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1. INTRODUCTION

The purpose of this document is the description of the geometric and thermal mathematical model built for HERSCHEL and PLANCK Service Modules as well as the presentation of the temperature results derived from the thermal analysis performed for both satellites.

In the present document each satellite has been described in a dedicate chapter, so that all aspects concerning HERSCHEL are presented and discuss in chapter 3, while the description and analysis of PLANCK is presented and discuss in chapter 4.

2. APPLICABLE AND REFERENCE DOCUMENT

2.1 APPLICABLE DOCUMENT

System Support Documents

AD-2.1	Herschel/Planck Environment and Tests Requirements	H-P-1-ASPI-SP-0030
AD-2.2	General Design & Interface Requirements	H-P-1-ASPI-SP-0027
AD-2.3	SVM Mechanical Interface control document	H-P-IC-AI-0001
AD-2.4	Reduced Geom. RGMM and Thermal RTMM Math. Models Requirements	H-P-RQ-AI-0002
AD-2.5	SVM Requirement Specification	H-P-4-ASPI-SP-0019
AD-2.6	SVM Interface Specification	H-P-4-ASPI-IS-0042
AD-2.7	TCS Design Description	H-P-RP-AI-0039
AD-2.8	PLANCK HEAT-PIPES Network Definition and Interfaces	H-P-TN-AI-0020
AD-2.9	Not used	
AD-2.10	Thermal Interface control document	H-P-IC-AI-0002
AD-2.11	Instrument Interface Document, Part B (IID-B): High Frequency Instrument	SCI-PT-IIDB/HFI-04141
AD-2.12	Instrument Interface Document, Part B (IID-B): Low Frequency Instrument	SCI-PT-IIDB/LFI-04142
AD-2.13	Instrument Interface Document, Part B (IID-B): Photo-conductor Instrument	SCI-PT-IIDB/PACS-2126
AD-2.14	Instrument Interface Document, Part B (IID-B): Instrument ”HIFI”	SCI-PT-IIDB/HIFI-2125

2.2 REFERENCE DOCUMENT

RD-2.1 Thermal Conductivity of Metallic Honeycomb Sandwich Panels NLR, Amsterdam, NL
RD-2.2 Analytical/Experimental Semiempirical Evaluation of Spacelab MLI Thermal Conductance
RP-AI-0237, dated 13/09/78
RD-2.3 Survey and Evaluation of Multilayer Insylation Heat Transfer Measurements
J.Doenecke (DASA), 23rd ICES, July 1993 - paper n.SAE 932117
RD-2.4 A Systematic Approach to Thermal Balance Test Evaluation and Thermal Mathematical Model Correlation for Spacecraft Thermal Design, L.Costamagna, V.Perotto, E.Sacchi (Alenia Spazio), 4th European Symposium on Space Environmental and Control Systems, October 1991.

2.3 LIST OF ACRONYMS

AAD	: Attitude Anomaly Detector
AIT	: Assembly Integration and Testing
BOL	: Beginning of Life
CoG	: Centre of Gravity
CSS	: Coarse Sun sensor
EOL	: End of Life
GMM	: Geometrical Mathematical Model
GYRO	: Gyroscope
HPLM	: Herschel Payload Module
H/W	: Hardware
L/GA	: Low Gain antenna
M/GA	: Medium Gain antenna
MGSE	: Mechanical Ground Support Equipment
MLI	: Multi Layer Insulation
OSR	: Optical Solar Reflector
PPLM	: Planck Payload Module
P/ST	: Primary Structure (occasionally used)
P.Tanks	: Propellant Tanks
PTSS	: Propellant Tank Support Structure
rpm	: revolution per minute
S/C	: Spacecraft or Satellite
SAS	: Sun Acquisition sensor
SCC	: Sorption Cooler Compressors
STM	: Star Mapper
STR	: Star Trackers
TBC	: To Be Confirmed
TBD	: To Be Defined
TMM	: Thermal Mathematical Model
VDA	: Vacuum Deposited Aluminum

3. HERSCHEL – MODEL DESCRIPTION AND THERMAL ANALYSIS

3.1 HERSCHEL - PRESENTATION OF THE MODEL

Herschel and Planck are two satellites dedicated to the observation of the universe.

