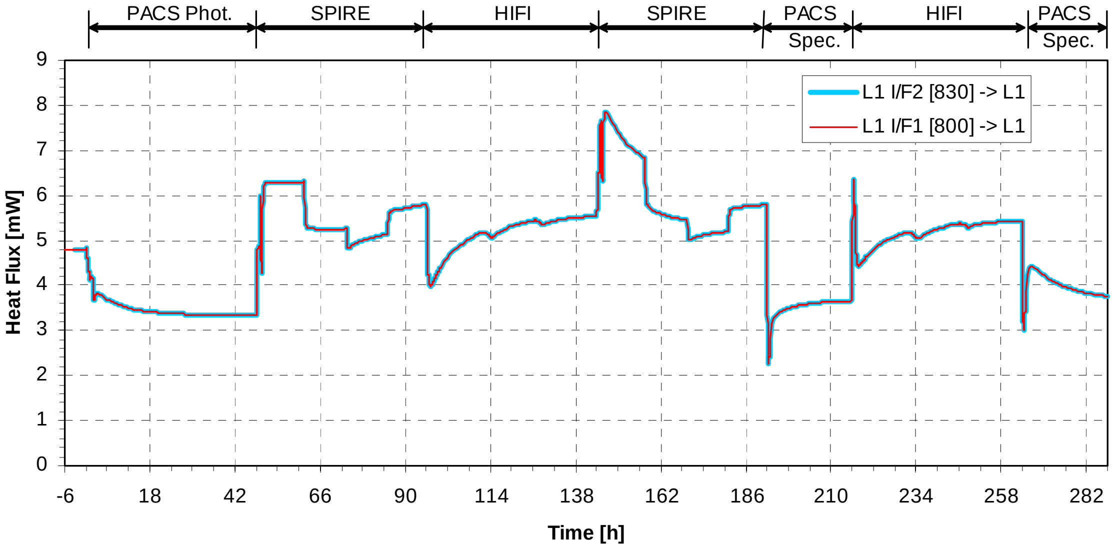


Figure 7.4-14: SPIRE L1 Interface Heat Flows

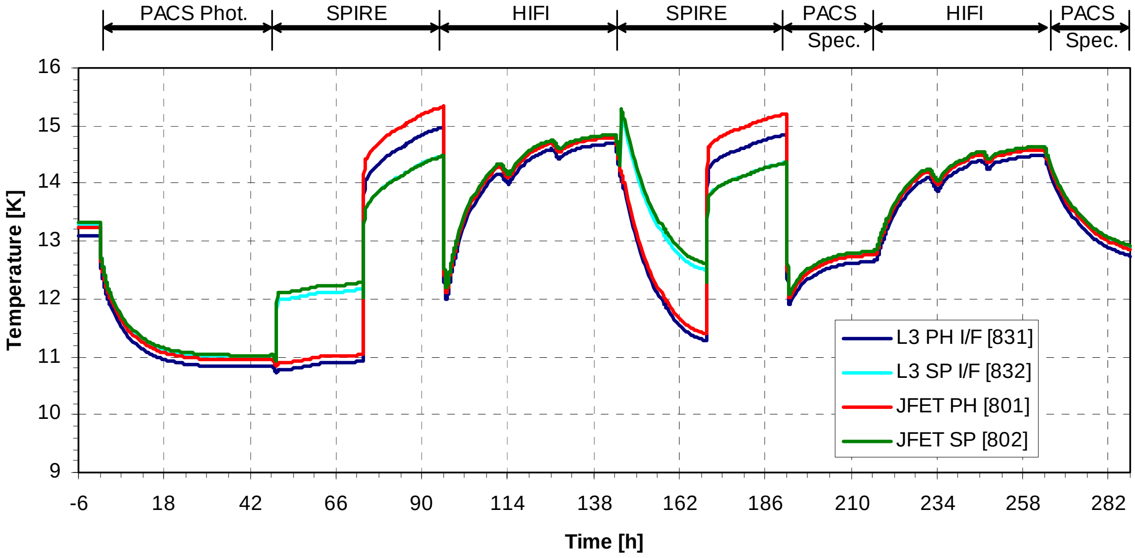


Figure 7.4-15: SPIRE L3 Interface Temperatures

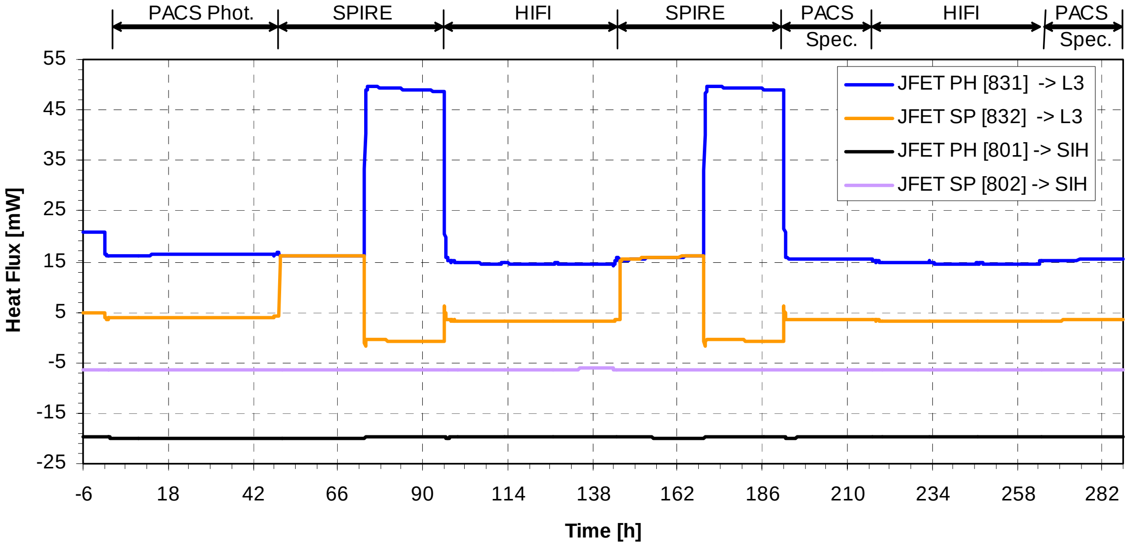


Figure 7.4-16: SPIRE L3 Interface Heat Flows

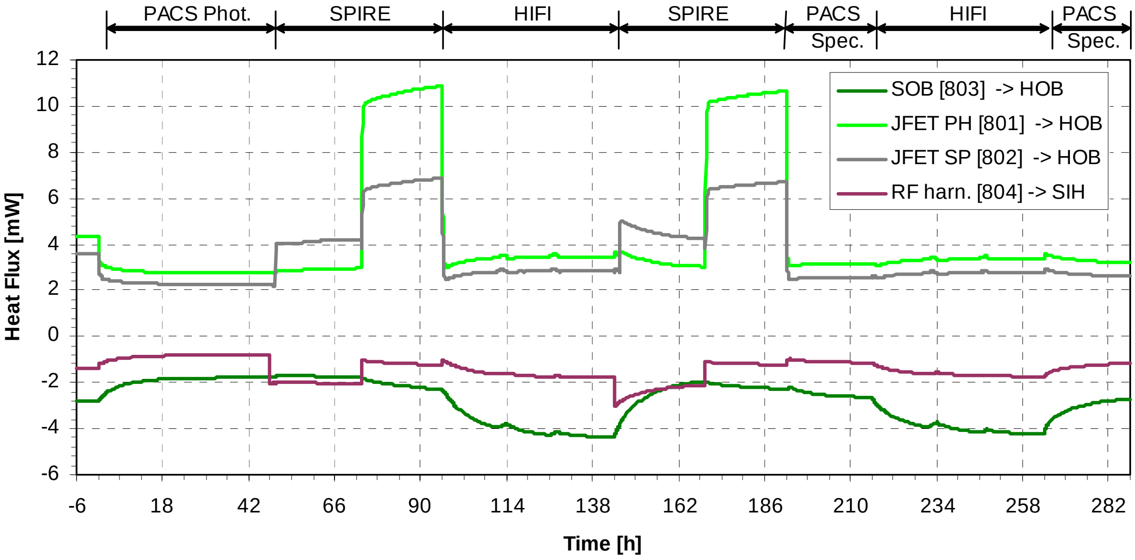


Figure 7.4-17: SPIRE L2 Interface Heat Flows

7.4.3 HIFI Interface Temperatures and Heat Flows

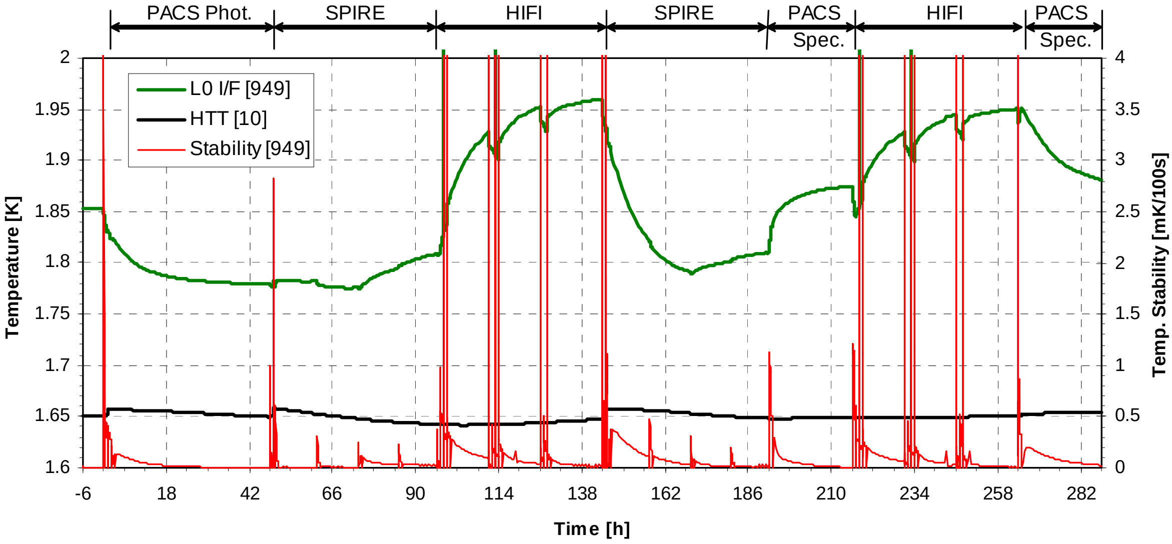


Figure 7.4-18: HIFI L0 Interface Temperature and Stability

Note that the temperature change peaks of HIFI are caused by short heat peak phases due to dissipation switching.