- Herschel key science targets are focused on the formation of stars and galaxies. It will complement the successful progress of ISO (‘95-‘98) and SIRTF (to be launched this year).

The spacecraft is planned to operate from Lissajous orbits around the Langragian point L2 of the Sun / Earth system. This point is aligned with the Earth and the Sun and located at 1.5 10^6 Km from the Earth.

Both satellites are planned to be launched by ARIANE 5 dual launch.

The main modules are:

- The Service Module (SVM)
- The Payload Module (PLM), carrying the scientific instruments and telescopes and relevant electronic units
- The Sunshields, protecting the Payload or the S/C and used also as Solar Arrays.

3.1.1 Geometric Mathematical Model (GMM)

The Geometric models detail all the satellite surfaces and their thermo-optical properties, in order to evaluate the radiative exchange factors among nodes and, only for the external nodes, the fluxes (solar, albedo and Earth shine) on spacecraft surfaces during the orbit. Due to the huge distance of the HERSCHEL orbit from the Earth, only solar fluxes have been considerate in the thermal analysis.

The Geometric Mathematical Model (GMM) of HERSCHEL satellite has been built using Esarad (version 4.3) software and it is composed by two models, which describe respectively the internal enclosures of the spacecraft and the external environment of the spacecraft. Some components of the Payload Module have been also considered in the external GMM in order to evaluate the radiative impact on the HERSCHEL Service Module.

The termo-optical properties of the material used in theGMM/TMM are listed in Table 3.1.1.
The geometrical nodes of HERSCHEL Service Module are shown on Table 3.1.1-1a (GMM Internal) and Table 3.1.1-1b (GMM External), while HERSCHEL Payload Module (HPLM) nodes are listed in Table 3.1.1-2.
Material and thermal properties of each node at BOL / EOL are provided in the same tables; data applicable to HPLM are in accordance to data provided from Alcatel to Alenia during the SVM Thermal System proposal.

The only thermal property assumed to change during the satellite life is the solar absorptivity of the OSR (Alenia experience) and of the MLI closure between the SVM and PLM (input data from AD-2.6).
In addition to the previous list, the nodal breakdown of the Geometric Model, both internal and external nodes, is shown on Fig 3.1.1-1 to Fig. 3.1.1-11

Table 3.1.1 HERSCHEL – Service Module Thermal Properties Materials

SURFACES	MATERIALS	Alpha	Alpha	Epsilon	Ref.
		BOL	EOL		
GMM INTERNAL					
High Emissivity Aluminum Internal surfaces (panels & units)	Black Paint	0.9	=	0.9	Alenia test data (worst case)
CFRP Internal surfaces (panels & cone)	CFRP	0.9	=	0.9	Assumption (TBC)
Internal Launcher Adaptor Ring	Aluminium Tape	0.15	=	0.05	Supplier data sheet
Internal MLI (-Y Panel, -Y-Z Panel, Internal STR baffle, Tanks)	VDA Kapton (Aluminized side)	0.15	=	0.05	Supplier data sheet
Bottom closure internal side	1/3 CFRP – 2/3 VDA Kapton (Aluminized side)	0.4	=	0.33	Effective α / ε values
GMM EXTERNAL					
Solar Array	Solar Array Cells	0.72	=	0.82	Data from Thermal System proposal
HPLM Tilted Shield	Aluminium	0.15	=	0.05	AD-2.6
External Launcher Adaptor Ring	Cromic Acid Anodization	0.5	=	0.5	Test data derived from Integral program
Radiator Panels +Y+Z and –Y+Z	OSR	0.1	0.18	0.8	Alenia test data
Others Radiator Panels	Electrodag 501	0.95	=	0.8	Alenia test data
MLI facing to HPLM	VDA Kapton (Aluminized side)	0.15	=	0.05	Supplier data sheet
External STR Baffle	Black Anodization	0.86	=	0.86	Assumption based on Alenia test data
External MLI	Carbon Filled Kapton Kapton	0.92	=	0.86	Supplier data sheet
MLI Closure to HPLM	White Paint	0.17	0.55	0.87	AD-2.6