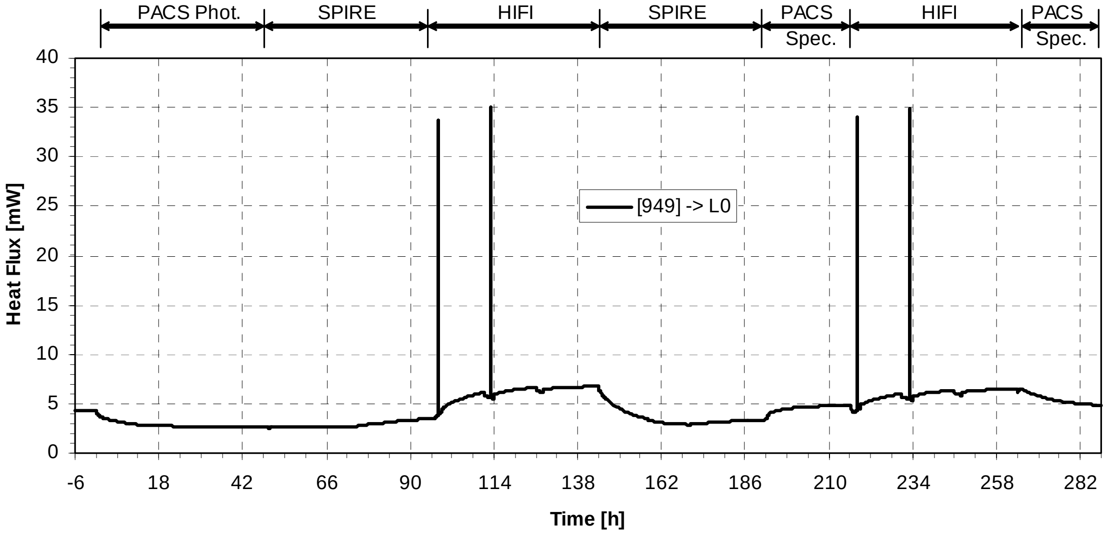


Figure 7.4-19: HIFI L0 Interface Heat Flow

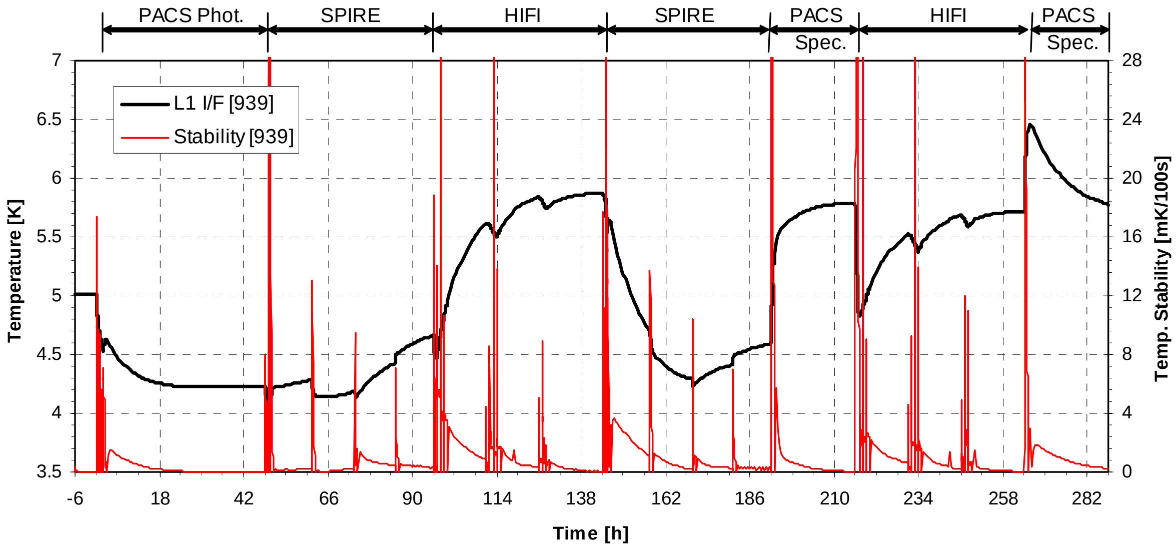


Figure 7.4-20: HIFI L1 Interface Temperature and Stability

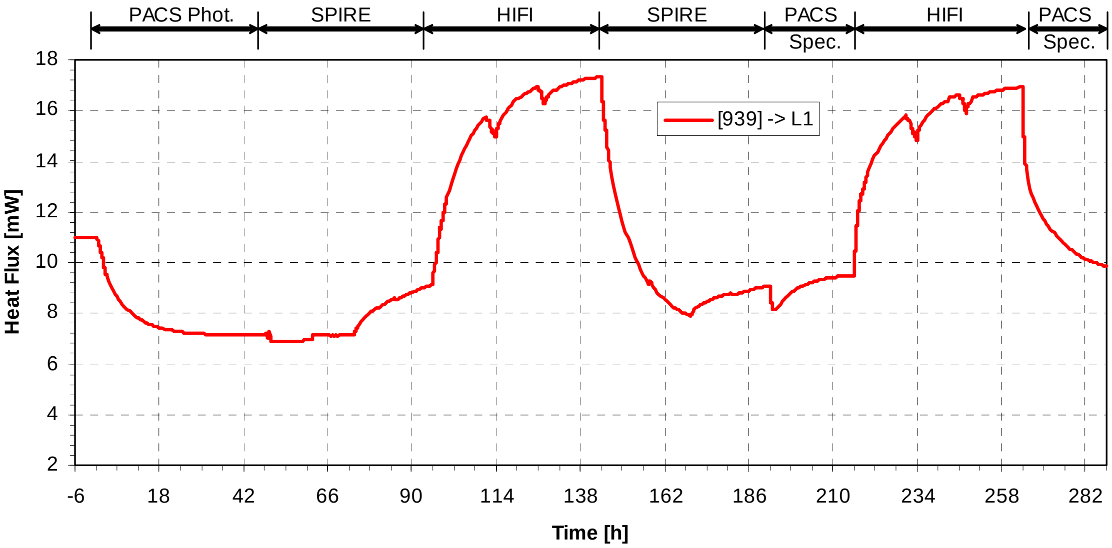


Figure 7.4-21: HIFI L1 Interface Heat Flow

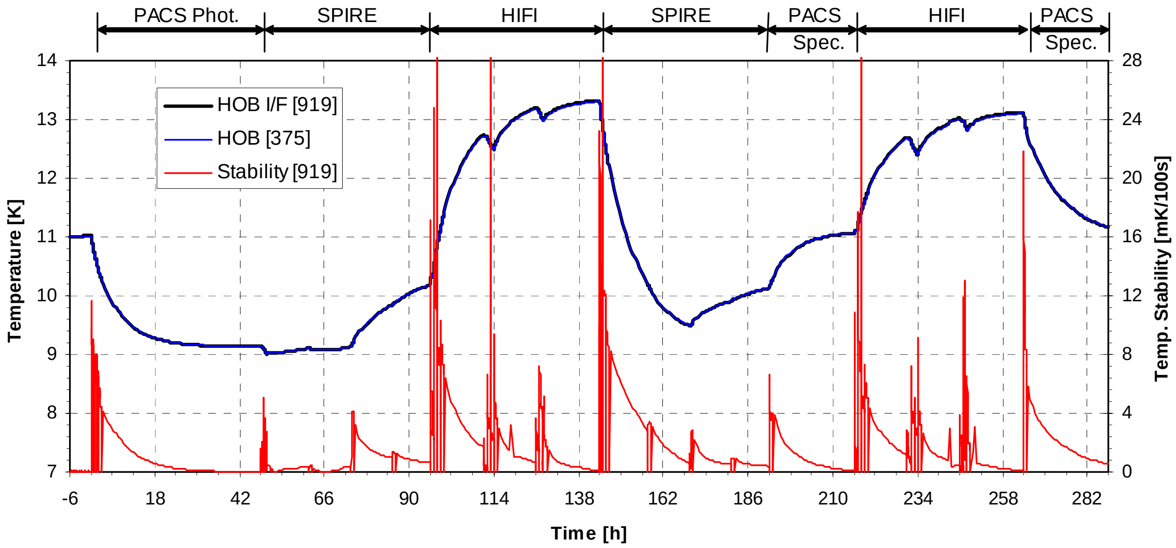


Figure 7.4-22: HIFI L2 Interface Temperature and Stability

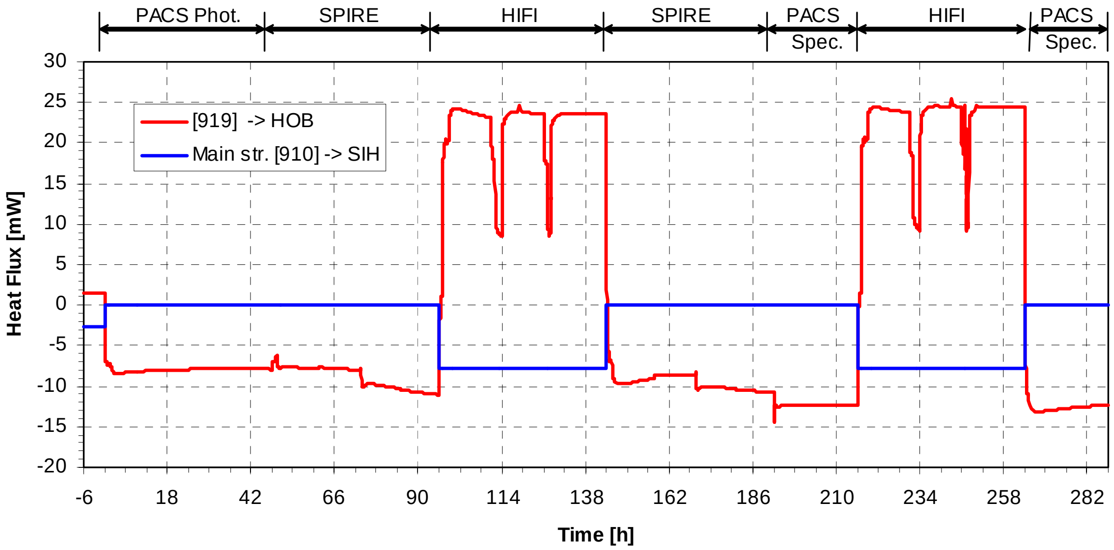


Figure 7.4-23: HIFI L2 Interface Heat Flow

7.4.4 Instrument Heat Load on HTT and He Mass Flow

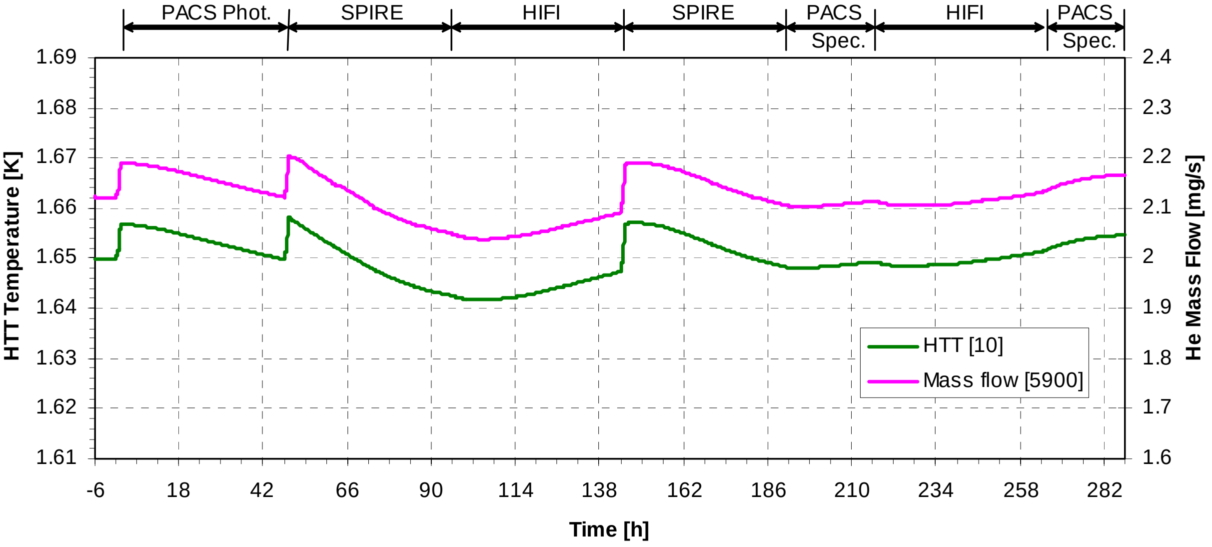


Figure 7.4-24: HTT Temperature and He Mass Flow Rate

	Average instrument dissipation	**Average instrument I/F heat flow**	**HERS-0530 AD 03**	**Remark**
Level 0	3.14 mW	10.1 mW	**10 mW**	
Level 1	3.94 mW	34.3 mW	**25 mW**	
Level 2	12.28 mW	0.4 mW	**35 mW**	L2 I/F heat flow is ~0 due to cooling via PACS and SPIRE L1 I/F
Level 3	8.98 mW	26.2 mW	**15 mW**	SPIRE JFET's

Table 7.4-1: Average Instrument Dissipation versus IID-A Allocation

Table 7.4-1 shows the discrepancy between the IID-A values taken for lifetime calculation and the actual I/F heat loads calculated with the current Instrument TMMs.

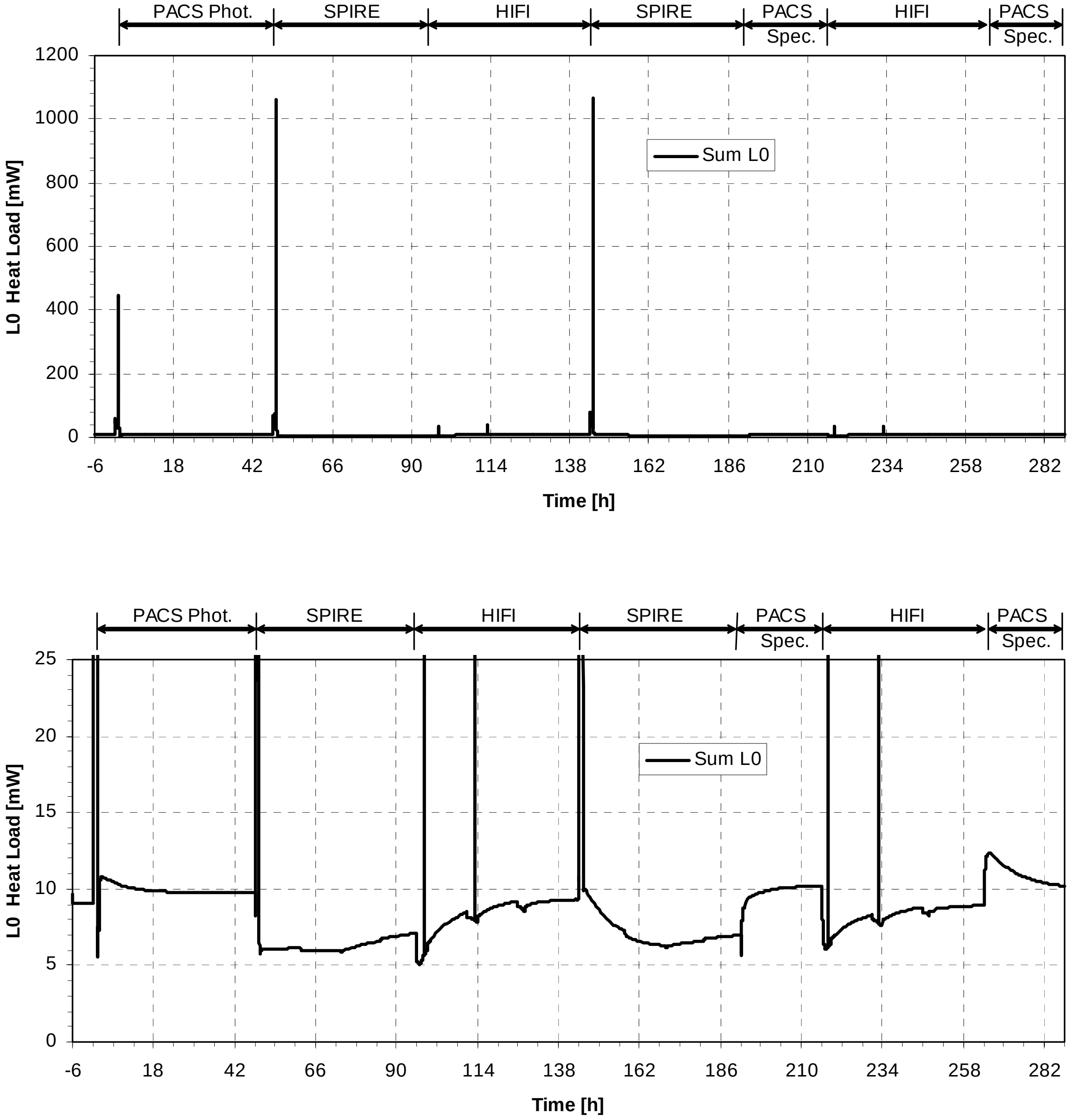


Figure 7.4-25: Total Instrument I/F Heat Load on HTT (different scales on Y-axis)

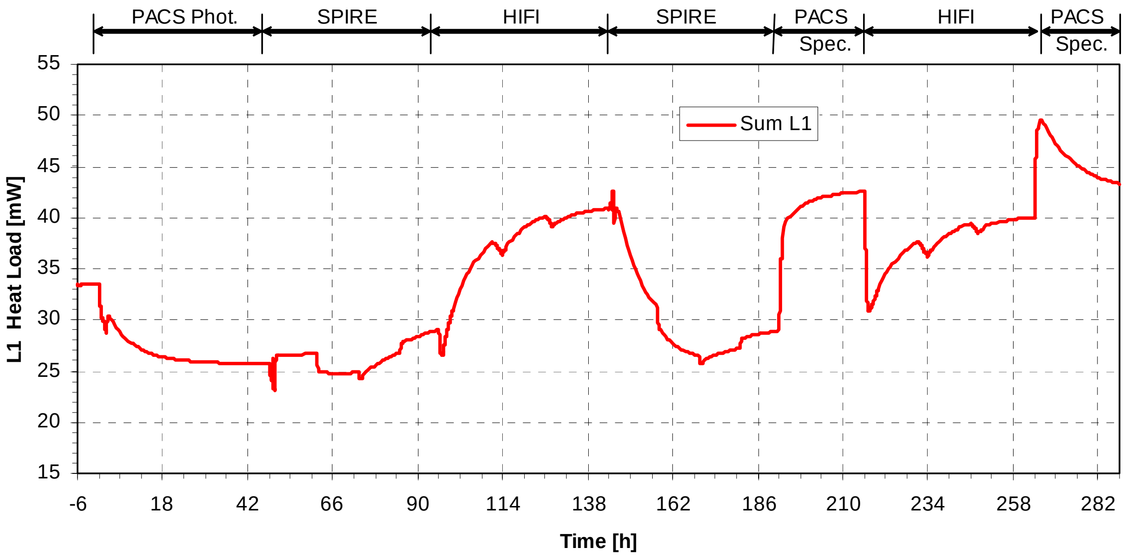


Figure 7.4-26: Total Instrument I/F Heat Load on L1 Ventline

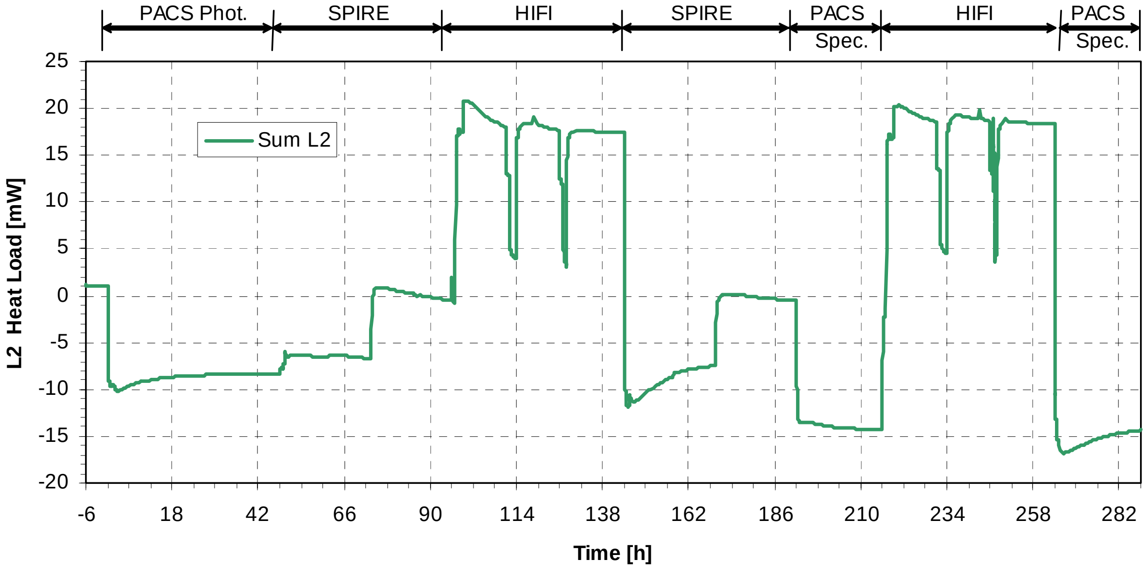


Figure 7.4-27: Total Instrument I/F Heat Load on L2 (Optical Bench Plate)

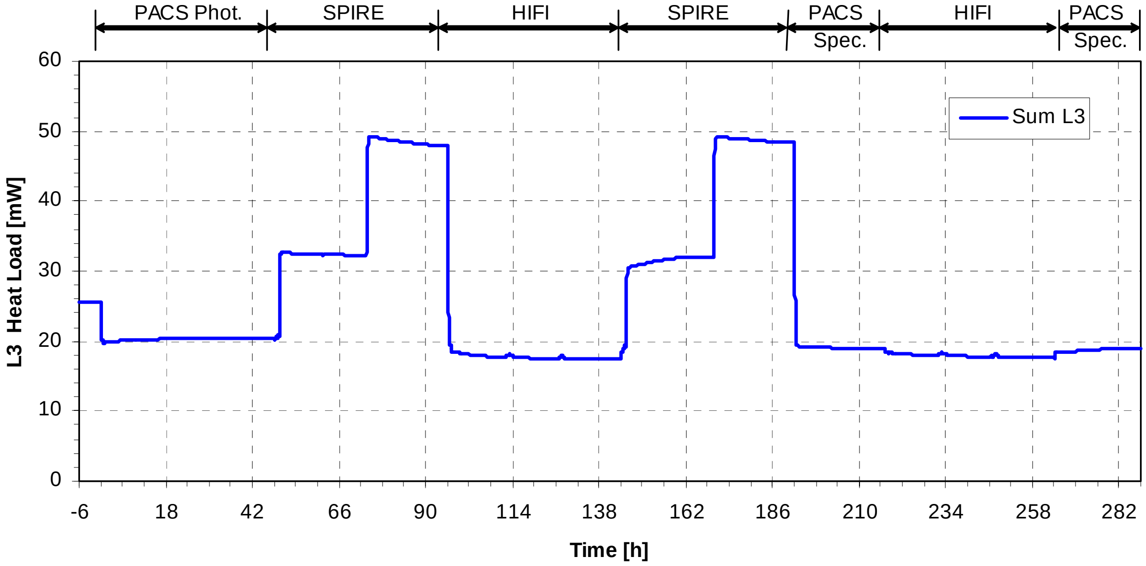


Figure 7.4-28: Total Instrument I/F Heat Load on L3 Ventline

7.4.5 Sensitivity Analysis

The following sensitivities have been performed:

- Hot Case EOL: hot case environment at L2 and 5 kg He in the tank
- Cold Case EOL: cold case environment at L2 and 5 kg He in the tank
- Hot Case BOL: hot case environment at L2 and 300 kg He in the tank

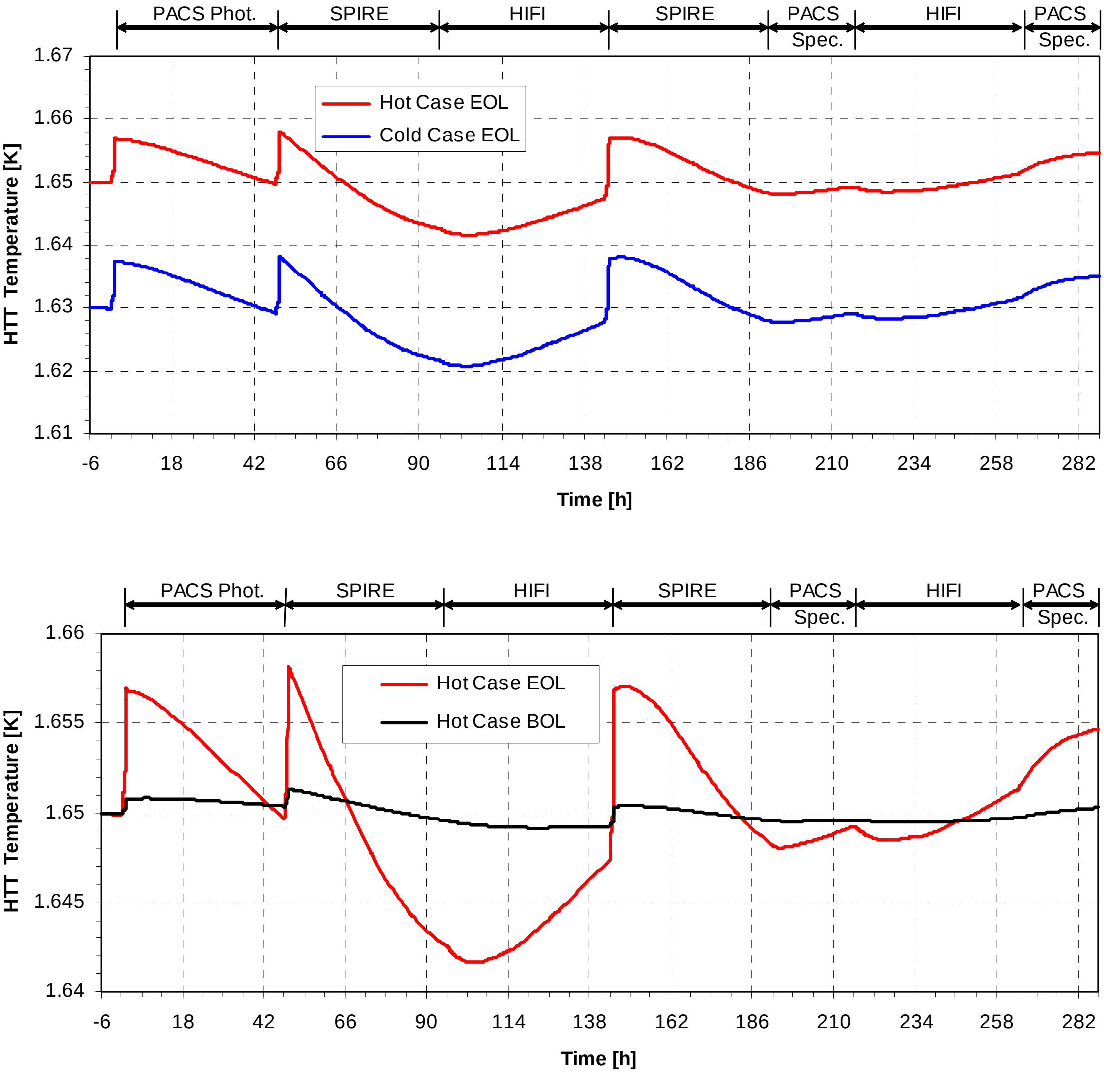
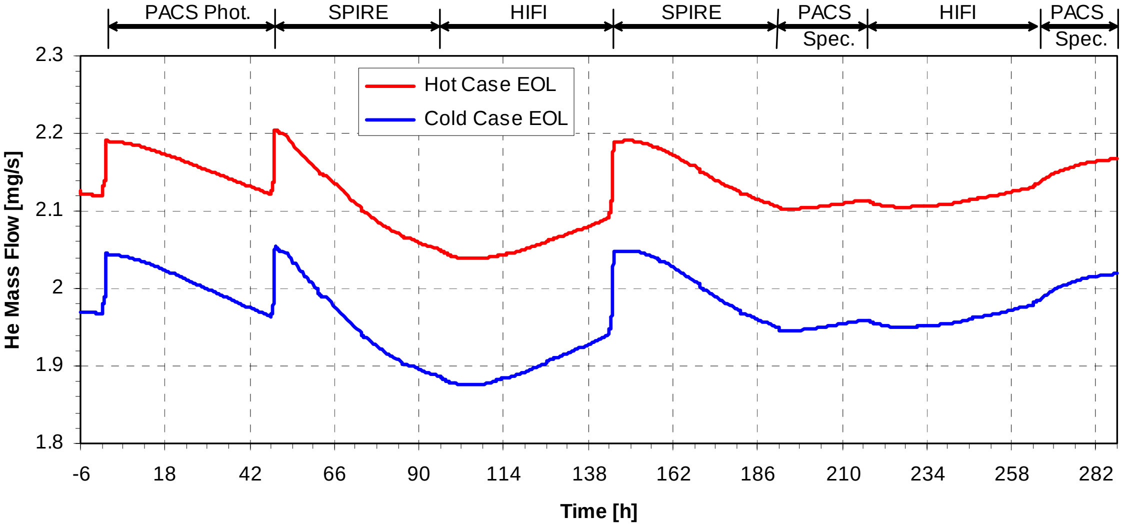


Figure 7.4-29: HTT Temperature for Different Conditions



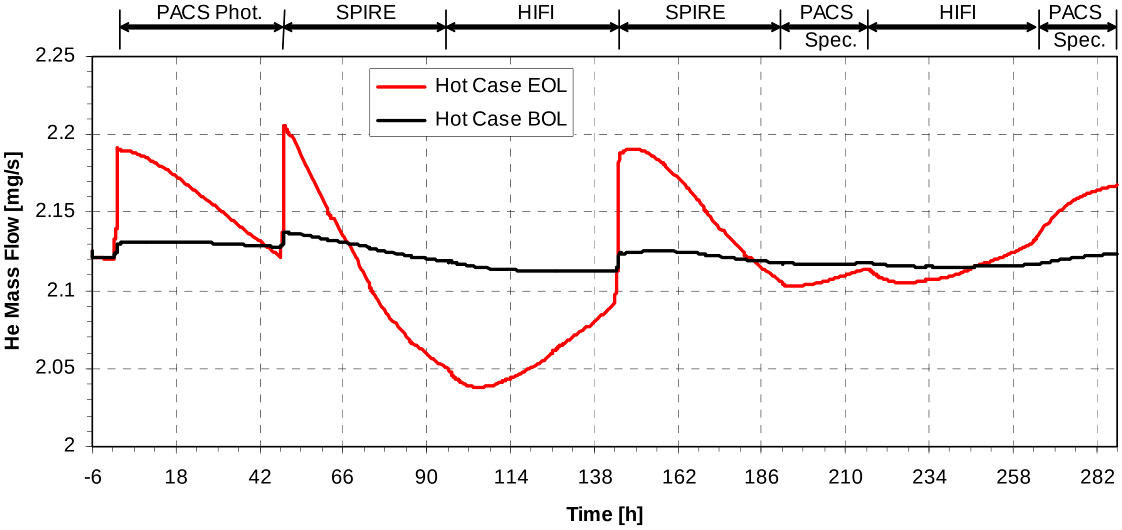


Figure 7.4-30: Helium Mass Flow for Different Conditions

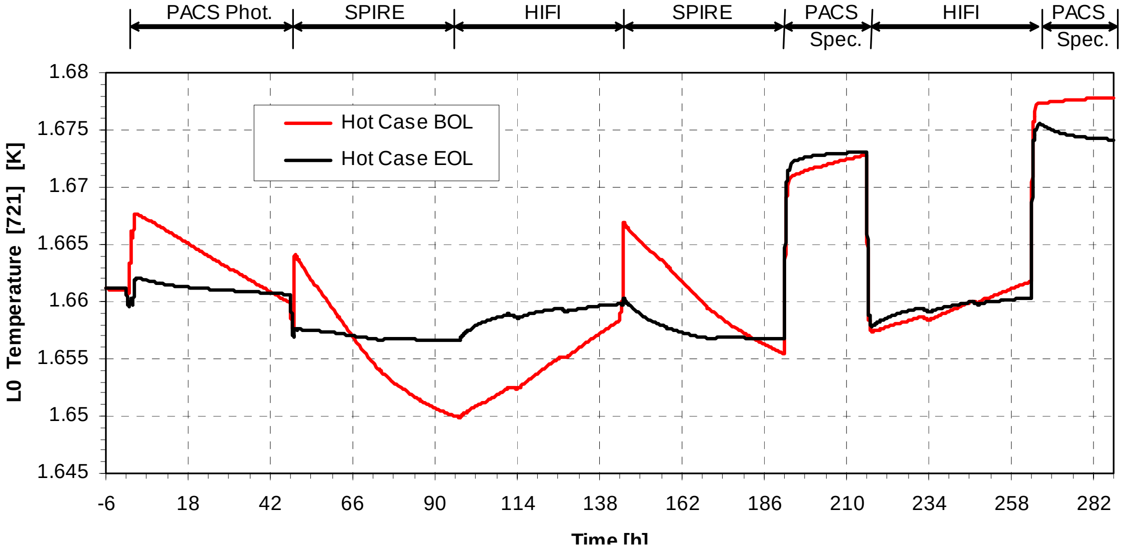


Figure 7.4-31: PACS L0 Temperature for Different Conditions

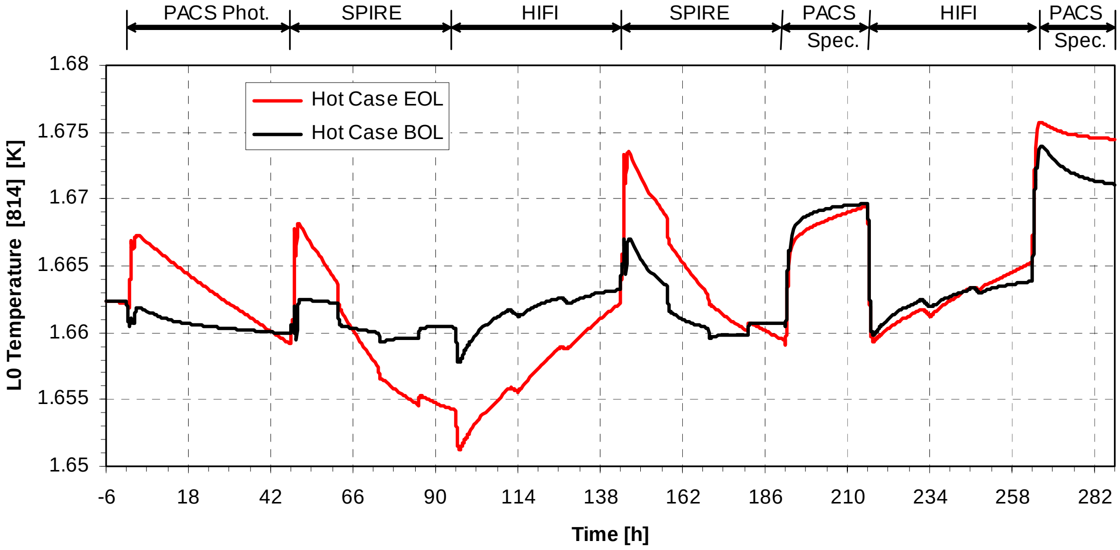


Figure 7.4-32: SPIRE L0 Temperature for Different Conditions

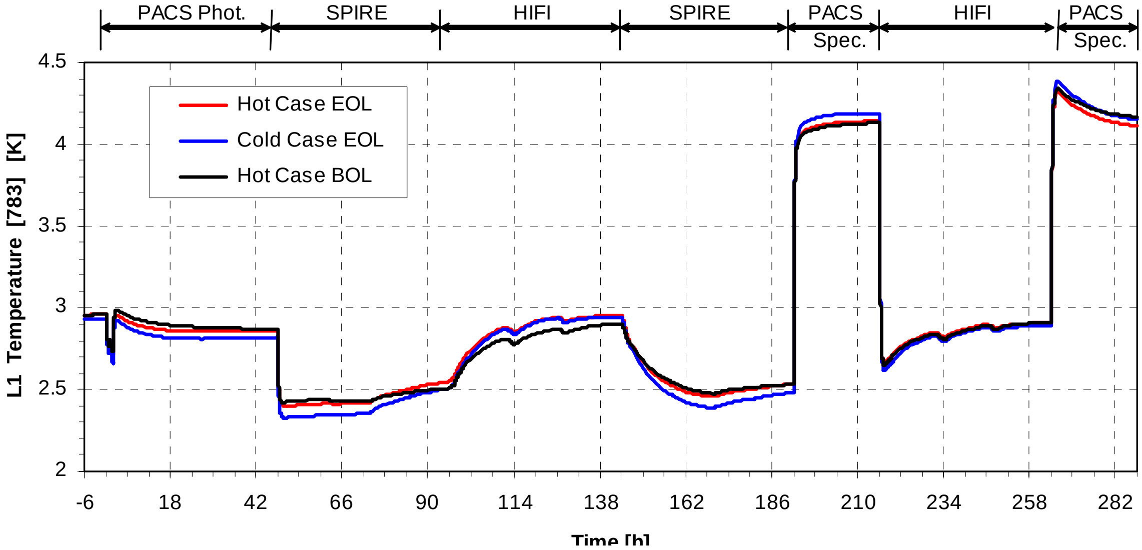


Figure 7.4-33: PACS L1 Temperature for Different Conditions

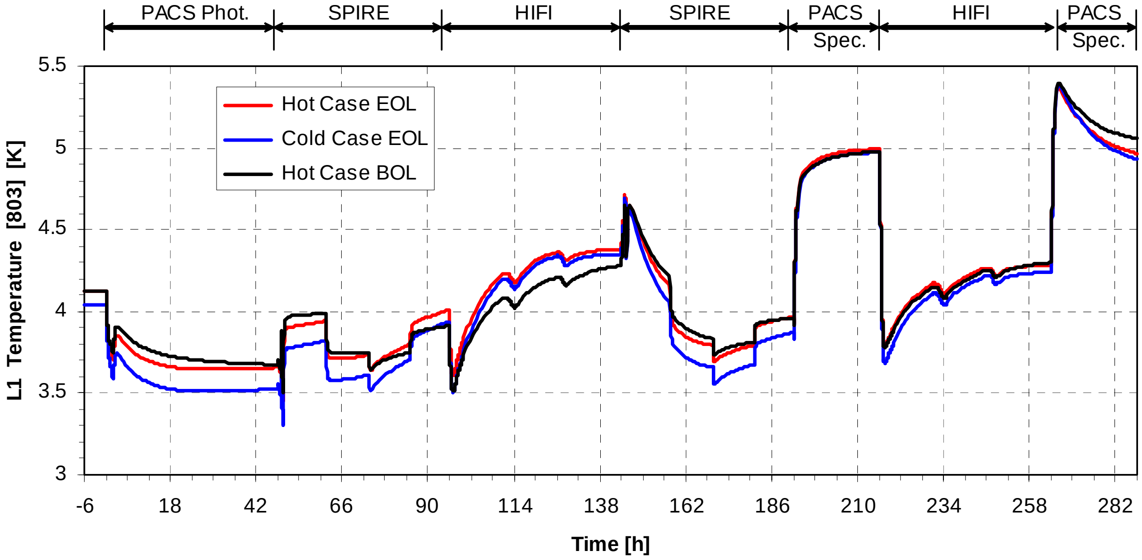


Figure 7.4-34: SPIRE L1 Temperature for Different Conditions

7.5 Lifetime Calculation

A thermal analysis run with implemented IID-A heat load allocations have been performed for the average thermal environment at L2 as defined in RD 01. This run has been performed to calculate the He mass flow relevant for the "contractual" lifetime.

According to the lifetime calculation formula described in section 4.2, the expected lifetime is calculated following:

m_n = 0.98 /1.15 * 145.338 kg/m³ * 2.367m³ = 293.16 kg
m_{trans} = 17.2 kg (output of section 7.2)
$m_{residual}$ = 0.94 * 0.33 kg/m³ * 2.367m³ = 0.73 kg
M_{He} = 2.267 mg/s
t_{trans} = 48 days (output of section 7.2)
$t_{uncertainty}$ = -126 days (see section 7.3.2)
t_{others} = +37 days

The lifetime compensation t_{others} due to changes introduced by ESA and ASPI is composed of following:

- Enlarged LOU radiator: - 7 days (radiator area increased by about 100 %)
- Startracker on CVV: - 14 days (additional 200 mW heat load to CVV)
- SPIRE overall shield: - 16 days (20 mm² additional stainless steel cross-section for CVV internal harness and 24 mm² additional manganin cross-section for CVV external harness)

Thus, the lifetime formula can be written:

Lifetime [days] = 0.9964*((293.16 kg – 17.2 kg – 0.73 kg)*1E6 / (M_{He} [mg/s]*3600*****24) + 48 days -126 days + 37 days)

or

Lifetime [days] = 0.9964*(3185.5 / M_{He} - 41 days) = 1359 days = **3.72 years**
with M_{He} to be inserted in [mg/s]

On the other hand, the corresponding lifetime using the TMM with implemented instrument models reveals a mass flow M_{He} of 2.125 mg/s even for hot case environment at L2 (see section 7.3) leading to a lifetime of **3.98 years** (including uncertainties).

The uncertainty of the nominal lifetime is evaluated using the sum of the mean root square of the uncertainty of 38 days due to 25 hours launch delay and the uncertainties shown in Table 7.3-2 and Table 7.3-3. This leads to an overall lifetime uncertainty of

-126 days for the negative sensitivities (already included in the lifetime calculation above)

+148 days for the positive sensitivities

7.6 Instrument Interface Temperatures for IID-B Allocations

	Interface	I/F Requirement		Node	Analysis Results	
		Heat Load	Temperature		2.2 mg/s	2.1 mg/s **
Level 0	PACS Red Detector	0.8 mW	1.6 K … 1.75 K	721	1.68 K ±0.06K	1.68 K ±0.06K
	PACS Blue Detector	2.0 mW	1.6 K … 2 K	723	1.73 K ±0.06K	1.73 K ±0.06K
	PACS Cooler Pump	2.0 mW	1.6 K … 5 K	761	1.73 K ±0.06K	1.73 K ±0.06K
		500 (peak) mW	1.6 K … 10 K		12.0 K ±0.06K	12.0 K ±0.06K
	PACS Cooler Evapor.	15 mW	1.6 K … 1.85 K	762	1.796 K ±0.06K	1.796 K ±0.06K
	SPIRE Detector	4 mW	< 2 K	814	1.74 K ±0.06K	1.74 K ±0.06K
		1 mW (goal)	< 1.71 K (goal)		(1.68 K ±0.06K)	(1.68 K ±0.06K)
	SPIRE Cooler Pump	2 mW	< 2 K	815	1.69 K ±0.06K	1.69 K ±0.06K
		500 mW (peak)	< 10 K (peak)		9.77 K ±0.06K	9.77 K ±0.06K
	SPIRE Cooler Evap.	15 mW	< 1.85 K	816	1.70 K ±0.06K	1.70 K ±0.06K
		15 mW (goal)	< 1.75 K (goal)			
	HIFI Detector	6.8 mW	< 2 K	949	1.96 K ±0.06K	1.96 K ±0.06K
Level 1	PACS FPU	30 mW	2 K … 5 K	781	3.55 K ±0.18K	3.60 K ±0.18K
				782	4.24 K ±0.18K	4.34 K ±0.18K
				783	4.43 K ±0.18K	4.57 K ±0.18K
	SPIRE FPU	15 mW	< 5.5 K	800	4.22 K ±0.35K	4.43 K ±0.35K
		13 mW (goal)	< 3.7 K (goal)			
	HIFI L1	15.5 mW	< 6 K	939	5.37 K ±0.32K	5.77 K ±0.32K
Level 2	OBP near PACS	0 mW	< 12 K	371	10.9 K ±0.5K	11.8 K ±0.5K
	OBP near SPIRE	0 mW	< 12 K	381	10.6 K ±0.5K	11.4 K ±0.5K
		0 mW (goal)	< 8K (goal)			
	Instr. Shield / SPIRE	0 mW	< 16 K	315	10.6 K ±0.5K	11.5 K ±0.5K
	HIFI FPU	22 mW	< 20 K	919	12.4 K ±0.5K	13.3 K ±0.5K
Level 3	SPIRE PM-JFET	50 mW	< 15 K	831	15.1 K ±0.5K	16.1 K ±0.5K
	SPIRE SM-JFET	25 mW	< 15 K	832	13.7 K ±0.5K	14.6 K ±0.5K
LOU	LOU (HIFI)	7000 mW	90 K …150 K	4200	(132-136) K* ±3K	

*) cold-hot case environment at L2

**) sensitivity analysis only

Table 7.6-1: Calculated Instrument Temperatures for IID-B Allocations, Hot Case Conditions at L2 and HTT at 1.65K

8 Summary and Conclusions

The CDR status (April 2004) of the H-EPLM TMM is described in detail and the corresponding analysis results are reported.

On-Ground autonomy analyses show that starting from 1.8 K, the HTT tank temperature is less than 2.1 K after six days autonomy. Thus, the on-ground autonomy requirement is fulfilled.

Calculation of the nominal lifetime applying the heat load allocations defined in IID-A [AD 01] lead to 3.7 years including uncertainties, which is compliant to the requirement of 3.5 years.

The corresponding lifetime prediction with implemented instrument TMMs lead to 4.0 years lifetime including uncertainties even for hot case environment at L2.

The updated instrument interface temperature requirements for L0, L1, L2 and L3 are met with the following exceptions: peak I/F heat load of PACS Cooler Pump and SPIRE L3 (PM JFET); when applying uncertainties marginal discrepancies are observed for HIFI detector (0.02K deviation) and PACS Cooler Evaporator (0.006K deviation). Please note that these outcomes are based on hot case, i.e. worst case conditions.

Transient analyses with instrument timeline have been conducted for hot and cold case environment at L2 orbit as well as for a nearly full HTT (BOL) and a nearly empty HTT (EOL).

Evaluation of instrument timeline results show that the HIFI temperature stability goals are met.

9 ANNEX 1: Nodal Temperature Listing

Node	LABEL	Orbit hot T [K]	Orbit cold T [K]	Orbit Safe T [K]	Ground T [K]	Ground, IMT T [K]
10	MAIN TANK He II	1.65	1.63013	1.58946	1.8	1.7
20	AUXILIARY TANK He I	19.5930	18.8189	18.4263	50.5643	4.3
111	MLI ON MAIN TANK LOW	4.8195	4.4082	4.1851	57.2500	2.0116
112	MLI ON MAIN TANK CYL	4.6996	4.3129	4.0972	53.2243	2.6114
113	MLI ON MAIN TANK UPP	3.6603	3.4010	3.2243	46.2624	12.1123
121	MLI ON AUX TANK LOW	23.7871	22.6356	22.0589	70.1784	4.7914
122	MLI ON AUX TANK UPP	23.0280	21.9455	21.4023	68.2690	4.9110
201	SF strut tank end lo	1.6625	1.6417	1.6006	1.9041	1.7017
211	SF belt pZ lo	18.7975	18.0691	17.7008	48.1399	5.9609
212	SF belt mY lo	18.8184	18.0896	17.7211	48.1843	5.9941
213	SF belt mZ lo	18.8018	18.0735	17.7052	48.1427	5.9759
214	SF belt pY lo	18.7899	18.0618	17.6937	48.1121	5.9529
221	SF Ti-head pZmY lo	18.8026	18.0740	17.7057	48.1603	5.9738
222	SF Ti-head mZmY lo	18.8259	18.0970	17.7285	48.2060	6.0116
223	SF Ti-head mZpY lo	18.7991	18.0709	17.7027	48.1420	5.9792
224	SF Ti-head pZpY lo	18.7909	18.0627	17.6947	48.1197	5.9584
231	SF strut tank end up	1.6548	1.6348	1.5931	1.8181	1.7022
241	SF belt pZ up	11.2516	11.1002	9.5554	22.2800	6.9464
242	SF belt mY up	11.3079	11.1520	9.6008	22.8051	7.2069
243	SF belt mZ up	11.3382	11.1804	9.6270	22.8487	7.1574
244	SF belt pY up	11.2886	11.1345	9.5842	22.3844	6.9123
251	SF Ti-head pZmY up	11.2498	11.0987	9.5548	22.2898	6.9722
252	SF Ti-head mZmY up	11.3278	11.1706	9.6170	22.9434	7.2690
253	SF Ti-head mZpY up	11.3460	11.1880	9.6343	22.8344	7.1328
254	SF Ti-head pZpY up	11.2792	11.1261	9.5762	22.2787	6.8593
271	Susp. Straps pZmY low	29.4759	28.4889	28.0003	72.8203	12.4424
272	Susp. Straps pZmY low	29.5678	28.5746	28.0778	73.4049	12.8411
273	Susp. Straps mZmY low	29.6060	28.6106	28.1126	73.6616	13.4075
274	Susp. Straps mZmY low	29.6344	28.6377	28.1380	73.7499	14.7368
275	Susp. Straps mZpY low	29.5799	28.5866	28.0911	73.4173	13.7530
276	Susp. Straps mZpY low	29.4781	28.4911	28.0040	72.8108	12.7673
277	Susp. Straps pZpY low	29.3612	28.3822	27.9031	72.0498	12.3689
278	Susp. Straps pZpY low	29.3550	28.3762	27.8971	72.0329	11.9719
281	Susp. Straps pZmY upp	26.7434	25.9347	25.3346	60.7841	17.4000
282	Susp. Straps pZmY upp	27.0770	26.2421	25.6145	64.9272	22.3926
283	Susp. Straps mZmY upp	27.0776	26.2417	25.6205	65.3875	22.6937
284	Susp. Straps mZmY upp	26.9238	26.1007	25.4872	62.9840	17.2089
285	Susp. Straps mZpY upp	26.9518	26.1311	25.5136	61.4160	13.6033
286	Susp. Straps mZpY upp	26.7423	25.9363	25.3406	59.3746	12.1487
287	Susp. Straps pZpY upp	26.2167	25.4503	24.8850	54.8957	12.2651
288	Susp. Straps pZpY upp	26.1468	25.3851	24.8215	54.6937	12.1356
310	Instr. Shield Cyl.	11.0993	10.9622	9.3300	22.9481	7.9022
311	Instr. Shield Top	11.1456	11.0021	9.3744	23.8587	8.2146
315	Instr. Shield Baffle	11.1554	11.0095	9.3825	24.2926	8.4417
371	Opt. Bench +Z	10.9099	10.7923	9.1602	19.5950	6.1352
372	Opt. Bench +Z -Y	10.7727	10.6685	9.0662	19.0962	6.3432
373	Opt. Bench +Z mid	10.9369	10.8171	9.1762	20.2029	6.5181
374	Opt. Bench +Z +Y	10.9747	10.8534	9.2151	19.9853	6.1185
375	Opt. Bench -Y	11.0053	10.8800	9.2055	21.5937	7.3973
376	Opt. Bench centre	11.0108	10.8846	9.2124	21.4747	7.2957
377	Opt. Bench +Y	11.0510	10.9230	9.2684	20.9492	6.4991
378	Opt. Bench -Z -Y	11.1500	11.0139	9.3566	22.5650	7.7096
379	Opt. Bench -Z mid	11.0976	10.9647	9.3042	22.1544	7.4902