Table 3.1.1-1a HERSCHEL – Service Module Internal Geometrical Nodes List

NODE	LABEL	MATERIALS	Alpha		Epsilon
			BOL	EOL	
101	RFDN	Black Paint	0.9	=	0.9
102	EPC1	Black Paint	0.9	=	0.9
103	EPC2	Black Paint	0.9	=	0.9
104	TRANSX1	Black Paint	0.9	=	0.9
105	TRANSX2	Black Paint	0.9	=	0.9
106	TWTA1	Black Paint	0.9	=	0.9
107	TWTA2	Black Paint	0.9	=	0.9
201	PCDU	Black Paint	0.9	=	0.9
202	CMDU	Black Paint	0.9	=	0.9
203	ACC	Black Paint	0.9	=	0.9
204	BATT	Black Paint	0.9	=	0.9
301	FPSPU1_2	Black Paint	0.9	=	0.9
303	FPDPU	Black Paint	0.9	=	0.9
304	FPBOLC	Black Paint	0.9	=	0.9
305	FPMECDEC	Black Paint	0.9	=	0.9
401	CRYOE	Black Paint	0.9	=	0.9

NODE	LABEL	MATERIALS	Alpha		Epsilon
			BOL	EOL	
404	HSDCU	Black Paint	0.9	=	0.9
405	HSDPU	Black Paint	0.9	=	0.9
406	HSFCU	Black Paint	0.9	=	0.9
701	RWL1_C	Black Paint	0.9	=	0.9
702	RWL2_C	Black Paint	0.9	=	0.9
703	RWL3_C	Black Paint	0.9	=	0.9
704	RWL4_C	Black Paint	0.9	=	0.9
705	RWDE	Black Paint	0.9	=	0.9
706	QRS1	Black Paint	0.9	=	0.9
707	QRS2	Black Paint	0.9	=	0.9
801	GYRO	Black Paint	0.9	=	0.9
802	PDU	Black Paint	0.9	=	0.9
811	STRMY	Black Paint	0.9	=	0.9
812	STRMY CONE UPPER INT	Kapton Aluminized	0.15	=	0.05
813	STRMY CONE UPPER INT	Kapton Aluminized	0.15	=	0.05
814	STRMY CONE UPPER INT	Kapton Aluminized	0.15	=	0.05
815	STRMY CONE UPPER INT	Kapton Aluminized	0.15	=	0.05
816	STRMY CONE UPPER INT	Kapton Aluminized	0.15	=	0.05
831	STRPY	Black Paint	0.9	=	0.9
832	STRPY CONE UPPER INT	Kapton Aluminized	0.15	=	0.05
833	STRPY CONE UPPER INT	Kapton Aluminized	0.15	=	0.05
834	STRPY CONE UPPER INT	Kapton Aluminized	0.15	=	0.05
835	STRPY CONE UPPER INT	Kapton Aluminized	0.15	=	0.05
836	STRPY CONE UPPER INT	Kapton Aluminized	0.15	=	0.05
900	TANK1 MLI	Kapton Aluminized	0.15	=	0.05
910	TANK2 MLI	Kapton Aluminized	0.15	=	0.05
1600	SVM Bot +Z	CFRP	0.9	=	0.9
1601	SVM Bot +Y+Z	CFRP	0.9	=	0.9
1602	SVM Bot +Y	CFRP	0.9	=	0.9
1603	SVM Bot +Y-Z	CFRP	0.9	=	0.9
1604	SVM Bot –Z	CFRP	0.9	=	0.9
1605	SVM Bot -Z-Y	CFRP	0.9	=	0.9
1606	SVM Bot –Y	CFRP	0.9	=	0.9
1607	SVM Bot -Y+Z	CFRP	0.9	=	0.9
2100	Launch Adapter Cone Int +Z	Aluminium Tape	0.15	=	0.05
2101	Launch Adapter Cone Int +Z+Y	Aluminium Tape	0.15	=	0.05
2102	Launch Adapter Cone Int +Y	Aluminium Tape	0.15	=	0.05
2103	Launch Adapter Cone Int +Y-Z	Aluminium Tape	0.15	=	0.05
2104	Launch Adapter Cone Int-Z	Aluminium Tape	0.15	=	0.05
2105	Launch Adapter Cone Int-Z-Y	Aluminium Tape	0.15	=	0.05
2106	Launch Adapter Cone Int-Y	Aluminium Tape	0.15	=	0.05
2107	Launch Adapter Cone Int-Y+Z	Aluminium Tape	0.15	=	0.05
2110	Launch Adapter Edge Int +Z	Aluminium Tape	0.15	=	0.05
2111	Launch Adapter Edge Int +Z+Y	Aluminium Tape	0.15	=	0.05
2112	Launch Adapter Edge Int +Y	Aluminium Tape	0.15	=	0.05
2113	Launch Adapter Edge Int +Y-Z	Aluminium Tape	0.15	=	0.05
2114	Launch Adapter Edge Int-Z	Aluminium Tape	0.15	=	0.05
2115	Launch Adapter Edge Int-Z-Y	Aluminium Tape	0.15	=	0.05
2116	Launch Adapter Edge Int-Y	Aluminium Tape	0.15	=	0.05
2117	Launch Adapter Edge Int-Y+Z	Aluminium Tape	0.15	=	0.05