Node	LABEL	Orbit hot T [K]	Orbit cold T [K]	Orbit Safe T [K]	Ground T [K]	Ground, IMT T [K]
380	Opt. Bench -Z +Y	11.2146	11.0762	9.4263	22.1265	7.3353
381	Opt. Bench -Z	11.0992	10.9653	9.3088	22.3236	7.5476
440	filling tube 440	67.1942	64.1326	61.4953	274.2778	269.9574
441	filling tube 441	65.8222	62.8570	60.3120	252.5463	247.4114
442	filling tube 442	63.4473	60.6317	58.2340	236.7143	230.4324
443	filling tube 443	61.1966	58.5221	56.2618	222.4804	214.5399
447	empty tube 447	36.6845	35.4812	34.8122	88.0482	46.6398
452	empty tube 452	34.3289	33.0141	31.9137	92.8410	87.8984
510	Vline wall Tank-PACS	1.6520	1.6320	1.5915	1.8059	4.2997
511	Vline wall Tank-PACS	1.6538	1.6337	1.5935	1.8093	4.2998
512	Vline wall Tank-PACS	1.6556	1.6354	1.5953	1.8125	4.2998
513	Vline wall Tank-PACS	1.6576	1.6373	1.5974	1.8157	4.2998
514	Vline wall Tank-PACS	1.9250	1.9154	1.7902	2.2182	4.3059
520	Vline wall PACS I/F 1	2.4044	2.3896	2.0966	5.1731	4.4689
521	Vline wall PACS I/F 1	2.4920	2.4759	2.1535	5.6979	4.5802
522	Vline wall PACS I/F 1	2.4383	2.4255	2.1226	5.1212	4.4710
523	Vline wall PACSI/F1/2	2.3160	2.3128	2.0555	3.3899	4.3509
524	Vline wall PACSI/F1/2	2.3585	2.3624	2.0924	2.9109	4.3440
525	Vline wall PACS I/F 2	2.7589	2.7438	2.3263	6.6677	4.5927
526	Vline wall PACS I/F 2	2.8066	2.7891	2.3545	7.0829	4.7390
527	Vline wall PACS I/F 2	2.7782	2.7638	2.3399	6.5662	4.5930
528	Vline wall PACSI/F2/3	2.7029	2.6995	2.3023	4.5068	4.4059
529	Vline wall PACSI/F2/3	2.8027	2.7929	2.3599	5.4918	4.4426
530	Vline wall PACS I/F 3	2.8832	2.8666	2.4049	6.7022	4.6253
531	Vline wall PACS I/F 3	2.9202	2.9002	2.4255	7.2720	4.8027
532	Vline wall PACS I/F 3	2.9111	2.8933	2.4226	6.8269	4.6551
533	Vline wall PACS-SPIRE	2.8981	2.8875	2.4258	5.1969	4.4678
534	Vline wall PACS-SPIRE	2.9900	2.9813	2.5046	5.0054	4.4609
535	Vline wall PACS-SPIRE	3.3167	3.2980	2.7650	6.8163	4.4972
536	Vline wall SPIRE IF12	3.8518	3.7966	3.1705	12.0653	5.2654
537	Vline wall SPIRE IF12	3.9571	3.8947	3.2499	13.0393	5.7169
538	Vline wall SPIRE IF12	3.9284	3.8726	3.2327	12.1335	5.2763
539	Vline wall SPIRE-HIFI	3.8961	3.8578	3.2228	9.5592	4.7107
543	Vline wall SPIRE-HIFI	4.1786	4.1616	3.4784	8.1937	4.6591
544	Vline wall HIFI I/F	4.8547	4.8414	4.0433	9.0616	4.6809
545	Vline wall HIFI I/F	4.9469	4.9335	4.1207	9.2071	4.6945
546	Vline wall HIFI I/F	4.9188	4.9088	4.1011	9.0611	4.6796
550	Vline wall L1-L2	4.9041	4.8985	4.0944	8.8999	4.6693
551	Vline wall L1-L2	5.0454	5.0581	4.2378	8.5958	4.6641
552	Vline wall L1-L2	5.4615	5.4906	4.6149	8.7061	4.6639
553	Vline wall L1-L2	6.3861	6.4237	5.4258	9.3624	4.6652
554	Vline wall L1-L2	8.1704	8.1821	6.9527	11.4234	4.6857
560	Vline wall Lev.2 OB	10.2188	10.1557	8.6333	15.1939	4.8808
561	Vline wall Lev.2 OB	10.8394	10.7297	9.1086	17.8191	5.0091
562	Vline wall Lev.2 OB	10.9532	10.8346	9.1983	18.9443	5.0929
563	Vline wall Lev.2 OB	11.0342	10.9088	9.2573	19.9394	5.2117
570	Vline wall L2-L3	11.2441	11.1331	9.4501	19.6604	5.1404
571	Vline wall L2-L3	11.7459	11.6400	9.8678	19.9396	5.1552
580	Vline wall PM JFET	12.8688	12.7264	10.7409	22.9871	6.8286
581	Vline wall PM JFET	13.0105	12.8618	10.8510	23.4404	7.9205
582	Vline wall PM JFET	12.9911	12.8458	10.8405	23.1083	6.9294
583	Vline wall PM/SM JFET	13.0030	12.8683	10.8705	21.1067	5.5079
584	Vline wall SM JFET	13.2429	13.0928	11.0472	22.1240	6.1720
585	Vline wall SM JFET	13.2711	13.1188	11.0679	22.2711	6.6646
586	Vline wall SM JFET	13.2630	13.1115	11.0627	22.1498	6.2094
590	Vline wall L3-TS1	13.2270	13.0776	11.0386	21.4743	5.6482

Node	LABEL	Orbit hot T [K]	Orbit cold T [K]	Orbit Safe T [K]	Ground T [K]	Ground, IMT T [K]
591	Vline wall L3-TS1	13.4877	13.3478	11.3905	21.5139	5.6472
592	Vline wall L3-TS1	25.1057	24.7335	24.5521	29.4714	5.6893
610	Vline wall TS1-2 pymz	35.8010	34.6625	34.1116	80.6533	11.1444
611	Vline wall TS2-3 pymz	45.6711	43.8307	43.1518	145.5185	22.0233
612	Vline w. TS3-CVV pymz	56.8131	54.3064	52.7997	225.9865	83.6846
620	Vline wall TS1-2 mypz	35.8820	34.7372	34.1751	81.4087	11.6574
621	Vline wall TS2-3 mypz	45.6730	43.8322	43.1530	146.1223	25.4389
622	Vline w. TS3-CVV mypz	56.8131	54.3065	52.7998	225.9865	83.6846
642	MLI filling tube 642	37.6888	36.3849	35.4191	118.5528	112.8482
643	MLI filling tube 643	36.9500	35.6968	34.7849	112.1025	105.1048
647	MLI filling tube 647	30.8023	29.8775	29.3926	67.4041	27.1034
652	MLI filling tube 652	30.5288	29.5615	28.9698	68.7765	47.0108
1001	Susp bolt lo pZmY TS1	36.1044	34.9175	34.3391	91.2211	15.1942
1002	Susp bolt lo pZmY TS1	36.2863	35.0848	34.4891	93.0703	16.2005
1003	Susp bolt lo mZmY TS1	36.3512	35.1449	34.5467	93.5671	17.1045
1004	Susp bolt lo mZmY TS1	36.4169	35.2065	34.6042	93.8668	19.3793
1005	Susp bolt lo mZpY TS1	36.3198	35.1171	34.5230	93.0319	17.6423
1006	Susp bolt lo mZpY TS1	36.0996	34.9139	34.3390	91.0568	15.7670
1007	Susp bolt lo pZpY TS1	35.8780	34.7101	34.1517	88.8309	15.1838
1008	Susp bolt lo pZpY TS1	35.8689	34.7014	34.1429	88.8258	14.7613
1011	@TS 1 lower bulk 1	35.3655	34.2553	33.7012	78.2023	12.5624
1012	@TS 1 lower bulk 2	35.5237	34.4001	33.8317	80.1832	13.4040
1013	@TS 1 lower bulk 3	35.6132	34.4821	33.9073	81.3640	14.4494
1014	@TS 1 lower bulk 4	35.6443	34.5112	33.9350	81.5894	15.7929
1015	@TS 1 lower bulk 5	35.5529	34.4277	33.8599	80.3774	15.0122
1016	@TS 1 lower bulk 6	35.3742	34.2638	33.7114	78.2807	13.7229
1017	@TS 1 lower bulk 7	35.2163	34.1190	33.5789	76.4368	12.7669
1018	@TS 1 lower bulk 8	35.2106	34.1136	33.5731	76.3903	12.2703
1021	@TS 1 lower cyl 1	35.3006	34.1975	33.6462	75.5304	11.2281
1022	@TS 1 lower cyl 2	35.5808	34.4538	33.8741	79.3477	12.6342
1023	@TS 1 lower cyl 3	35.6557	34.5220	33.9402	80.9764	13.4661
1024	@TS 1 lower cyl 4	35.6551	34.5218	33.9426	80.9216	14.1624
1025	@TS 1 lower cyl 5	35.5867	34.4605	33.8874	79.3199	13.5842
1026	@TS 1 lower cyl 6	35.2787	34.1780	33.6330	75.4101	11.7930
1027	@TS 1 lower cyl 7	34.8846	33.8172	33.3018	70.7066	10.8987
1028	@TS 1 lower cyl 8	34.8822	33.8148	33.2986	70.6641	10.5179
1031	@TS 1 upper cyl 1	35.2400	34.1428	33.5937	74.0927	10.6263
1032	@TS 1 upper cyl 2	35.5523	34.4283	33.8469	78.5700	12.2256
1033	@TS 1 upper cyl 3	35.6145	34.4846	33.9032	80.2854	12.6939
1034	@TS 1 upper cyl 4	35.5857	34.4583	33.8824	79.9072	12.3717
1035	@TS 1 upper cyl 5	35.5450	34.4229	33.8505	78.3547	12.9593
1036	@TS 1 upper cyl 6	35.2448	34.1480	33.6034	74.4342	14.1448
1037	@TS 1 upper cyl 7	34.7481	33.6932	33.1861	68.3246	10.9210
1038	@TS 1 upper cyl 8	34.7417	33.6871	33.1796	68.1931	9.9498
1041	@TS 1 upper bulk 1	35.2261	34.1286	33.5802	75.5214	11.5255
1042	@TS 1 upper bulk 2	35.4236	34.3092	33.7426	78.2597	12.2868
1043	@TS 1 upper bulk 3	35.5086	34.3868	33.8147	79.6277	12.6930
1044	@TS 1 upper bulk 4	35.5008	34.3799	33.8103	79.4462	12.7373
1045	@TS 1 upper bulk 5	35.4185	34.3052	33.7434	78.0737	12.9634
1046	@TS 1 upper bulk 6	35.2257	34.1289	33.5837	75.5500	13.0386
1047	@TS 1 upper bulk 7	35.0116	33.9328	33.4042	72.8986	11.9014
1048	@TS 1 upper bulk 8	35.0105	33.9316	33.4021	72.8680	11.2843
1061	Susp bolt up pZmY TS1	35.5459	34.4162	33.8548	80.1207	9.8327
1062	Susp bolt up pZmY TS1	35.9412	34.7787	34.1665	85.4773	12.6985
1063	Susp bolt up mZmY TS1	35.8964	34.7366	34.1429	85.8305	13.1367
1064	Susp bolt up mZmY TS1	35.8154	34.6619	34.0790	84.8486	11.8772

Node	LABEL	Orbit hot T [K]	Orbit cold T [K]	Orbit Safe T [K]	Ground T [K]	Ground, IMT T [K]
1065	Susp bolt up mZpY TS1	35.9380	34.7780	34.1812	84.8856	12.7259
1066	Susp bolt up mZpY TS1	35.4634	34.3409	33.7926	79.5286	9.4013
1067	Susp bolt up pZpY TS1	34.5630	33.5167	33.0324	69.2654	8.8865
1068	Susp bolt up pZpY TS1	34.5459	33.5011	33.0183	69.1316	8.4776
1111	TS 1 lower bulk MLI 1	38.4344	36.9510	36.2961	126.2126	14.4501
1112	TS 1 lower bulk MLI 2	38.5230	37.0365	36.3756	125.4588	15.1828
1113	TS 1 lower bulk MLI 3	38.5624	37.0761	36.4145	124.2613	16.0457
1114	TS 1 lower bulk MLI 4	38.5827	37.0958	36.4336	123.9683	17.0729
1115	TS 1 lower bulk MLI 5	38.5410	37.0544	36.3944	124.8053	16.2706
1116	TS 1 lower bulk MLI 6	38.4386	36.9557	36.3024	125.6538	15.1431
1117	TS 1 lower bulk MLI 7	38.3418	36.8632	36.2158	126.1203	14.4167
1118	TS 1 lower bulk MLI 8	38.3385	36.8599	36.2121	126.3313	14.1327
1121	TS 1 lower cyl MLI 1	39.5501	37.9600	37.2807	129.9588	13.6246
1122	TS 1 lower cyl MLI 2	39.6641	38.0731	37.3860	128.3904	14.7300
1123	TS 1 lower cyl MLI 3	39.6251	38.0446	37.3693	124.4599	15.4724
1124	TS 1 lower cyl MLI 4	39.6207	38.0413	37.3682	123.5095	15.5696
1125	TS 1 lower cyl MLI 5	39.6630	38.0735	37.3913	126.7786	14.7743
1126	TS 1 lower cyl MLI 6	39.5350	37.9465	37.2713	128.8846	13.3572
1127	TS 1 lower cyl MLI 7	39.3334	37.7523	37.0884	129.6116	12.9232
1128	TS 1 lower cyl MLI 8	39.3330	37.7516	37.0871	129.9964	13.0409
1131	TS 1 upper cyl MLI 1	39.7287	38.1124	37.4292	131.6615	14.4450
1132	TS 1 upper cyl MLI 2	39.8555	38.2376	37.5448	132.4195	19.2079
1133	TS 1 upper cyl MLI 3	39.8025	38.1964	37.5174	128.4011	19.6325
1134	TS 1 upper cyl MLI 4	39.7709	38.1687	37.4953	124.5758	15.1662
1135	TS 1 upper cyl MLI 5	39.8437	38.2288	37.5428	127.8612	14.7208
1136	TS 1 upper cyl MLI 6	41.1863	39.4225	38.5668	145.0303	104.2841
1137	TS 1 upper cyl MLI 7	39.4788	37.8725	37.2067	130.6548	13.3727
1138	TS 1 upper cyl MLI 8	39.4758	37.8694	37.2032	131.0835	13.1506
1141	TS 1 upper bulk MLI 1	38.9497	37.4035	36.7404	130.2493	16.4225
1142	TS 1 upper bulk MLI 2	39.0525	37.5027	36.8323	130.2822	18.0029
1143	TS 1 upper bulk MLI 3	39.0791	37.5306	36.8613	128.9941	18.2304
1144	TS 1 upper bulk MLI 4	39.0708	37.5235	36.8563	127.8380	16.9886
1145	TS 1 upper bulk MLI 5	39.0462	37.4978	36.8311	128.5326	16.5220
1146	TS 1 upper bulk MLI 6	38.9483	37.4028	36.7421	129.3686	16.5434
1147	TS 1 upper bulk MLI 7	38.8259	37.2857	36.6326	129.6382	15.7580
1148	TS 1 upper bulk MLI 8	38.8256	37.2852	36.6314	129.9163	15.6506
1211	TS 1 low strap I/F 1	35.3603	34.2509	33.6973	77.5489	12.1486
1212	TS 1 low strap I/F 2	35.5679	34.4409	33.8673	80.2505	13.2055
1213	TS 1 low strap I/F 3	35.6508	34.5168	33.9386	81.5885	14.1627
1214	TS 1 low strap I/F 4	35.7256	34.5865	34.0034	82.1520	17.1160
1215	TS 1 low strap I/F 5	35.6098	34.4806	33.9081	80.5190	15.2942
1216	TS 1 low strap I/F 6	35.3590	34.2503	33.7001	77.5627	13.1714
1217	TS 1 low strap I/F 7	35.1095	34.0218	33.4905	74.6270	12.4073
1218	TS 1 low strap I/F 8	35.0980	34.0110	33.4798	74.5339	11.7006
1221	TS 1 upp strap I/F 1	35.3486	34.2433	33.6892	73.4391	9.4358
1222	TS 1 upp strap I/F 2	35.7575	34.6175	34.0106	79.5672	12.3750
1223	TS 1 upp strap I/F 3	35.7220	34.5833	33.9938	81.2489	12.7638
1224	TS 1 upp strap I/F 4	35.6400	34.5076	33.9292	80.4992	11.6133
1225	TS 1 upp strap I/F 5	35.7555	34.6179	34.0268	79.3963	12.5671
1226	TS 1 upp strap I/F 6	35.2637	34.1658	33.6251	73.0044	9.1248
1227	TS 1 upp strap I/F 7	34.3361	33.3176	32.8433	61.6344	8.5454
1228	TS 1 upp strap I/F 8	34.3188	33.3018	32.8291	61.4115	8.0289
2001	Susp bolt lo pZmY TS2	45.9803	44.1326	43.3443	144.3879	40.1580
2002	Susp bolt lo pZmY TS2	45.9425	44.0997	43.3165	143.8115	41.4084
2003	Susp bolt lo mZmY TS2	45.8489	44.0172	43.2476	141.9652	42.4099
2004	Susp bolt lo mZmY TS2	45.8378	44.0082	43.2404	141.5183	41.7308