NODE	LABEL	MATERIALS	Alpha		Epsilon
			BOL	EOL	
2120	Launch Adapter Cyl Int +Z	Aluminium Tape	0.15	=	0.05
2121	Launch Adapter Cyl Int +Z+Y	Aluminium Tape	0.15	=	0.05
2122	Launch Adapter Cyl Int +Y	Aluminium Tape	0.15	=	0.05
2123	Launch Adapter Cyl Int +Y-Z	Aluminium Tape	0.15	=	0.05
2124	Launch Adapter Cyl Int-Z	Aluminium Tape	0.15	=	0.05
2125	Launch Adapter Cyl Int-Z-Y	Aluminium Tape	0.15	=	0.05
2126	Launch Adapter Cyl Int-Y	Aluminium Tape	0.15	=	0.05
2127	Launch Adapter Cyl Int-Y+Z	Aluminium Tape	0.15	=	0.05
2150	Adapter Cone Covered Int +Z	Aluminium Tape	0.15	=	0.05
2151	Adapter Cone Covered Int +Z+Y	Aluminium Tape	0.15	=	0.05
2152	Adapter Cone Covered Int +Y	Aluminium Tape	0.15	=	0.05
2153	Adapter Cone Covered Int +Y-Z	Aluminium Tape	0.15	=	0.05
2154	Adapter Cone Covered Int -Z	Aluminium Tape	0.15	=	0.05
2155	Adapter Cone Covered Int –Z-Y	Aluminium Tape	0.15	=	0.05
2156	Adapter Cone Covered Int –Y	Aluminium Tape	0.15	=	0.05
2157	Adapter Cone Covered Int –Y+Z	Aluminium Tape	0.15	=	0.05
2400	RCS Panel Int +Z	1/3 BP- 2/3 VDA Kapton	0.4	=	0.33
2401	RCS Panel Int +Z+Y	1/3 BP- 2/3 VDA Kapton	0.4	=	0.33
2402	RCS Panel Int +Y	1/3 BP- 2/3 VDA Kapton	0.4	=	0.33
2403	RCS Panel Int +Y-Z	1/3 BP- 2/3 VDA Kapton	0.4	=	0.33
2404	RCS Panel Int –Z	1/3 BP- 2/3 VDA Kapton	0.4	=	0.33
2405	RCS Panel Int –Z-Y	1/3 BP- 2/3 VDA Kapton	0.4	=	0.33
2406	RCS Panel Int –Y	1/3 BP- 2/3 VDA Kapton	0.4	=	0.33
2407	RCS Panel Int –Y+Z	1/3 BP- 2/3 VDA Kapton	0.4	=	0.33
2408	RCS Panel Central Int	1/3 BP- 2/3 VDA Kapton	0.4	=	0.33
2500	SVM Cone Ext +Z	CFRP	0.9	=	0.9
2501	SVM Cone Ext +Z+Y	CFRP	0.9	=	0.9
2502	SVM Cone Ext +Y	CFRP	0.9	=	0.9
2503	SVM Cone Ext +Y-Z	CFRP	0.9	=	0.9
2504	SVM Cone Ext -Z	CFRP	0.9	=	0.9
2505	SVM Cone Ext -Z-Y	CFRP	0.9	=	0.9
2506	SVM Cone Ext -Y	CFRP	0.9	=	0.9
2507	SVM Cone Ext -Z+Y	CFRP	0.9	=	0.9
2510	SVM Cone Ext +Z	CFRP	0.9	=	0.9
2511	SVM Cone Ext +Z+Y	CFRP	0.9	=	0.9
2512	SVM Cone Ext +Y	CFRP	0.9	=	0.9
2513	SVM Cone Ext +Y-Z	CFRP	0.9	=	0.9
2514	SVM Cone Ext -Z	CFRP	0.9	=	0.9
2515	SVM Cone Ext -Z-Y	CFRP	0.9	=	0.9
2516	SVM Cone Ext -Y	CFRP	0.9	=	0.9
2517	SVM Cone Ext -Z+Y	CFRP	0.9	=	0.9
2520	SVM Cone Ext +Z	CFRP	0.9	=	0.9
2521	SVM Cone Ext +Z+Y	CFRP	0.9	=	0.9
2522	SVM Cone Ext +Y	CFRP	0.9	=	0.9
2523	SVM Cone Ext +Y-Z	CFRP	0.9	=	0.9
2524	SVM Cone Ext -Z	CFRP	0.9	=	0.9
2525	SVM Cone Ext -Z-Y	CFRP	0.9	=	0.9
2526	SVM Cone Ext -Y	CFRP	0.9	=	0.9
2527	SVM Cone Ext -Z+Y	CFRP	0.9	=	0.9
2530	SVM Cone Ext +Z	CFRP	0.9	=	0.9
2531	SVM Cone Ext +Z+Y	CFRP	0.9	=	0.9
2532	SVM Cone Ext +Y	CFRP	0.9	=	0.9

NODE	LABEL	MATERIALS	Alpha		Epsilon
			BOL	EOL	
2533	SVM Cone Ext +Y-Z	CFRP	0.9	=	0.9
2534	SVM Cone Ext -Z	CFRP	0.9	=	0.9
2535	SVM Cone Ext -Z-Y	CFRP	0.9	=	0.9
2536	SVM Cone Ext -Y	CFRP	0.9	=	0.9
2537	SVM Cone Ext -Z+Y	CFRP	0.9	=	0.9
2540	SVM Cone Ext +Z	CFRP	0.9	=	0.9
2541	SVM Cone Ext +Z+Y	CFRP	0.9	=	0.9
2542	SVM Cone Ext +Y	CFRP	0.9	=	0.9
2543	SVM Cone Ext +Y-Z	CFRP	0.9	=	0.9
2544	SVM Cone Ext –Z	CFRP	0.9	=	0.9
2545	SVM Cone Ext –Z-Y	CFRP	0.9	=	0.9
2546	SVM Cone Ext –Y	CFRP	0.9	=	0.9
2547	SVM Cone Ext –Z+Y	CFRP	0.9	=	0.9
2600	SVM Cone Int +Z	CFRP	0.9	=	0.9
2601	SVM Cone Int +Z+Y	CFRP	0.9	=	0.9
2602	SVM Cone Int +Y	CFRP	0.9	=	0.9
2603	SVM Cone Int +Y-Z	CFRP	0.9	=	0.9
2604	SVM Cone Int -Z	CFRP	0.9	=	0.9
2605	SVM Cone Int -Z-Y	CFRP	0.9	=	0.9
2606	SVM Cone Int -Y	CFRP	0.9	=	0.9
2607	SVM Cone Int -Z+Y	CFRP	0.9	=	0.9
2610	SVM Cone Int +Z	CFRP	0.9	=	0.9
2611	SVM Cone Int +Z+Y	CFRP	0.9	=	0.9
2612	SVM Cone Int +Y	CFRP	0.9	=	0.9
2613	SVM Cone Int +Y-Z	CFRP	0.9	=	0.9
2614	SVM Cone Int -Z	CFRP	0.9	=	0.9
2615	SVM Cone Int -Z-Y	CFRP	0.9	=	0.9
2616	SVM Cone Int -Y	CFRP	0.9	=	0.9
2617	SVM Cone Int -Z+Y	CFRP	0.9	=	0.9
2620	SVM Cone Int +Z	CFRP	0.9	=	0.9
2621	SVM Cone Int +Z+Y	CFRP	0.9	=	0.9
2622	SVM Cone Int +Y	CFRP	0.9	=	0.9
2623	SVM Cone Int +Y-Z	CFRP	0.9	=	0.9
2624	SVM Cone Int -Z	CFRP	0.9	=	0.9
2625	SVM Cone Int -Z-Y	CFRP	0.9	=	0.9
2626	SVM Cone Int -Y	CFRP	0.9	=	0.9
2627	SVM Cone Int -Z+Y	CFRP	0.9	=	0.9
2630	SVM Cone Int +Z	CFRP	0.9	=	0.9
2631	SVM Cone Int +Z+Y	CFRP	0.9	=	0.9
2632	SVM Cone Int +Y	CFRP	0.9	=	0.9
2633	SVM Cone Int +Y-Z	CFRP	0.9	=	0.9
2634	SVM Cone Int -Z	CFRP	0.9	=	0.9
2635	SVM Cone Int -Z-Y	CFRP	0.9	=	0.9
2636	SVM Cone Int -Y	CFRP	0.9	=	0.9
2637	SVM Cone Int -Z+Y	CFRP	0.9	=	0.9
2640	SVM Cone Int +Z	CFRP	0.9	=	0.9
2641	SVM Cone Int +Z+Y	CFRP	0.9	=	0.9
2642	SVM Cone Int +Y	CFRP	0.9	=	0.9
2643	SVM Cone Int +Y-Z	CFRP	0.9	=	0.9
2644	SVM Cone Int -Z	CFRP	0.9	=	0.9
2645	SVM Cone Int -Z-Y	CFRP	0.9	=	0.9
2646	SVM Cone Int -Y	CFRP	0.9	=	0.9
2647	SVM Cone Int -Z+Y	CFRP	0.9	=	0.9
5051	Shear Web1 +Z	CFRP	0.9	=	0.9
5052	Shear Web1 +Z	CFRP	0.9	=	0.9