Node	LABEL	Orbit hot T [K]	Orbit cold T [K]	Orbit Safe T [K]	Ground T [K]	Ground, IMT T [K]
2005	Susp bolt lo mZpY TS2	45.9041	44.0668	43.2891	142.9412	40.1086
2006	Susp bolt lo mZpY TS2	45.9427	44.0999	43.3170	143.7586	38.9251
2007	Susp bolt lo pZpY TS2	45.9595	44.1141	43.3290	143.6327	38.9639
2008	Susp bolt lo pZpY TS2	45.9709	44.1239	43.3373	143.8612	39.5933
2011	@TS 2 lower bulk 1	45.3669	43.5434	42.8426	144.2495	27.4676
2012	@TS 2 lower bulk 2	45.3173	43.4995	42.8063	143.0081	27.5195
2013	@TS 2 lower bulk 3	45.2619	43.4507	42.7658	141.3813	27.3655
2014	@TS 2 lower bulk 4	45.2591	43.4484	42.7640	140.9926	26.7119
2015	@TS 2 lower bulk 5	45.3121	43.4953	42.8030	142.2145	26.1681
2016	@TS 2 lower bulk 6	45.3626	43.5399	42.8399	143.5959	26.2061
2017	@TS 2 lower bulk 7	45.3908	43.5647	42.8603	144.4607	26.6591
2018	@TS 2 lower bulk 8	45.3924	43.5660	42.8614	144.7083	27.2120
2021	@TS 2 lower cyl 1	45.3562	43.5305	42.8320	144.4152	26.3766
2022	@TS 2 lower cyl 2	45.2733	43.4571	42.7714	142.1827	26.2407
2023	@TS 2 lower cyl 3	45.1191	43.3209	42.6583	137.5526	26.4125
2024	@TS 2 lower cyl 4	45.1114	43.3145	42.6533	136.4929	24.6163
2025	@TS 2 lower cyl 5	45.2649	43.4503	42.7662	140.3989	23.3612
2026	@TS 2 lower cyl 6	45.3513	43.5265	42.8290	143.2557	23.9358
2027	@TS 2 lower cyl 7	45.3886	43.5594	42.8560	144.6057	25.0588
2028	@TS 2 lower cyl 8	45.3903	43.5607	42.8570	145.0260	26.3399
2031	@TS 2 upper cyl 1	45.3389	43.5057	42.8107	146.8186	30.8558
2032	@TS 2 upper cyl 2	45.2611	43.4361	42.7528	147.0865	37.6485
2033	@TS 2 upper cyl 3	45.1040	43.2972	42.6375	142.4073	37.8453
2034	@TS 2 upper cyl 4	45.0753	43.2730	42.6183	138.1976	29.2256
2035	@TS 2 upper cyl 5	45.2471	43.4253	42.7450	142.0926	26.2542
2036	@TS 2 upper cyl 6	45.3372	43.5046	42.8104	145.4481	27.5771
2037	@TS 2 upper cyl 7	45.3695	43.5331	42.8336	146.3794	27.5189
2038	@TS 2 upper cyl 8	45.3704	43.5338	42.8340	146.8533	29.0491
2041	@TS 2 upper bulk 1	45.3256	43.4834	42.7914	148.2340	34.3112
2042	@TS 2 upper bulk 2	45.2838	43.4461	42.7604	147.8495	36.3766
2043	@TS 2 upper bulk 3	45.2282	43.3970	42.7197	146.1705	36.2914
2044	@TS 2 upper bulk 4	45.2208	43.3909	42.7149	144.8904	33.6805
2045	@TS 2 upper bulk 5	45.2772	43.4410	42.7566	145.9089	32.1965
2046	@TS 2 upper bulk 6	45.3231	43.4815	42.7901	147.2467	32.1072
2047	@TS 2 upper bulk 7	45.3448	43.5006	42.8058	147.9344	32.2844
2048	@TS 2 upper bulk 8	45.3455	43.5012	42.8061	148.2467	33.0543
2050	@TS 2 baffle	45.3328	43.4728	42.7821	150.0679	37.4093
2061	Susp bolt up pZmY TS2	45.5563	43.7172	42.9896	144.5164	28.8402
2062	Susp bolt up pZmY TS2	45.4864	43.6552	42.9387	143.0030	28.6784
2063	Susp bolt up mZmY TS2	45.1369	43.3460	42.6814	133.9787	30.8931
2064	Susp bolt up mZmY TS2	45.1136	43.3263	42.6657	131.8082	26.7871
2065	Susp bolt up mZpY TS2	45.4688	43.6411	42.9280	140.1614	23.8873
2066	Susp bolt up mZpY TS2	45.5450	43.7079	42.9824	143.2109	25.3510
2067	Susp bolt up pZpY TS2	45.5563	43.7176	42.9890	143.5981	26.8923
2068	Susp bolt up pZpY TS2	45.5592	43.7200	42.9909	144.0904	29.5009
2090	TS 2 LO Baffles.	45.2755	43.4435	42.7556	164.0343	74.2162
2111	TS 2 lower bulk MLI 1	52.3938	49.9513	48.6341	213.4925	76.0162
2112	TS 2 lower bulk MLI 2	52.4315	49.9837	48.6565	216.1529	81.0975
2113	TS 2 lower bulk MLI 3	52.4333	49.9847	48.6545	217.5837	85.0892
2114	TS 2 lower bulk MLI 4	52.4222	49.9755	48.6469	217.5830	84.8515
2115	TS 2 lower bulk MLI 5	52.4046	49.9612	48.6379	216.1620	80.5214
2116	TS 2 lower bulk MLI 6	52.3675	49.9294	48.6160	213.5147	75.3664
2117	TS 2 lower bulk MLI 7	52.3209	49.8885	48.5867	210.5467	72.8590
2118	TS 2 lower bulk MLI 8	52.3314	49.8973	48.5939	210.5449	73.1877
2121	TS 2 lower cyl MLI 1	52.9877	50.5262	49.1794	212.3508	59.7776
2122	TS 2 lower cyl MLI 2	53.0598	50.5886	49.2237	217.0483	71.5073

Node	LABEL	Orbit hot T [K]	Orbit cold T [K]	Orbit Safe T [K]	Ground T [K]	Ground, IMT T [K]
2123	TS 2 lower cyl MLI 3	53.0446	50.5733	49.2065	219.1080	81.4002
2124	TS 2 lower cyl MLI 4	53.0288	50.5601	49.1955	219.1082	80.8931
2125	TS 2 lower cyl MLI 5	53.0236	50.5582	49.1986	217.0900	70.3773
2126	TS 2 lower cyl MLI 6	52.9539	50.4978	49.1558	212.4641	58.2293
2127	TS 2 lower cyl MLI 7	52.7657	50.3321	49.0311	203.3343	55.1127
2128	TS 2 lower cyl MLI 8	52.7787	50.3430	49.0402	203.3501	56.1708
2131	TS 2 upper cyl MLI 1	52.1081	49.6698	48.3700	215.2758	84.4799
2132	TS 2 upper cyl MLI 2	52.1275	49.6851	48.3780	217.7508	89.5926
2133	TS 2 upper cyl MLI 3	52.0852	49.6454	48.3413	218.7994	93.3616
2134	TS 2 upper cyl MLI 4	52.0635	49.6268	48.3260	218.6266	92.8024
2135	TS 2 upper cyl MLI 5	52.0953	49.6585	48.3564	217.6900	88.9443
2136	TS 2 upper cyl MLI 6	52.8294	50.3427	48.9543	219.9135	130.1896
2137	TS 2 upper cyl MLI 7	52.0407	49.6122	48.3269	212.5362	82.0480
2138	TS 2 upper cyl MLI 8	52.0508	49.6206	48.3337	212.4129	82.0754
2141	TS 2 upper bulk MLI 1	52.6728	50.2074	48.8695	218.5974	93.8141
2142	TS 2 upper bulk MLI 2	52.6936	50.2251	48.8811	220.1977	96.7323
2143	TS 2 upper bulk MLI 3	52.6889	50.2205	48.8752	221.0985	98.9229
2144	TS 2 upper bulk MLI 4	52.6774	50.2108	48.8673	221.0960	98.8292
2145	TS 2 upper bulk MLI 5	52.6702	50.2055	48.8652	220.2979	96.6935
2146	TS 2 upper bulk MLI 6	52.6520	50.1900	48.8553	218.8711	94.1084
2147	TS 2 upper bulk MLI 7	52.6318	50.1722	48.8430	217.2420	92.1809
2148	TS 2 upper bulk MLI 8	52.6401	50.1791	48.8487	217.1404	92.1012
2211	TS 2 low strap I/F 1	45.3813	43.5560	42.8534	144.3285	27.4550
2212	TS 2 low strap I/F 2	45.3172	43.4992	42.8065	142.6665	27.4762
2213	TS 2 low strap I/F 3	45.2162	43.4101	42.7325	139.6918	27.5136
2214	TS 2 low strap I/F 4	45.2110	43.4057	42.7291	139.0023	26.3769
2215	TS 2 low strap I/F 5	45.3095	43.4929	42.8016	141.4276	25.4931
2216	TS 2 low strap I/F 6	45.3757	43.5513	42.8498	143.4493	25.7007
2217	TS 2 low strap I/F 7	45.4077	43.5795	42.8729	144.4971	26.4165
2218	TS 2 low strap I/F 8	45.4096	43.5811	42.8742	144.8214	27.2830
2221	TS 2 upp strap I/F 1	45.3639	43.5337	42.8349	145.2611	25.2910
2222	TS 2 upp strap I/F 2	45.2780	43.4576	42.7725	142.8064	24.5417
2223	TS 2 upp strap I/F 3	44.9079	43.1306	42.5006	131.8504	26.4866
2224	TS 2 upp strap I/F 4	44.8869	43.1129	42.4866	129.3347	21.9595
2225	TS 2 upp strap I/F 5	45.2657	43.4479	42.7654	139.4255	19.2472
2226	TS 2 upp strap I/F 6	45.3598	43.5306	42.8327	143.6961	21.4625
2227	TS 2 upp strap I/F 7	45.3938	43.5604	42.8569	145.2066	23.3772
2228	TS 2 upp strap I/F 8	45.3952	43.5615	42.8577	145.8110	26.2048
3001	Susp bolt lo pZmY TS3	56.8177	54.2837	52.6877	221.7734	107.3551
3002	Susp bolt lo pZmY TS3	56.8577	54.3224	52.7103	224.7394	113.1102
3003	Susp bolt lo mZmY TS3	56.7283	54.2097	52.6101	226.0772	118.0758
3004	Susp bolt lo mZmY TS3	56.6361	54.1323	52.5431	226.0613	117.8111
3005	Susp bolt lo mZpY TS3	56.5595	54.0625	52.4864	224.7283	112.5416
3006	Susp bolt lo mZpY TS3	56.5307	54.0317	52.4719	221.8074	106.6923
3007	Susp bolt lo pZpY TS3	56.5562	54.0511	52.4998	216.8707	104.8224
3008	Susp bolt lo pZpY TS3	56.6475	54.1308	52.5685	216.8824	105.2308
3011	@TS 3 lower bulk 1	56.3083	53.8189	52.3237	220.8951	85.1991
3012	@TS 3 lower bulk 2	56.3819	53.8855	52.3746	223.7794	90.2133
3013	@TS 3 lower bulk 3	56.4093	53.9109	52.3930	225.3769	94.1658
3014	@TS 3 lower bulk 4	56.3955	53.8992	52.3831	225.3966	93.9655
3015	@TS 3 lower bulk 5	56.3478	53.8564	52.3498	223.8324	89.7262
3016	@TS 3 lower bulk 6	56.2746	53.7901	52.2993	220.9566	84.6483
3017	@TS 3 lower bulk 7	56.1984	53.7209	52.2467	217.7601	82.1451
3018	@TS 3 lower bulk 8	56.2119	53.7324	52.2564	217.7429	82.4259
3021	@TS 3 lower cyl 1	56.2646	53.7796	52.2945	218.2297	67.5994
3022	@TS 3 lower cyl 2	56.3853	53.8884	52.3777	223.2471	79.1841

Node	LABEL	Orbit hot T [K]	Orbit cold T [K]	Orbit Safe T [K]	Ground T [K]	Ground, IMT T [K]
3023	@TS 3 lower cyl 3	56.4200	53.9204	52.4009	225.5858	88.9138
3024	@TS 3 lower cyl 4	56.4027	53.9057	52.3885	225.6270	88.4995
3025	@TS 3 lower cyl 5	56.3425	53.8518	52.3467	223.3670	78.2649
3026	@TS 3 lower cyl 6	56.2235	53.7443	52.2645	218.4038	66.3344
3027	@TS 3 lower cyl 7	55.9703	53.5162	52.0883	208.7456	63.1260
3028	@TS 3 lower cyl 8	55.9863	53.5299	52.1000	208.7389	64.0147
3031	@TS 3 upper cyl 1	56.3424	53.8482	52.3480	223.5220	94.3281
3032	@TS 3 upper cyl 2	56.4089	53.9085	52.3938	226.1438	98.9720
3033	@TS 3 upper cyl 3	56.4290	53.9275	52.4072	227.5460	102.7605
3034	@TS 3 upper cyl 4	56.4131	53.9140	52.3959	227.6009	102.6993
3035	@TS 3 upper cyl 5	56.3709	53.8761	52.3666	226.3873	99.0231
3036	@TS 3 upper cyl 6	56.3082	53.8190	52.3232	224.2305	95.2560
3037	@TS 3 upper cyl 7	56.2321	53.7498	52.2707	220.6261	92.1366
3038	@TS 3 upper cyl 8	56.2458	53.7615	52.2806	220.4617	92.0619
3041	@TS 3 upper bulk 1	56.3643	53.8674	52.3632	225.5141	101.8763
3042	@TS 3 upper bulk 2	56.4088	53.9078	52.3939	227.2218	104.6964
3043	@TS 3 upper bulk 3	56.4253	53.9234	52.4051	228.2567	106.8969
3044	@TS 3 upper bulk 4	56.4132	53.9131	52.3965	228.3179	106.9179
3045	@TS 3 upper bulk 5	56.3806	53.8838	52.3738	227.4275	104.8485
3046	@TS 3 upper bulk 6	56.3378	53.8448	52.3443	225.8556	102.2750
3047	@TS 3 upper bulk 7	56.3023	53.8122	52.3199	224.1003	100.3455
3048	@TS 3 upper bulk 8	56.3130	53.8213	52.3275	223.9759	100.2281
3061	Susp bolt up pZmY TS3	56.5120	53.9997	52.4636	222.2315	96.7700
3062	Susp bolt up pZmY TS3	56.5792	54.0619	52.5084	225.3224	103.4756
3063	Susp bolt up mZmY TS3	56.5301	54.0211	52.4707	226.3842	109.2186
3064	Susp bolt up mZmY TS3	56.4811	53.9803	52.4359	226.3080	108.9296
3065	Susp bolt up mZpY TS3	56.4308	53.9347	52.4001	225.3199	103.0311
3066	Susp bolt up mZpY TS3	56.3706	53.8777	52.3602	222.5453	96.6718
3067	Susp bolt up pZpY TS3	56.2908	53.8028	52.3073	217.1038	94.0718
3068	Susp bolt up pZpY TS3	56.3374	53.8429	52.3414	217.0547	94.4131
3111	TS 3 lower bulk MLI 1	69.1264	65.6082	62.5042	288.2788	285.5754
3112	TS 3 lower bulk MLI 2	68.7869	65.3205	62.2478	288.4073	285.6025
3113	TS 3 lower bulk MLI 3	68.0999	64.7354	61.7068	288.4804	285.6260
3114	TS 3 lower bulk MLI 4	67.5551	64.2713	61.2916	288.4813	285.6248
3115	TS 3 lower bulk MLI 5	67.3918	64.1234	61.1707	288.4097	285.5997
3116	TS 3 lower bulk MLI 6	67.7232	64.3962	61.4370	288.2815	285.5726
3117	TS 3 lower bulk MLI 7	68.4423	65.0104	62.0030	288.1438	285.5602
3118	TS 3 lower bulk MLI 8	68.9987	65.4930	62.4133	288.1431	285.5616
3121	TS 3 lower cyl MLI 1	68.6954	65.1988	62.2311	288.3067	285.7253
3122	TS 3 lower cyl MLI 2	68.4187	64.9715	62.0031	288.5197	285.7698
3123	TS 3 lower cyl MLI 3	67.2028	63.9079	61.0885	288.6232	285.8171
3124	TS 3 lower cyl MLI 4	66.5430	63.3570	60.6114	288.6251	285.8148
3125	TS 3 lower cyl MLI 5	66.2098	63.0511	60.3513	288.5249	285.7658
3126	TS 3 lower cyl MLI 6	66.5738	63.3386	60.6415	288.3139	285.7211
3127	TS 3 lower cyl MLI 7	67.8582	64.4600	61.6061	287.9371	285.7111
3128	TS 3 lower cyl MLI 8	68.5137	65.0321	62.0996	287.9369	285.7138
3131	TS 3 upper cyl MLI 1	67.7157	64.2351	61.4111	287.1455	283.5874
3132	TS 3 upper cyl MLI 2	67.3536	63.9298	61.1078	287.2994	283.6264
3133	TS 3 upper cyl MLI 3	66.4046	63.1247	60.3955	287.3836	283.6609
3134	TS 3 upper cyl MLI 4	65.2848	62.1442	59.5798	287.3869	283.6604
3135	TS 3 upper cyl MLI 5	65.0665	61.9468	59.4224	287.3140	283.6268
3136	TS 3 upper cyl MLI 6	65.8144	62.5942	59.9854	287.1867	283.5949
3137	TS 3 upper cyl MLI 7	67.1038	63.7022	60.9716	286.9808	283.5702
3138	TS 3 upper cyl MLI 8	67.6122	64.1407	61.3474	286.9716	283.5696
3141	TS 3 upper bulk MLI 1	68.2906	64.7786	61.9691	288.3541	285.4590
3142	TS 3 upper bulk MLI 2	67.9587	64.4887	61.6754	288.4362	285.4806

Node	LABEL	Orbit hot T [K]	Orbit cold T [K]	Orbit Safe T [K]	Ground T [K]	Ground, IMT T [K]
3143	TS 3 upper bulk MLI 3	67.3262	63.9428	61.1996	288.4867	285.4983
3144	TS 3 upper bulk MLI 4	66.3603	63.0757	60.4644	288.4897	285.4984
3145	TS 3 upper bulk MLI 5	66.2034	62.9343	60.3581	288.4462	285.4818
3146	TS 3 upper bulk MLI 6	66.9620	63.6083	60.9590	288.3704	285.4620
3147	TS 3 upper bulk MLI 7	67.6953	64.2443	61.5160	288.2873	285.4478
3148	TS 3 upper bulk MLI 8	68.2063	64.7025	61.9196	288.2815	285.4470
3211	TS 3 low strap I/F 1	56.3040	53.8152	52.3215	219.6109	77.5708
3212	TS 3 low strap I/F 2	56.3998	53.9018	52.3875	223.5519	85.6481
3213	TS 3 low strap I/F 3	56.4254	53.9258	52.4043	225.5064	92.4654
3214	TS 3 low strap I/F 4	56.4073	53.9104	52.3912	225.5354	92.1574
3215	TS 3 low strap I/F 5	56.3524	53.8611	52.3529	223.6356	84.9472
3216	TS 3 low strap I/F 6	56.2580	53.7756	52.2879	219.7269	76.7087
3217	TS 3 low strap I/F 7	56.0975	53.6306	52.1767	213.2859	73.9897
3218	TS 3 low strap I/F 8	56.1149	53.6455	52.1893	213.2750	74.5370
3221	TS 3 upp strap I/F 1	56.3233	53.8318	52.3351	221.1021	83.1925
3222	TS 3 upp strap I/F 2	56.4133	53.9131	52.3969	224.8106	90.7942
3223	TS 3 upp strap I/F 3	56.4337	53.9326	52.4100	226.6072	97.2437
3224	TS 3 upp strap I/F 4	56.4144	53.9162	52.3962	226.6482	97.0149
3225	TS 3 upp strap I/F 5	56.3638	53.8707	52.3609	224.9847	90.3987
3226	TS 3 upp strap I/F 6	56.2770	53.7919	52.3012	221.5509	83.1625
3227	TS 3 upp strap I/F 7	56.1242	53.6538	52.1954	215.1746	80.1848
3228	TS 3 upp strap I/F 8	56.1417	53.6688	52.2082	215.0864	80.5085
4011	@CVV LOW BULK 1	72.0411	68.5101	65.2398	293	293
4012	@CVV LOW BULK 2	71.6426	68.1670	64.9292	293	293
4013	@CVV LOW BULK 3	70.8548	67.4880	64.2903	293	293
4014	@CVV LOW BULK 4	70.2332	66.9532	63.8027	293	293
4015	@CVV LOW BULK 5	70.0550	66.7906	63.6675	293	293
4016	@CVV LOW BULK 6	70.4496	67.1211	63.9943	293	293
4017	@CVV LOW BULK 7	71.2850	67.8441	64.6716	293	293
4018	@CVV LOW BULK 8	71.9141	68.3954	65.1487	293	293
4021	@CVV LOW CYL 1	71.4759	67.9649	64.8484	293	293
4022	@CVV LOW CYL 2	71.1403	67.6828	64.5642	293	293
4023	@CVV LOW CYL 3	69.7455	66.4488	63.4850	293	293
4024	@CVV LOW CYL 4	68.9890	65.8106	62.9227	293	293
4025	@CVV LOW CYL 5	68.6157	65.4647	62.6231	293	293
4026	@CVV LOW CYL 6	69.0605	65.8241	62.9879	293	293
4027	@CVV LOW CYL 7	70.5799	67.1700	64.1646	293	293
4028	@CVV LOW CYL 8	71.3205	67.8233	64.7377	293	293
4031	@CVV UPP CYL 1	71.1990	67.6835	64.6730	293	293
4032	@CVV UPP CYL 2	70.7520	67.2989	64.2854	293	293
4033	@CVV UPP CYL 3	69.6095	66.3144	63.3958	293	293
4034	@CVV UPP CYL 4	68.2537	65.1101	62.3718	293	293
4035	@CVV UPP CYL 5	67.9981	64.8761	62.1815	293	293
4036	@CVV UPP CYL 6	68.9280	65.6948	62.9079	293	293
4037	@CVV UPP CYL 7	70.4988	67.0671	64.1544	293	293
4038	@CVV UPP CYL 8	71.1001	67.5932	64.6146	293	293
4041	@CVV UPP BULK 1	71.1466	67.6120	64.6673	293	293
4042	@CVV UPP BULK 2	70.7578	67.2672	64.3138	293	293
4043	@CVV UPP BULK 3	70.0263	66.6278	63.7472	293	293
4044	@CVV UPP BULK 4	68.9082	65.6117	62.8710	293	293
4045	@CVV UPP BULK 5	68.7321	65.4515	62.7489	293	293
4046	@CVV UPP BULK 6	69.6231	66.2538	63.4756	293	293
4047	@CVV UPP BULK 7	70.4764	67.0038	64.1430	293	293
4048	@CVV UPP BULK 8	71.0602	67.5336	64.6174	293	293
4050	@CVV -Z Radiator low cyl	68.3762	65.2656	62.4464	293	293
4051	CVV -Z Rad. arithm. low	68.5874	65.4454	62.6006	293	293

Node	LABEL	Orbit hot T [K]	Orbit cold T [K]	Orbit Safe T [K]	Ground T [K]	Ground, IMT T [K]
4052	CVV -Z Rad. arithm. upp	67.6598	64.5847	61.9200	293	293
4053	@CVV -Z Radiator upp cyl	67.4557	64.4142	61.7774	293	293
4055	@CVV -Y Radiator	69.5828	66.3007	63.3739	293	293
4057	@CVV +Y Radiator	68.9101	65.6853	62.8880	293	293
4070	Cryostat baffle pz	70.6511	67.1298	64.2674	293	293
4071	Cryostat baffle my	70.2444	66.7737	63.9213	293	293
4072	Cryostat baffle mz	69.2678	65.8775	63.1524	293	293
4073	Cryostat baffle py	70.1340	66.6679	63.8551	293	293
4075	Cryostat inner baffle	70.0258	66.5030	63.7171	293	293
4079	Cryostat baffle top	70.0714	66.5866	63.7821	293	293
4081	Pretension 1	69.9586	66.5617	63.6083	293	293
4082	Pretension 2	69.6616	66.3124	63.3555	293	293
4083	Pretension 3	68.3984	65.1941	62.3770	293	293
4084	Pretension 4	67.7113	64.6140	61.8658	293	293
4085	Pretension 5	67.3696	64.2972	61.5917	293	293
4086	Pretension 6	67.7653	64.6165	61.9176	293	293
4087	Pretension 7	69.1297	65.8258	62.9762	293	293
4088	Pretension 8	69.8026	66.4198	63.4973	293	293
4090	CVV LO windows	70.3448	66.9305	63.9498	290.5867	290.5214
4103	CVV MLI LOW BULK top 3	104.3280	96.1662	91.3549	293	293
4104	CVV MLI LOW BULK top 4	73.8992	67.4721	60.7327	293	293
4105	CVV MLI LOW BULK top 5	72.7533	66.4512	59.8777	293	293
4106	CVV MLI LOW BULK top 6	86.1911	79.3012	75.7825	293	293
4111	CVV MLI LOW BULK 1	166.6960	152.3088	144.1848	293	293
4112	CVV MLI LOW BULK 2	156.5086	142.2864	131.8998	293	293
4113	CVV MLI LOW BULK 3	154.9937	138.9761	121.9490	293	293
4114	CVV MLI LOW BULK 4	146.6231	130.3217	110.5642	293	293
4115	CVV MLI LOW BULK 5	145.1607	128.8472	108.9206	293	293
4116	CVV MLI LOW BULK 6	148.1449	132.2131	115.0166	293	293
4117	CVV MLI LOW BULK 7	150.1818	136.1998	126.2617	293	293
4118	CVV MLI LOW BULK 8	165.9684	151.6166	143.6621	293	293
4121	CVV MLI LOW CYL 1	158.2577	146.2594	143.1928	293	293
4122	CVV MLI LOW CYL 2	135.7188	125.2542	121.2421	293	293
4127	CVV MLI LOW CYL 7	129.1416	118.9007	115.8565	293	293
4128	CVV MLI LOW CYL 8	158.1030	146.0881	143.1961	293	293
4131	CVV MLI UPP CYL 1	155.1393	143.0487	140.4781	293	293
4132	CVV MLI UPP CYL 2	131.0880	120.9034	116.8956	293	293
4137	CVV MLI UPP CYL 7	125.2484	115.0592	112.5497	293	293
4138	CVV MLI UPP CYL 8	155.1118	142.9828	140.5282	293	293
4141	CVV MLI UPP BULK 1	137.1854	124.0930	121.9264	293	293
4142	CVV MLI UPP BULK 2	118.9705	107.7734	105.3933	293	293
4143	CVV MLI UPP BULK 3	88.0814	80.5297	78.0993	293	293
4146	CVV MLI UPP BULK 6	84.4002	77.0146	75.1622	293	293
4147	CVV MLI UPP BULK 7	116.7346	105.5126	103.4947	293	293
4148	CVV MLI UPP BULK 8	136.8958	123.7728	121.7057	293	293
4155	CVV -Y Rad. MLI	129.0661	119.5700	114.8238	293	293
4156	CVV -Y Rad. MLI2	64.5318	61.3153	58.5992	293	293
4157	CVV +Y Rad. MLI	141.4920	130.4908	127.7031	293	293
4158	CVV +Y Rad. MLI2	63.8810	60.5701	58.1314	293	293
4170	Cryos. baf. MLI pz	139.4143	126.7997	124.5951	293	293
4171	Cryos. baf. MLI my	108.9089	99.3201	96.9904	293	293
4173	Cryos. baf. MLI py	107.0370	97.4637	95.4429	293	293
4179	Cryos. baf. MLI top	86.9743	78.7526	75.9377	293	293
4200	LOU support plate	136.3769	132.2158	103.5813	293	293
4205	LOU MLI +Y	133.8348	124.8083	117.5990	293	293
4210	LOU baseplate	136.4541	132.2903	103.6101	293	293

Node	LABEL	Orbit hot T [K]	Orbit cold T [K]	Orbit Safe T [K]	Ground T [K]	Ground, IMT T [K]
4250	LOU Radiator low.	120.4372	116.9527	97.4543	293	293
4251	LOU Radiator upp.	130.2848	126.4094	101.4186	293	293
4260	LOU Rad. straps pX	135.1327	131.0178	103.1599	293	293
4261	LOU Rad. supp. pZpX	131.7516	127.7171	102.0197	293	293
4263	LOU Rad. supp. pZmX	124.7031	120.8552	99.4433	293	293
4265	LOU Rad. supp. pZ	128.9186	124.9859	100.9272	293	293
4267	LOU Rad. supp. mZpX	133.0774	129.0407	102.4388	293	293
4269	LOU Rad. supp. mZmX	122.5213	118.8915	98.3587	293	293
4301	LOU harness 1	148.0763	142.2305	113.6088	293	293
4302	LOU harness 2	172.4521	162.9890	134.3653	293	293
4303	LOU harness 3	197.9995	184.5545	155.9479	293	293
4304	LOU harness 4	224.3242	206.9917	178.4668	293	293
4305	LOU harness 5	251.7360	230.5671	202.7215	293	293
4306	LOU harness 6	279.2279	254.1823	227.5395	293	293
4361	LOUA Waveguid 1	135.1223	128.2181	110.8149	293	293
4362	LOUA Waveguid 2	135.3336	126.6737	117.4848	293	293
4363	LOUA Waveguid 3	133.0324	124.4869	118.5023	293	293
4364	LOUA Waveguid 4	138.9598	130.9166	125.4385	293	293
4365	LOUA Waveguid 5	168.6839	159.3386	151.2587	293	293
4366	LOUA Waveguid 6	265.2987	244.7020	224.0156	293	293
5000	GHe tank outlet	1.6500	1.6301	1.5895	1.8	4.3
5010	GHe Tank-PACS	1.6517	1.6318	1.5913	1.80315	4.2998
5011	GHe Tank-PACS	1.6535	1.6334	1.5932	1.8063	4.2998
5012	GHe Tank-PACS	1.6552	1.6351	1.5951	1.80945	4.2998
5013	GHe Tank-PACS	1.6571	1.6370	1.5971	1.81264	4.2998
5014	GHe PACS I/F 1	1.8842	1.8778	1.7702	2.01496	4.3030
5020	GHe PACS I/F 1	1.9945	1.9927	1.8487	2.196	4.3162
5021	GHe PACS I/F 1	2.0413	2.0411	1.8812	2.27568	4.3248
5022	GHe PACS I/F 1	2.1285	2.1306	1.9408	2.43758	4.3364
5023	GHe PACS I/F 1/2	2.2527	2.2559	2.0226	2.67807	4.3408
5024	GHe PACS I/F 2	2.3578	2.3620	2.0922	2.85047	4.3433
5025	GHe PACS I/F 2	2.4565	2.4616	2.1550	3.07202	4.3631
5026	GHe PACS I/F 2	2.4947	2.4996	2.1789	3.17034	4.3754
5027	GHe PACS I/F 2	2.5660	2.5702	2.2228	3.36992	4.3927
5028	GHe PACS I/F 2/3	2.6840	2.6840	2.2933	3.73652	4.3983
5029	GHe PACS I/F 3	2.7517	2.7488	2.3333	4.00281	4.4075
5030	GHe PACS I/F 3	2.7866	2.7819	2.3536	4.17171	4.4248
5031	GHe PACS I/F 3	2.8023	2.7966	2.3627	4.25436	4.4371
5032	GHe PACS I/F 3	2.8315	2.8241	2.3798	4.41923	4.4544
5033	GHe PACS-SPIRE	2.8886	2.8796	2.4202	4.66154	4.4598
5034	GHe PACS-SPIRE	2.9828	2.9754	2.4997	4.79549	4.4603
5035	GHe SPIRE I/F 1	3.2983	3.2834	2.7532	5.67895	4.4785
5036	GHe SPIRE I/F 1	3.4802	3.4608	2.8967	6.25843	4.5409
5037	GHe SPIRE I/F 1	3.5520	3.5301	2.9531	6.52655	4.5791
5038	GHe SPIRE I/F 1	3.6788	3.6516	3.0525	7.05401	4.6343
5039	GHe SPIRE I/F 2	3.8612	3.8286	3.1991	7.88026	4.6576
5043	GHe HIFI I/F	4.1778	4.1609	3.4778	8.10165	4.6586
5044	GHe HIFI I/F	4.4347	4.4336	3.7125	8.1856	4.6604
5045	GHe HIFI I/F	4.5256	4.5281	3.7930	8.22221	4.6615
5046	GHe HIFI I/F	4.6783	4.6844	3.9240	8.29551	4.6629
5050	GHe L1-L2	4.8021	4.8075	4.0248	8.37794	4.6637
5051	GHe L1-L2	4.9375	4.9537	4.1527	8.40711	4.6637
5052	GHe L1-L2	5.2397	5.2787	4.4393	8.44775	4.6638
5053	GHe L1-L2	5.9503	6.0224	5.0910	8.576	4.6639
5054	GHe L1-L2	7.4922	7.5844	6.4605	9.01121	4.6666
5060	GHe Lev.2 OB	10.2126	10.1499	8.6283	13.82738	4.8088

Node	LABEL	Orbit hot T [K]	Orbit cold T [K]	Orbit Safe T [K]	Ground T [K]	Ground, IMT T [K]
5061	GHe Lev.2 OB	10.8380	10.7283	9.1075	17.45367	4.9674
5062	GHe Lev.2 OB	10.9529	10.8344	9.1981	18.38084	5.0247
5063	GHe Lev.2 OB	11.0340	10.9087	9.2572	19.61386	5.1399
5070	GHe L2-L3	11.2436	11.1326	9.4496	19.64181	5.1401
5071	GHe PM JFET I/F	11.7447	11.6388	9.8669	19.92011	5.1522
5080	GHe PM JFET I/F	12.4865	12.3844	10.5035	20.32625	5.2847
5081	GHe PM JFET I/F	12.6717	12.5627	10.6457	20.49968	5.3697
5082	GHe PM JFET I/F	12.8842	12.7582	10.7884	20.84712	5.4928
5083	GHe SM JFET I/F	13.0028	12.8681	10.8703	21.09769	5.5057
5084	GHe SM JFET I/F	13.1634	13.0240	11.0004	21.23335	5.5584
5085	GHe SM JFET I/F	13.2020	13.0598	11.0282	21.29043	5.5942
5086	GHe SM JFET I/F	13.2429	13.0957	11.0536	21.4043	5.6428
5090	GHe L3-TS1	13.2270	13.0776	11.0387	21.4701	5.6471
5091	GHe L3-TS1	13.4866	13.3470	11.3897	21.4916	5.6471
5092	GHe L3-TS1	25.0792	24.7075	24.5221	26.2794	5.6631
5110	GHe TS 1 / line pymz	34.3150	33.2980	32.8243	61.5537	7.3750
5111	GHe TS 1 / line pymz	35.2616	34.1638	33.6233	72.9783	8.3923
5112	GHe TS 1 / line pymz	35.7543	34.6169	34.0259	79.3816	10.7206
5113	GHe TS 1 / line pymz	35.6403	34.5079	33.9294	80.4966	11.1428
5119	GHe TS 1 / line pymz	35.8006	34.6622	34.1112	80.6529	11.1442
5120	GHe TS 1 / line mypz	34.2977	33.2822	32.8102	61.3313	7.0777
5121	GHe TS 1 / line mypz	35.3462	34.2411	33.6871	73.4114	8.4457
5122	GHe TS 1 / line mypz	35.7565	34.6167	34.0099	79.5531	10.6328
5123	GHe TS 1 / line mypz	35.7221	34.5834	33.9938	81.2450	11.6547
5129	GHe TS 1 / line mypz	35.8816	34.7368	34.1747	81.4083	11.6570
5210	GHe TS 2 / line pymz	44.8662	43.0936	42.4675	127.9740	14.3273
5211	GHe TS 2 / line pymz	45.2648	43.4471	42.7647	139.3993	17.4483
5212	GHe TS 2 / line pymz	45.3596	43.5304	42.8326	143.6862	20.0811
5213	GHe TS 2 / line pymz	45.3937	43.5603	42.8568	145.2031	21.9999
5219	GHe TS 2 / line pymz	45.6705	43.8300	43.1512	145.5177	22.0205
5220	GHe TS 2 / line mypz	44.8873	43.1115	42.4816	130.4952	16.2680
5221	GHe TS 2 / line mypz	45.2771	43.4568	42.7719	142.7782	21.8050
5222	GHe TS 2 / line mypz	45.3637	43.5335	42.8347	145.2554	24.2001
5223	GHe TS 2 / line mypz	45.3952	43.5615	42.8576	145.8097	25.4163
5229	GHe TS 2 / line mypz	45.6724	43.8316	43.1523	146.1216	25.4366
5310	GHe TS 3 / line pymz	55.9468	53.4941	52.0679	208.4730	41.4732
5311	GHe TS 3 / line pymz	56.2228	53.7437	52.2641	218.3811	62.8682
5312	GHe TS 3 / line pymz	56.3422	53.8515	52.3465	223.3556	76.5630
5313	GHe TS 3 / line pymz	56.4025	53.9056	52.3884	225.6178	83.0442
5320	GHe TS 3 / line mypz	55.9628	53.5078	52.0795	208.4698	44.0295
5321	GHe TS 3 / line mypz	56.2640	53.7790	52.2940	218.2074	64.3978
5322	GHe TS 3 / line mypz	56.3850	53.8881	52.3775	223.2356	77.5776
5323	GHe TS 3 / line mypz	56.4199	53.9203	52.4008	225.5762	83.7500
5329	GHe TS 3 out	56.8122	54.3055	52.7988	225.9856	83.6822
5900	Mass Flow Rate [mg/s]	2.12515	1.97001	1.624	24.6149	100
5901	Helium: Init Mass [kg]	337	337	337	337	337
5902	Helium: Act Mass [kg]	337	337	337	337	337
5950	Lifetime [days]	1497.4	1696.0	2039.3	213.8	116.6
5951	Heat to Tank [mW]	48.5383	44.8934	36.8280	570.5736	61.0742
6204	SVM SHIELD C. +Y-Z	135.2559	122.2438	108.7946	293	293
6205	SVM SHIELD C. -Y-Z	138.2657	124.8208	110.9331	293	293
6206	SVM SHIELD -Z	132.3103	120.1911	107.1607	293	293
6304	SVM SHLD MLI C. +Y-Z	112.5392	102.7605	96.3784	293	293
6305	SVM SHLD MLI C. -Y-Z	119.1208	109.0636	102.0675	293	293
6306	SVM SHLD MLI -Z	94.9576	86.5132	78.0667	293	293
6501	STRUT1_CVVSVM	232.2567	229.3936	201.5496	293	293