NODE	LABEL	MATERIALS	Alpha		Epsilon
			BOL	EOL	
5053	Shear Web1 +Z	CFRP	0.9	=	0.9
5054	Shear Web1 +Z	CFRP	0.9	=	0.9
5055	Shear Web1 +Z	CFRP	0.9	=	0.9
5061	Shear Web1 +Z	CFRP	0.9	=	0.9
5062	Shear Web1 +Z	CFRP	0.9	=	0.9
5063	Shear Web1 +Z	CFRP	0.9	=	0.9
5064	Shear Web1 +Z	CFRP	0.9	=	0.9
5065	Shear Web1 +Z	CFRP	0.9	=	0.9
5071	Shear Web2 +Z	CFRP	0.9	=	0.9
5072	Shear Web2 +Z	CFRP	0.9	=	0.9
5073	Shear Web2 +Z	CFRP	0.9	=	0.9
5074	Shear Web2 +Z	CFRP	0.9	=	0.9
5075	Shear Web2 +Z	CFRP	0.9	=	0.9
5081	Shear Web2 +Z	CFRP	0.9	=	0.9
5082	Shear Web2 +Z	CFRP	0.9	=	0.9
5083	Shear Web2 +Z	CFRP	0.9	=	0.9
5084	Shear Web2 +Z	CFRP	0.9	=	0.9
5085	Shear Web2 +Z	CFRP	0.9	=	0.9
5251	Shear Web3 +Y	CFRP	0.9	=	0.9
5252	Shear Web3 +Y	CFRP	0.9	=	0.9
5253	Shear Web3 +Y	CFRP	0.9	=	0.9
5254	Shear Web3 +Y	CFRP	0.9	=	0.9
5255	Shear Web3 +Y	CFRP	0.9	=	0.9
5261	Shear Web3 +Y	CFRP	0.9	=	0.9
5262	Shear Web3 +Y	CFRP	0.9	=	0.9
5263	Shear Web3 +Y	CFRP	0.9	=	0.9
5264	Shear Web3 +Y	CFRP	0.9	=	0.9
5265	Shear Web3 +Y	CFRP	0.9	=	0.9
5271	Shear Web4 +Y	CFRP	0.9	=	0.9
5272	Shear Web4 +Y	CFRP	0.9	=	0.9
5273	Shear Web4 +Y	CFRP	0.9	=	0.9
5274	Shear Web4 +Y	CFRP	0.9	=	0.9
5275	Shear Web4 +Y	CFRP	0.9	=	0.9
5281	Shear Web4 +Y	CFRP	0.9	=	0.9
5282	Shear Web4 +Y	CFRP	0.9	=	0.9
5283	Shear Web4 +Y	CFRP	0.9	=	0.9
5284	Shear Web4 +Y	CFRP	0.9	=	0.9
5285	Shear Web4 +Y	CFRP	0.9	=	0.9
5451	Shear Web5 –Z	CFRP	0.9	=	0.9
5452	Shear Web5 –Z	CFRP	0.9	=	0.9
5453	Shear Web5 –Z	CFRP	0.9	=	0.9
5454	Shear Web5 –Z	CFRP	0.9	=	0.9
5455	Shear Web5 –Z	CFRP	0.9	=	0.9
5461	Shear Web5 –Z	CFRP	0.9	=	0.9
5462	Shear Web5 –Z	CFRP	0.9	=	0.9
5463	Shear Web5 –Z	CFRP	0.9	=	0.9
5464	Shear Web5 –Z	CFRP	0.9	=	0.9
5465	Shear Web5 –Z	CFRP	0.9	=	0.9
5471	Shear Web6 –Z	CFRP	0.9	=	0.9
5472	Shear Web6 –Z	CFRP	0.9	=	0.9
5473	Shear Web6 –Z	CFRP	0.9	=	0.9
5474	Shear Web6 –Z	CFRP	0.9	=	0.9
5475	Shear Web6 –Z	CFRP	0.9	=	0.9
5481	Shear Web6 –Z	CFRP	0.9	=	0.9
5482	Shear Web6 –Z	CFRP	0.9	=	0.9