Node	LABEL	Orbit hot T [K]	Orbit cold T [K]	Orbit Safe T [K]	Ground T [K]	Ground, IMT T [K]
6502	STRUT1_CVVSVM	177.8560	171.6939	155.3139	293	293
6503	STRUT1_CVVSVM	121.5320	114.3138	105.4815	293	293
6511	STRUT2_CVVSVM	231.1281	228.5300	200.5180	293	293
6512	STRUT2_CVVSVM	176.2510	170.4211	153.8384	293	293
6513	STRUT2_CVVSVM	120.6965	113.6314	104.6964	293	293
6521	STRUT3_CVVSVM	230.7616	228.2418	200.1414	293	293
6522	STRUT3_CVVSVM	174.4353	168.9917	152.2225	293	293
6523	STRUT3_CVVSVM	117.5307	111.1401	102.1183	293	293
6531	STRUT4_CVVSVM	229.7160	227.4184	199.0066	293	293
6532	STRUT4_CVVSVM	172.5394	167.4918	150.3628	293	293
6533	STRUT4_CVVSVM	116.4219	110.2559	101.0759	293	293
6541	STRUT5_CVVSVM	230.4351	227.9273	199.3639	293	293
6542	STRUT5_CVVSVM	172.7318	167.7165	150.4828	293	293
6543	STRUT5_CVVSVM	115.1544	109.4503	100.3613	293	293
6551	STRUT6_CVVSVM	230.1435	227.5744	198.4818	293	293
6552	STRUT6_CVVSVM	172.0245	166.9580	148.9208	293	293
6553	STRUT6_CVVSVM	113.4697	108.0688	98.7765	293	293
6561	STRUT7_CVVSVM	228.3651	226.2380	197.1248	293	293
6562	STRUT7_CVVSVM	166.5749	162.7674	144.8269	293	293
6563	STRUT7_CVVSVM	106.0326	102.4226	93.6150	293	293
6571	STRUT8_CVVSVM	227.2786	225.4249	196.2900	293	293
6572	STRUT8_CVVSVM	166.0878	162.2870	144.0885	293	293
6573	STRUT8_CVVSVM	105.4671	101.9466	93.0606	293	293
6581	STRUT9_CVVSVM	227.0280	225.2371	196.0873	293	293
6582	STRUT9_CVVSVM	165.3033	161.6737	143.4438	293	293
6583	STRUT9_CVVSVM	104.5039	101.1561	92.2623	293	293
6591	STRUT10_CVVSVM	226.5700	224.9174	195.7833	293	293
6592	STRUT10_CVVSVM	164.8917	161.3648	143.1113	293	293
6593	STRUT10_CVVSVM	104.9962	101.4587	92.3678	293	293
6601	STRUT11_CVVSVM	226.4144	224.8071	195.6896	293	293
6602	STRUT11_CVVSVM	164.4075	161.0224	142.8330	293	293
6603	STRUT11_CVVSVM	104.6414	101.2085	92.1722	293	293
6611	STRUT12_CVVSVM	226.3720	224.7753	195.6599	293	293
6612	STRUT12_CVVSVM	164.3911	160.9967	142.7914	293	293
6613	STRUT12_CVVSVM	104.9168	101.3550	92.2135	293	293
6621	STRUT13_CVVSVM	226.3707	224.7754	195.6672	293	293
6622	STRUT13_CVVSVM	164.3249	160.9569	142.7947	293	293
6623	STRUT13_CVVSVM	104.2124	100.9000	91.9834	293	293
6631	STRUT14_CVVSVM	226.7956	225.0647	195.9380	293	293
6632	STRUT14_CVVSVM	164.9807	161.4076	143.1898	293	293
6633	STRUT14_CVVSVM	104.5861	101.1549	92.1870	293	293
6641	STRUT15_CVVSVM	226.8085	225.0856	195.9985	293	293
6642	STRUT15_CVVSVM	164.7208	161.2984	143.3147	293	293
6643	STRUT15_CVVSVM	104.4072	101.1317	92.4160	293	293
6651	STRUT16_CVVSVM	227.4432	225.5541	196.5292	293	293
6652	STRUT16_CVVSVM	165.4856	161.8902	144.0110	293	293
6653	STRUT16_CVVSVM	104.9656	101.5551	92.8596	293	293
6661	STRUT17_CVVSVM	227.6221	225.7209	196.8377	293	293
6662	STRUT17_CVVSVM	165.7827	162.2799	144.9258	293	293
6663	STRUT17_CVVSVM	107.3343	103.3754	94.7887	293	293
6671	STRUT18_CVVSVM	228.2703	226.3142	197.8540	293	293
6672	STRUT18_CVVSVM	167.5171	163.7188	146.8241	293	293
6673	STRUT18_CVVSVM	109.4068	105.0144	96.4962	293	293
6681	STRUT19_CVVSVM	228.8078	226.7420	198.4031	293	293
6682	STRUT19_CVVSVM	170.7681	166.1384	149.2109	293	293
6683	STRUT19_CVVSVM	114.6225	108.8561	99.9495	293	293

Node	LABEL	Orbit hot T [K]	Orbit cold T [K]	Orbit Safe T [K]	Ground T [K]	Ground, IMT T [K]
6691	STRUT20_CVVSVM	230.3287	227.9091	199.8330	293	293
6692	STRUT20_CVVSVM	173.4509	168.2108	151.5290	293	293
6693	STRUT20_CVVSVM	116.2763	110.1282	101.2585	293	293
6701	STRUT21_CVVSVM	230.7384	228.2342	200.2486	293	293
6702	STRUT21_CVVSVM	175.3583	169.7351	153.2308	293	293
6703	STRUT21_CVVSVM	119.8473	112.9748	104.1675	293	293
6711	STRUT22_CVVSVM	232.1108	229.2755	201.4406	293	293
6712	STRUT22_CVVSVM	177.5374	171.4306	155.0885	293	293
6713	STRUT22_CVVSVM	121.2097	114.0338	105.2515	293	293
6721	STRUT23_CVVSVM	232.3224	229.4423	201.6422	293	293
6722	STRUT23_CVVSVM	178.2593	172.0108	155.7235	293	293
6723	STRUT23_CVVSVM	122.3800	114.9746	106.2233	293	293
6731	STRUT24_CVVSVM	232.3855	229.4933	201.6775	293	293
6732	STRUT24_CVVSVM	178.4854	172.1807	155.8529	293	293
6733	STRUT24_CVVSVM	122.5660	115.1170	106.3144	293	293
7000	SOLGEN CELLS Mid low	396.2246	371.2320	371.1619	293	293
7001	SOLGEN CELLS -Y low	375.6112	351.9295	351.8515	293	293
7002	SOLGEN CELLS +Y low	375.6985	352.0398	351.9959	293	293
7010	SOLGEN CELLS Mid cent	397.5389	372.5100	372.5072	293	293
7011	SOLGEN CELLS -Y cent	376.4902	352.7960	352.7917	293	293
7012	SOLGEN CELLS +Y cent	376.4908	352.7972	352.7936	293	293
7020	SOLGEN CELLS Mid up	395.4491	370.1109	370.1075	293	293
7021	SOLGEN CELLS -Y up	374.4691	350.3556	350.2974	293	293
7022	SOLGEN CELLS +Y up	374.4675	350.3541	350.2963	293	293
7050	SUNSHADE OSR Mid low	278.0777	224.6095	224.6011	293	293
7051	SUNSHADE OSR -Y low	260.9394	210.8981	210.8867	293	293
7052	SUNSHADE OSR +Y low	260.9383	210.8961	210.8859	293	293
7053	SUNSHADE flap -Y	220.1816	182.8317	182.8199	293	293
7054	SUNSHADE flap +Y	220.1790	182.8281	182.8189	293	293
7060	SUNSHADE OSR Mid lcen	276.2000	219.4206	219.4185	293	293
7061	SUNSHADE OSR -Y lcen	258.4253	205.1364	205.1327	293	293
7062	SUNSHADE OSR +Y lcen	258.4250	205.1357	205.1325	293	293
7070	SUNSHADE OSR Mid ucen	276.1234	219.1050	219.1048	293	293
7071	SUNSHADE OSR -Y ucen	258.4218	204.9169	204.9153	293	293
7072	SUNSHADE OSR +Y ucen	258.4215	204.9164	204.9151	293	293
7080	SUNSHADE OSR Mid up	276.1524	219.1270	219.1270	293	293
7081	SUNSHADE OSR -Y up	261.4637	207.4135	207.4133	293	293
7082	SUNSHADE OSR +Y up	261.4637	207.4134	207.4132	293	293
7100	SOLGEN MLI Mid low	270.2911	252.8390	252.0360	293	293
7101	SOLGEN MLI -Y low	257.5156	240.7836	239.6461	293	293
7102	SOLGEN MLI +Y low	257.3947	240.6867	239.6332	293	293
7103	SOLGEN -x rib MLI +Z low	281.4372	262.6082	260.3779	293	293
7104	SOLGEN -x rib MLI -Y low	266.9377	248.9620	246.1954	293	293
7105	SOLGEN -x rib MLI +Y low	267.0462	249.0706	246.3256	293	293
7106	SOLGEN -x rib MLI +Z up	268.9463	251.7317	251.3626	293	293
7107	SOLGEN -x rib MLI -Y up	255.3311	238.9786	238.5696	293	293
7108	SOLGEN -x rib MLI +Y up	255.2315	238.9009	238.5730	293	293
7110	SOLGEN MLI Mid cent	268.6164	251.4594	251.0540	293	293
7111	SOLGEN MLI -Y cent	255.0598	238.7342	238.2376	293	293
7112	SOLGEN MLI +Y cent	254.9469	238.6206	238.1715	293	293
7120	SOLGEN MLI Mid up	267.4955	250.1590	249.7949	293	293
7121	SOLGEN MLI -Y up	254.1775	237.6007	237.1134	293	293
7122	SOLGEN MLI +Y up	253.8633	237.2997	236.8738	293	293
7130	SOLGEN MLI Mid up2	266.8890	249.4433	249.2651	293	293
7131	SOLGEN MLI -Y up2	252.9994	236.3593	236.1157	293	293
7132	SOLGEN MLI +Y up2	252.8955	236.2641	236.0440	293	293

Node	LABEL	Orbit hot T [K]	Orbit cold T [K]	Orbit Safe T [K]	Ground T [K]	Ground, IMT T [K]
7133	SOLGEN +x rib MLI +Z low	269.4557	251.9191	251.3948	293	293
7134	SOLGEN +x rib MLI -Y low	255.7052	238.9697	238.3363	293	293
7135	SOLGEN +x rib MLI +Y low	255.5353	238.8062	238.2240	293	293
7136	SOLGEN +x rib MLI +Z up	268.0778	250.3023	250.0650	293	293
7137	SOLGEN +x rib MLI -Y up	253.9965	237.0906	236.8146	293	293
7138	SOLGEN +x rib MLI +Y up	253.8956	236.9958	236.7328	293	293
7140	SUNSHADE MLI Mid low2	202.1102	167.4591	166.8242	293	293
7141	SUNSHADE MLI -Y low2	191.1503	159.1031	158.2632	293	293
7142	SUNSHADE MLI +Y low2	191.0357	158.9087	158.1894	293	293
7143	SSHADE rib MLI +Z low	200.3546	168.5983	167.7013	293	293
7144	SSHADE rib MLI -Y low	189.5939	160.1528	159.0148	293	293
7145	SSHADE rib MLI +Y low	189.3922	159.8684	158.8527	293	293
7146	SSHADE rib MLI +Z up	194.3383	159.6085	159.1022	293	293
7147	SSHADE rib MLI -Y up	182.1703	149.7776	149.2648	293	293
7148	SSHADE rib MLI +Y up	182.0692	149.6385	149.1720	293	293
7150	SUNSHADE MLI Mid low	201.3738	165.2731	164.8041	293	293
7151	SUNSHADE MLI -Y low	189.3879	155.8571	155.3132	293	293
7152	SUNSHADE MLI +Y low	189.3960	155.8273	155.3307	293	293
7153	SUNSHADE flap MLI -Y	164.3984	138.7878	138.1970	293	293
7154	SUNSHADE flap MLI +Y	164.4594	138.8578	138.2948	293	293
7160	SUNSHADE MLI Mid lcen	196.0547	157.3455	157.0666	293	293
7161	SUNSHADE MLI -Y lcen	184.1041	148.1366	147.7742	293	293
7162	SUNSHADE MLI +Y lcen	184.0850	148.0980	147.7700	293	293
7170	SUNSHADE MLI Mid ucen	191.9152	152.3907	152.3743	293	293
7171	SUNSHADE MLI -Y ucen	179.9158	142.8815	142.8296	293	293
7172	SUNSHADE MLI +Y ucen	179.8921	142.8430	142.8020	293	293
7180	SUNSHADE MLI Mid up	191.6453	152.1147	152.1073	293	293
7181	SUNSHADE MLI -Y up	181.6824	144.1959	144.1841	293	293
7182	SUNSHADE MLI +Y up	181.6851	144.1939	144.1817	293	293
7203	SShld SVM gapMLI mX	255.4271	233.6852	212.7838	293	293
7204	SShld SVM gapMLI mY mX	253.4893	231.9759	211.3172	293	293
7205	SShld SVM gapMLI pY mX	254.0316	232.4634	211.7457	293	293
7206	SShld SVM gapMLI pX	228.3279	210.0370	198.7191	293	293
7207	SShld SVM gapMLI mY pX	214.9924	197.5574	185.4994	293	293
7208	SShld SVM gapMLI pY pX	215.0503	197.6047	185.6061	293	293
8000	TELESCOPE M1 Mirror	87.8334	78.3463	76.5536	293	293
8100	TELESCOPE M2 Mirror	87.4701	78.0908	76.3244	293	293
8200	TELESCOPE Hexapod	87.5139	78.1198	76.3507	293	293
8400	TEL-CVV I/F node	81.1262	74.1710	72.1534	293	293
8501	TEL M1 MLI inner ring	133.4852	122.3295	120.1051	293	293
8502	TEL M1 MLI inner ring	123.1034	112.9022	110.3712	293	293
8503	TEL M1 MLI inner ring	100.9247	92.4448	90.0951	293	293
8504	TEL M1 MLI inner ring	80.4910	73.4616	71.4839	293	293
8505	TEL M1 MLI inner ring	79.1465	72.0834	70.3665	293	293
8506	TEL M1 MLI inner ring	98.1971	89.7668	87.9965	293	293
8507	TEL M1 MLI inner ring	120.3370	110.1955	108.0006	293	293
8508	TEL M1 MLI inner ring	132.8446	121.6900	119.5392	293	293
8511	TEL M1 MLI outer ring	130.6856	116.0268	114.2069	293	293
8512	TEL M1 MLI outer ring	116.0690	104.4654	102.3514	293	293
8513	TEL M1 MLI outer ring	84.8117	77.0133	74.9499	293	293
8514	TEL M1 MLI outer ring	69.0417	61.9321	60.2901	293	293
8515	TEL M1 MLI outer ring	68.9408	61.8005	60.2593	293	293
8516	TEL M1 MLI outer ring	83.7647	75.8919	74.1538	293	293
8517	TEL M1 MLI outer ring	115.2403	103.5811	101.7252	293	293
8518	TEL M1 MLI outer ring	130.2384	115.5676	113.8662	293	293
8550	TEL M1 MLI on cryo baf	89.6498	80.8958	78.5978	293	293

Node	LABEL	Orbit hot T [K]	Orbit cold T [K]	Orbit Safe T [K]	Ground T [K]	Ground, IMT T [K]
9001	CVV CBs 1	71.6857	68.1380	64.9818	290.8227	290.5515
9002	CVV CBs 2	71.9164	68.3520	64.9873	288.0506	287.3288
9003	CVV CBs 3	70.2819	66.8987	63.8547	290.1986	289.8919
9004	CVV CBs 4	69.9309	66.6095	63.5874	290.2256	289.9826
9005	CVV CBs 5	69.9518	66.5954	63.5275	287.0020	286.4402
9006	CVV CBs 6	69.1859	65.9312	63.0781	292.7085	292.6703
9007	CVV CBs 7	71.1563	67.6655	64.4944	289.3401	289.0018
9008	CVV CBs 8	71.6055	68.0688	64.8886	290.8594	290.6532
9101	PACS int. harn. 11	5.6364	5.5858	4.5086	11.6344	5.7957
9102	PACS int. harn. 11	8.3239	8.2487	6.7956	15.1078	6.0267
9103	PACS int. harn. 11	10.1003	10.0049	8.4056	17.9474	6.2475
9104	PACS int. harn. 11	10.7997	10.6936	9.0911	19.2165	6.3544
9105	PACS int. harn. 11	17.6107	17.1760	16.0600	35.0872	10.7435
9106	PACS int. harn. 11	26.4582	25.6665	24.8226	55.1664	16.2856
9107	PACS int. harn. 11	33.0001	31.9596	31.2728	70.7955	20.4253
9108	PACS int. harn. 11	35.8044	34.6581	34.0527	77.6648	22.2173
9109	PACS int. harn. 11	43.3092	41.6436	40.4522	123.5640	95.5541
9110	PACS int. harn. 11	55.9760	53.4302	51.3021	198.3261	185.0650
9111	PACS int. harn. 11	66.7746	63.5325	60.6840	261.8841	257.8735
9121	PACS int. harn. 13	11.6919	11.6696	4.4833	11.6211	5.7942
9122	PACS int. harn. 13	15.5792	15.5397	6.7693	15.0622	6.0223
9123	PACS int. harn. 13	14.3582	14.2909	8.3850	17.8696	6.2407
9124	PACS int. harn. 13	10.8155	10.7108	9.0736	19.1233	6.3466
9125	PACS int. harn. 13	27.7449	27.4899	15.8355	31.5911	10.5296
9126	PACS int. harn. 13	38.1647	37.6661	24.3390	47.8695	15.8408
9127	PACS int. harn. 13	38.8679	38.0689	30.5984	60.7295	19.8075
9128	PACS int. harn. 13	34.9416	33.8780	33.2961	66.4458	21.5246
9129	PACS int. harn. 13	42.8303	41.2380	39.8829	116.2193	95.2595
9130	PACS int. harn. 13	55.8294	53.3308	50.9495	194.7121	184.8854
9131	PACS int. harn. 13	66.7265	63.5082	60.5106	260.8382	257.8668
9141	PACS int. harn. 15	8.8031	8.7715	4.5296	11.7312	5.7735
9142	PACS int. harn. 15	11.9659	11.9107	6.8336	15.3279	5.9627
9143	PACS int. harn. 15	12.1405	12.0544	8.4550	18.2534	6.1449
9144	PACS int. harn. 15	10.8940	10.7809	9.1453	19.5580	6.2337
9145	PACS int. harn. 15	25.2932	25.0084	15.8583	32.0847	11.1306
9146	PACS int. harn. 15	35.2110	34.6647	24.3624	48.5521	17.1377
9147	PACS int. harn. 15	37.1903	36.3474	30.6360	61.5427	21.5783
9148	PACS int. harn. 15	35.0044	33.9341	33.3417	67.3055	23.4945
9149	PACS int. harn. 15	42.8451	41.2567	39.8392	116.4315	95.5169
9150	PACS int. harn. 15	55.6890	53.2157	50.7594	194.1744	184.2918
9151	PACS int. harn. 15	66.3907	63.2128	60.1822	259.6339	256.5549
9201	PACS int. harn. res.	3.0352	3.0017	2.4846	9.4652	5.6760
9301	SPIRE int. harn. 3	19.8282	19.2415	17.5104	53.0744	47.7549
9302	SPIRE int. harn. 3	28.6644	27.6073	25.8884	88.9860	85.6274
9303	SPIRE int. harn. 3	35.3016	33.9176	32.0964	118.4213	115.7484
9304	SPIRE int. harn. 3	38.1788	36.6565	34.7772	131.9399	129.5422
9305	SPIRE int. harn. 3	41.6799	39.9785	38.0201	148.8063	146.7244
9306	SPIRE int. harn. 3	48.1438	46.0482	43.8451	180.3080	178.7004
9307	SPIRE int. harn. 3	54.0737	51.6312	49.1945	209.7220	208.5157
9308	SPIRE int. harn. 3	56.8747	54.2723	51.7287	223.7653	222.7400
9309	SPIRE int. harn. 3	59.1946	56.4615	53.8298	235.4556	234.5764
9310	SPIRE int. harn. 3	63.6484	60.6683	57.8715	258.0527	257.4449
9311	SPIRE int. harn. 3	67.8851	64.6741	61.7242	279.7126	279.3530
9321	SPIRE int. harn. 11	6.8756	6.7996	5.0874	19.3626	10.5490
9322	SPIRE int. harn. 11	9.4746	9.3763	7.2200	20.5959	12.2463
9323	SPIRE int. harn. 11	10.8916	10.7663	8.7842	21.7616	10.6080

Node	LABEL	Orbit hot T [K]	Orbit cold T [K]	Orbit Safe T [K]	Ground T [K]	Ground, IMT T [K]
9324	SPIRE int. harn. 11	11.2593	11.1184	9.4576	22.3227	7.4424
9325	SPIRE int. harn. 11	19.2195	18.7712	16.4925	39.5161	21.7727
9326	SPIRE int. harn. 11	28.3610	27.5537	25.3802	62.0428	31.2635
9327	SPIRE int. harn. 11	34.4083	33.3252	31.9302	79.4957	33.6558
9328	SPIRE int. harn. 11	36.6735	35.4607	34.7541	87.2847	32.1736
9329	SPIRE int. harn. 11	43.6057	41.9402	40.6236	129.4094	98.0501
9330	SPIRE int. harn. 11	55.3702	52.9230	50.7077	199.4146	184.4841
9331	SPIRE int. harn. 11	65.4046	62.3277	59.4903	259.5249	254.8982
9341	SPIRE int. harn. res.	4.1730	4.0925	3.3936	18.7176	7.3104
9361	PM JFET int. hn. res.	13.2495	13.0835	11.0096	25.3108	10.2787
9381	SM JFET int. hn. res.	13.3320	13.1740	11.1072	22.9397	7.7699
9401	HIFI int. harn. 1	11.7822	11.6675	9.1803	21.4035	7.2890
9402	HIFI int. harn. 1	12.2339	12.1292	9.1523	20.6042	6.9420
9403	HIFI int. harn. 1	11.6655	11.5623	9.1243	19.7736	6.5734
9404	HIFI int. harn. 1	10.8233	10.7158	9.1102	19.3454	6.3797
9405	HIFI int. harn. 1	17.8937	17.4344	16.2869	37.8078	13.8315
9406	HIFI int. harn. 1	26.9928	26.1559	25.2342	60.7563	22.2775
9407	HIFI int. harn. 1	33.7020	32.6026	31.8034	78.4194	28.3625
9408	HIFI int. harn. 1	36.5768	35.3658	34.6326	86.2470	30.9692
9409	HIFI int. harn. 1	43.9234	42.2051	40.8656	128.8863	97.4161
9410	HIFI int. harn. 1	56.4018	53.8233	51.5147	199.6045	184.3119
9411	HIFI int. harn. 1	67.0641	63.8010	60.7504	260.3057	255.3714
9421	HIFI int. harn. 2	16.8269	16.7444	9.1821	21.4127	7.2908
9422	HIFI int. harn. 2	19.8032	19.7362	9.1577	20.6332	6.9474
9423	HIFI int. harn. 2	16.7559	16.6815	9.1332	19.8246	6.5822
9424	HIFI int. harn. 2	10.8519	10.7437	9.1209	19.4083	6.3901
9425	HIFI int. harn. 2	18.2058	17.7557	16.2336	38.0419	13.9572
9426	HIFI int. harn. 2	27.3634	26.5371	25.2004	61.1612	22.5835
9427	HIFI int. harn. 2	33.9075	32.8115	31.8061	78.8212	28.8157
9428	HIFI int. harn. 2	36.6121	35.3977	34.6539	86.6461	31.4875
9429	HIFI int. harn. 2	44.0861	42.3600	40.9131	129.2515	97.8660
9430	HIFI int. harn. 2	56.6006	54.0192	51.5725	199.9356	184.6970
9431	HIFI int. harn. 2	67.1590	63.8960	60.7749	260.4378	255.5301
9441	HIFI int. harn. 3	11.6902	11.5746	9.1803	21.4033	7.2890
9442	HIFI int. harn. 3	12.0855	11.9796	9.1522	20.6035	6.9419
9443	HIFI int. harn. 3	11.5724	11.4684	9.1241	19.7725	6.5732
9444	HIFI int. harn. 3	10.8229	10.7155	9.1100	19.3440	6.3794
9445	HIFI int. harn. 3	17.8933	17.4342	16.2859	37.7957	13.8151
9446	HIFI int. harn. 3	26.9915	26.1549	25.2323	60.7319	22.2465
9447	HIFI int. harn. 3	33.6995	32.6004	31.8010	78.3865	28.3218
9448	HIFI int. harn. 3	36.5735	35.3628	34.6299	86.2092	30.9243
9449	HIFI int. harn. 3	43.9220	42.2040	40.8637	128.8597	97.4000
9450	HIFI int. harn. 3	56.4019	53.8236	51.5137	199.5913	184.3046
9451	HIFI int. harn. 3	67.0644	63.8014	60.7501	260.3018	255.3694
9461	HIFI int. harn. 4	16.3546	16.2699	9.1820	21.4123	7.2908
9462	HIFI int. harn. 4	19.1255	19.0563	9.1574	20.6318	6.9472
9463	HIFI int. harn. 4	16.2811	16.2048	9.1327	19.8222	6.5819
9464	HIFI int. harn. 4	10.8506	10.7424	9.1203	19.4054	6.3896
9465	HIFI int. harn. 4	18.2151	17.7651	16.2359	38.0463	13.9584
9466	HIFI int. harn. 4	27.3737	26.5475	25.2022	61.1659	22.5827
9467	HIFI int. harn. 4	33.9124	32.8165	31.8069	78.8223	28.8125
9468	HIFI int. harn. 4	36.6123	35.3979	34.6540	86.6451	31.4832
9469	HIFI int. harn. 4	44.0882	42.3619	40.9145	129.2577	97.8819
9470	HIFI int. harn. 4	56.6031	54.0216	51.5743	199.9446	184.7128
9471	HIFI int. harn. 4	67.1601	63.8971	60.7757	260.4417	255.5364
9481	HIFI int. harn. 5	23.6593	23.6025	9.1766	21.3845	7.2850

Node	LABEL	Orbit hot T [K]	Orbit cold T [K]	Orbit Safe T [K]	Ground T [K]	Ground, IMT T [K]
9482	HIFI int. harn. 5	29.1853	29.1420	9.1413	20.5444	6.9307
9483	HIFI int. harn. 5	23.6013	23.5510	9.1059	19.6685	6.5562
9484	HIFI int. harn. 5	10.8229	10.7171	9.0881	19.2157	6.3602
9485	HIFI int. harn. 5	19.4989	19.0759	16.3640	37.1452	13.5748
9486	HIFI int. harn. 5	28.7533	27.9698	25.2825	59.7234	21.7246
9487	HIFI int. harn. 5	34.5365	33.4691	31.7981	77.6016	27.5700
9488	HIFI int. harn. 5	36.5424	35.3368	34.6001	85.5703	30.0710
9489	HIFI int. harn. 5	43.9497	42.2694	40.7164	127.9314	95.7132
9490	HIFI int. harn. 5	56.4779	53.9362	51.3084	198.4802	182.7093
9491	HIFI int. harn. 5	67.1330	63.8856	60.6595	259.8215	254.6984
9521	HIFI int. harn. res.	11.0105	10.8847	9.1943	21.7927	7.4555
9801	TS1 CB on strap 3	35.6847	34.5509	33.9598	76.1040	20.3292
9802	TS2 CB on strap 4	36.4436	35.2468	34.5317	84.5177	28.7410
9803	TS3 CB on strap 5	35.9788	34.8196	34.2027	83.3834	21.1760
9804	TS4 CB on strap 6	35.6400	34.5076	33.9292	80.4992	11.6133
9805	TS5 CB on strap 7	36.4485	35.2570	34.5853	84.5213	28.7203
9806	TS6 CB on strap 8	35.2977	34.1974	33.6539	73.2605	10.6650
9807	TS7 CB on strap 1	34.8267	33.7715	33.2223	65.4546	21.4382
9808	TS8 CB on strap 2	34.7579	33.7099	33.1713	64.5695	19.4504
	EPLM:PACS					
711	Top Optic Housing	3.0337	2.9999	2.4846	9.5172	5.7004
712	Spectrometer Housing	3.0342	3.0007	2.4839	9.4625	5.6760
713	Collimator Housing	3.0290	2.9957	2.4808	9.4321	5.6639
714	Photometer Housing	2.8627	2.8348	2.3879	8.1954	5.2634
721	2K Feed-Through Red D	1.6611	1.6413	1.5966	1.8938	1.7535
722	2K Feed-Through Blue D	1.8025	1.7815	1.6528	2.7990	2.0866
723	2K StSt I/F Blue Det.	1.6685	1.6488	1.5975	1.9074	1.7576
731	Grating Assy	3.0530	3.0200	2.4808	9.4321	5.6639
741	Red Detector *	1.7132	1.6926	1.6277	2.4302	1.9489
742	Red Detector CRE	3.0515	3.0183	2.4791	9.3828	5.6466
743	CFRP-Strut Red Det.	2.3737	2.3466	2.0558	6.5927	3.8662
744	Harness Red Det. Int	2.4919	2.4644	2.1052	7.0055	4.2830
751	Blue Detector *	1.8790	1.8573	1.6817	3.2891	2.2669
752	Blue Detector CRE	3.0522	3.0190	2.4793	9.3867	5.6479
753	CFRP-Strut Blue Det.	2.4566	2.4290	2.0828	6.8712	4.0288
754	Harness Blue Det. Int	2.5470	2.5190	2.1258	7.1481	4.3530
761	Photometer Cooler Pump	1.6779	1.6584	1.5913	1.8312	1.7174
762	Photometer Cooler Evap	1.6613	1.6415	1.5924	1.8472	1.7742
763	Photometer Buffer *	1.7745	1.7548	1.6200	2.3011	1.9639
771	CFRP-Strut (OB) 1	7.8586	7.7551	6.3778	16.9789	6.5154
772	CFRP-Strut (OB) 2	7.7263	7.6307	6.3042	15.2967	5.7095
773	CFRP-Strut (OB) 3	7.8593	7.7556	6.3787	16.9963	6.5294
781	Level 1,1 I/F	2.5929	2.5734	2.2155	6.4838	4.7733
782	Level 1,2 I/F	2.8578	2.8365	2.3828	7.7134	4.9676
783	Level 1,3 I/F	2.9554	2.9312	2.4432	8.0519	5.0927
	EPLM:SPIRE					
800	L1 Strap IF1 @ SOB	4.0167	3.9483	3.2924	14.0290	6.1561
801	PH_JFET_ENCLOSURE	13.2346	13.0699	10.9969	25.1706	10.1369
802	SP_JFET_ENCLOSURE	13.3256	13.1682	11.1019	22.8789	7.7085
803	FPU_OPTICAL_BENCH	4.1225	4.0419	3.3553	18.7081	7.2890
804	RF_FILTER_BOXES	4.1722	4.0917	3.3930	18.7165	7.3104
805	BSM	4.1457	4.0656	3.3553	18.7081	7.2951
806	SMECm	4.1400	4.0598	3.3553	18.7081	7.3715
807	PH_CALIB	4.1462	4.0662	3.3553	18.7081	7.2959

Node	LABEL	Orbit hot T [K]	Orbit cold T [K]	Orbit Safe T [K]	Ground T [K]	Ground, IMT T [K]
808	SPEC_CALIB	4.1225	4.0419	3.3553	18.7081	7.2890
809	PH_DETECTOR_ENCLOSURE	1.6819	1.6610	1.6103	2.7295	1.8434
810	SP_DETECTOR_ENCLOSURE	1.6672	1.6469	1.6008	2.2608	1.7885
811	L0 Enclosure Flexible S	1.6633	1.6432	1.5984	2.1372	1.7740
812	L0 Pump Flexible Strap	1.6846	1.6649	1.5935	1.9312	1.8123
813	L0 Evap Flexible Strap	1.6531	1.6332	1.5903	1.8338	1.7354
814	L0 Enclosure External S	1.6624	1.6423	1.5978	2.1086	1.7704
815	L0 Pump External Strap	1.6821	1.6624	1.5932	1.9199	1.8067
816	L0 Evaporator External	1.6518	1.6319	1.5900	1.8190	1.7331
817	COOLER_PUMP	1.7098	1.6903	1.6935	5.2694	1.8867
818	COOLER_SHUNT	1.6540	1.6341	1.5910	1.8627	1.7389
819	COOLER_EVAP	0.2900	0.2900	1.6259	3.4253	0.2900
820	COOLER_EVAP_HS	1.6541	1.6342	1.5910	1.8604	1.7390
821	COOLER_PUMP_HS	1.6887	1.6690	1.5942	1.9576	1.8256
822	PH_DETECTORS	0.2917	0.2917	1.6259	3.4252	0.2921
823	SP DETECTORS	0.2936	0.2935	1.6259	3.4232	0.2942
830	L1 Strap IF2 @ SOB	4.0167	3.9483	3.2924	14.0290	6.1561
831	PH_L3 IF	13.0836	12.9299	10.9018	23.8840	8.7764
832	SP_L3 IF	13.2912	13.1371	11.0812	22.4552	7.1634
	EPLM:HIFI					
910	HIFI_FPU_Main_structure	11.0105	10.8847	9.1943	21.7925	7.4555
911	Calibration_source_assem	11.0154	10.8897	9.1943	21.7925	7.4555
912	Focal_Plane_Chopper	11.0145	10.8887	9.1943	21.7925	7.4555
913	Diplexer_Rooftop_Transla	11.0105	10.8847	9.1943	21.7925	7.4555
914	Second_stage_amplifier	11.0341	10.9086	9.1943	21.7925	7.4555
919	L2-boundary	11.0093	10.8835	9.2016	21.6633	7.4010
920	Mixer_Sub_Assembly	10.9960	10.8709	9.1661	21.6943	7.4386
921	First_stage_amplifier	11.0156	10.8909	9.1661	21.6943	7.4402
922	EMC-filtering	11.0042	10.8793	9.1661	21.6943	7.4386
925	Magnet_current_dissipati	8.6539	8.5677	7.2238	16.6947	6.2651
930	Console_level1_decks	5.0339	5.0179	4.1893	9.4326	4.7178
935	Magnet_current_dissipati	3.8774	3.8623	3.2688	7.1145	3.7072
939	L1_boundary	5.0106	4.9953	4.1713	9.3701	4.7118
940	Console_level0_decks	1.8610	1.8404	1.7305	2.7306	2.0827
941	Mixer_Unit	1.8662	1.8457	1.7305	2.7306	2.0827
942	Heater	1.8610	1.8404	1.7305	2.7306	2.0827
943	LO-power	1.8617	1.8412	1.7305	2.7306	2.0827
949	L0-boundary	1.8528	1.8323	1.7254	2.6883	2.0569
	EPLM:CCC					
4800	Cryostat Cover door	68.9571	64.1140	61.7634	293	293
4801	Cover Heat Shield CHS	67.8798	62.4433	60.3921	254.7771	80
4802	Internal MLI -X side	68.0996	62.7886	60.6742	263.8370	197.0783
4803	Internal MLI +X side	68.7454	63.7898	61.4961	286.5051	277.1779
4810	Inlet Junction	68.8547	63.9544	61.6317	289.7136	276.9534
4811	Outlet Junction	68.8547	63.9544	61.6317	289.7136	276.9534
	SVM					
6001	SVM wall pZ	318	291	265	293	293
6002	SVM wall pYpZ	318	291	265	293	293
6003	SVM wall pY	318	291	265	293	293
6004	SVM wall pYmZ	318	291	265	293	293
6005	SVM wall mZ	318	291	265	293	293
6006	SVM wall mYmZ	318	291	265	293	293
6007	SVM wall mY	318	291	265	293	293

Node	LABEL	Orbit hot T [K]	Orbit cold T [K]	Orbit Safe T [K]	Ground T [K]	Ground, IMT T [K]
6008	SVM wall mYpZ	318	291	265	293	293
6020	SVM I/F to CVV struts	293	293	245	293	293
6021	SVM I/F to SVM shield	293	266	240	293	293
6022	SVM I/F to Sshld str.	293	266	240	293	293
6023	SVM I/F to waveguides	293	266	240	293	293
6024	SVM I/F to harness	293	266	240	293	293
6051	SVM top pZ	230	203	168	293	293
6052	SVM top pYpZ	230	203	168	293	293
6053	SVM top pY	230	203	168	293	293
6054	SVM top pYmZ	230	203	168	293	293
6055	SVM top mZ	230	203	168	293	293
6056	SVM top mYmZ	230	203	168	293	293
6057	SVM top mY	230	203	168	293	293
6058	SVM top mYpZ	230	203	168	293	293
6101	SVM top disc pZ	230	203	168	293	293
6102	SVM top disc pYpZ	230	203	168	293	293
6103	SVM top disc pY	230	203	168	293	293
6104	SVM top disc pYmZ	230	203	168	293	293
6105	SVM top disc mZ	230	203	168	293	293
6106	SVM top disc mYmZ	230	203	168	293	293
6107	SVM top disc mY	230	203	168	293	293
6108	SVM top disc mYpZ	230	203	168	293	293
6151	MLI THR pZ	230	203	168	293	293
6152	MLI THR pY	230	203	168	293	293
6153	MLI THR mZ	230	203	168	293	293
6154	MLI THR mY	230	203	168	293	293
6155	MLI SAS pZ	230	203	168	293	293
6156	MLI SAS pZ BRK	230	203	168	293	293
6157	MLI SAS mZ	230	203	168	293	293
6158	MLI SAS mZ BRK	230	203	168	293	293
6159	MLI AAD	230	203	168	293	293
6160	MLI VMC	230	203	168	293	293
6161	MLI SREM	230	203	168	293	293

	Name	Dep./Comp.		Name	Dep./Comp.
X	Alberti von Mathias Dr.	AOE22		Stritter Rene	AED11
	Alo Hakan	OTN/TP 45		Tenhaeff Dieter	AOE22
X	Barlage Bernhard	AED11		Thörmer Klaus-Horst Dr.	OTN/AED65
X	Bayer Thomas	AET52	X	Wagner Klaus	AOE23
X	Faas Horst	AEA65		Wietbrock, Walter	AET12
	Fehringer Alexander	AOE13		Wöhler Hans	AOE22
X	Frey Albrecht	AED422			
	Gerner Willi	AED11			
	Grasl Andreas	OTN/AET52			
	Grasshoff Brigitte	AET12			
X	Hauser Armin	AOE23			
X	Hinger Jürgen	AOE23			
X	Hohn Rüdiger	AET52	X	Alcatel	ASP
	Huber Johann	AOA4	X	ESA/ESTEC	ESA
	Hund Walter	ASE4A			
X	Idler Siegmund	AED432		**Instruments:**	
	Ivády von András	FAE22	X	MPE (PACS)	MPE
X	Jahn Gerd Dr.	AOE23	X	RAL (SPIRE)	RAL
	Kalde Clemens	APE3	X	SRON (HIFI)	SRON
	Kameter Rudolf	OTN/AET52			
X	Kettner Bernhard	AOE22		**Subcontractors:**	
X	Knoblauch August	AET32		Air Liquide, Space Department	AIR
	Koelle Markus	AET22		Air Liquide, Space Department	AIRS
X	Kroeker Jürgen	AED65		Air Liquide, Orbital System	AIRT
X	Kunz Oliver Dr.	AOE23		Alcatel Bell Space	ABSP
	Lamprecht Ernst	OTN/ASI21		Astrium Sub-Subsyst. & Equipment	ASSE
X	Lang Jürgen	ASE4A		Austrian Aerospace	AAE
X	Langfermann Michael	AET52		Austrian Aerospace	AAEM
	Mack Paul	OTN/AET52		APCO Technologies S. A.	APCO
	Muhl Eckhard	OTN/AET52		Bieri Engineering B. V.	BIER
X	Pastorino Michel	ASPI Resid.		BOC Edwards	BOCE
	Peitzker Helmut	AED65		Dutch Space Solar Arrays	DSSA
	Peltz Heinz-Willi	AET42		EADS CASA Espacio	CASA
	Pietroboni Karin	AED65		EADS CASA Espacio	ECAS
	Platzer Wilhelm	AED22		EADS Space Transportation	ASIP
	Puttlitz Joachim	OTN/AET52		Eurocopter	ECD
	Rebholz Reinhold	AET52		HTS AG Zürich	HTSZ
X	Reuß Friedhelm	AED62		Linde	LIND
X	Rühe Wolfgang	AED65		Patria New Technologies Oy	PANT
	Runge Axel	OTN/AET52		Phoenix, Volkmarsen	PHOE
	Sachsse Bernt	AED21		Prototech AS	PROT
X	Schink Dietmar	AED422		QMC Instruments Ltd.	QMC
X	Schlosser Christian	OTN/AET52		Rembe, Brilon	REMB
	Schmidt Rudolf	FAE22		SENER Ingenieria SA	SEN
X	Schweickert Gunn	AOE22		Stöhr, Königsbrunn	STOE
	Stauss Oliver	AOE13		Rosemount Aerospace GmbH	ROSE
	Steininger Eric	AED422		RYMSA, Radiación y Microondas S.A.	RYM