NODE	LABEL	MATERIALS	Alpha		Epsilon
			BOL	EOL	
5483	Shear Web6 –Z	CFRP	0.9	=	0.9
5484	Shear Web6 –Z	CFRP	0.9	=	0.9
5485	Shear Web6 –Z	CFRP	0.9	=	0.9
5651	Shear Web7 –Y	CFRP	0.9	=	0.9
5652	Shear Web7 –Y	CFRP	0.9	=	0.9
5653	Shear Web7 –Y	CFRP	0.9	=	0.9
5654	Shear Web7 –Y	CFRP	0.9	=	0.9
5655	Shear Web7 –Y	CFRP	0.9	=	0.9
5661	Shear Web7 –Y	CFRP	0.9	=	0.9
5662	Shear Web7 –Y	CFRP	0.9	=	0.9
5663	Shear Web7 –Y	CFRP	0.9	=	0.9
5664	Shear Web7 –Y	CFRP	0.9	=	0.9
5665	Shear Web7 –Y	CFRP	0.9	=	0.9
5671	Shear Web8 –Y	CFRP	0.9	=	0.9
5672	Shear Web8 –Y	CFRP	0.9	=	0.9
5673	Shear Web8 –Y	CFRP	0.9	=	0.9
5674	Shear Web8 –Y	CFRP	0.9	=	0.9
5675	Shear Web8 –Y	CFRP	0.9	=	0.9
5681	Shear Web8 –Y	CFRP	0.9	=	0.9
5682	Shear Web8 –Y	CFRP	0.9	=	0.9
5683	Shear Web8 –Y	CFRP	0.9	=	0.9
5684	Shear Web8 –Y	CFRP	0.9	=	0.9
5685	Shear Web8 –Y	CFRP	0.9	=	0.9
6001-72	Internal Panel +Z	Black Paint	0.9	=	0.9
6101-48	Internal Panel +Y+Z	Black Paint	0.9	=	0.9
6201-72	Internal Panel +Y	Black Paint	0.9	=	0.9
6301-48	Internal Panel +Y-Z	Black Paint	0.9	=	0.9
6401-72	Internal Panel –Z	Black Paint	0.9	=	0.9
6501-48	Internal Panel -Y-Z	Black Paint	0.9	=	0.9
6601-72	Internal Panel –Y	Black Paint	0.9	=	0.9
6701-48	Internal Panel –Y+Z	Black Paint	0.9	=	0.9
7400	SVM Top Disc Int +Z	CFRP	0.9	=	0.9
7401	SVM Top Disc Int +Z+Y	CFRP	0.9	=	0.9
7402	SVM Top Disc Int +Y	CFRP	0.9	=	0.9
7403	SVM Top Disc Int +Y-Z	CFRP	0.9	=	0.9
7404	SVM Top Disc Int –Z	CFRP	0.9	=	0.9
7405	SVM Top Disc Int –Z-Y	CFRP	0.9	=	0.9
7406	SVM Top Disc Int –Y	CFRP	0.9	=	0.9
7407	SVM Top Disc Int –Y+Z	CFRP	0.9	=	0.9
7600	SVM Top Int +Z	CFRP	0.9	=	0.9
7601	SVM Top Int +Y+Z	CFRP	0.9	=	0.9
7602	SVM Top Int +Y	CFRP	0.9	=	0.9
7603	SVM Top Int +Y-Z	CFRP	0.9	=	0.9
7604	SVM Top Int –Z	CFRP	0.9	=	0.9
7605	SVM Top Int -Z-Y	CFRP	0.9	=	0.9
7606	SVM Top Int –Y	CFRP	0.9	=	0.9
7607	SVM Top Int -Y+Z	CFRP	0.9	=	0.9
8800-9	SUPPORT STR +X	CFRP	0.9	=	0.9
8820-9	SUPPORT STR +X	CFRP	0.9	=	0.9
8860-9	SUPPORT STR +X	CFRP	0.9	=	0.9
8880-9	SUPPORT STR +X	CFRP	0.9	=	0.9
9501-48	MLI on Internal Panel –Y-Z	Kapton Aluminized	0.15	=	0.05
9591	MLI on Unit FHWOV	Kapton Aluminized	0.15	=	0.05

NODE	LABEL	MATERIALS	Alpha		Epsilon
			BOL	EOL	
9592	MLI on Unit FHHRV	Kapton Aluminized	0.15	=	0.05
9593	MLI on Unit FHICU	Kapton Aluminized	0.15	=	0.05
9594	MLI on Unit FHFCU	Kapton Aluminized	0.15	=	0.05
9596	MLI on Unit FHWEH	Kapton Aluminized	0.15	=	0.05
9597	MLI on Unit FH3DV	Kapton Aluminized	0.15	=	0.05
9601-72	MLI on Internal Panel –Y	Kapton Aluminized	0.15	=	0.05
9691	MLI on Unit FHWOH	Kapton Aluminized	0.15	=	0.05
9692	MLI on Unit FHWEH	Kapton Aluminized	0.15	=	0.05
9693	MLI on Unit FHHRH	Kapton Aluminized	0.15	=	0.05
9694	MLI on Unit FHLCU	Kapton Aluminized	0.15	=	0.05
9695	MLI on Unit FHLSU	Kapton Aluminized	0.15	=	0.05
9696	MLI on Unit FH3DH	Kapton Aluminized	0.15	=	0.05

Table 3.1.1-1b HERSCHEL – Service Module External Geometrical Nodes List

NODE	LABEL	MATERILAS	Alpha		Epsilon
			BOL	EOL	
811	STRMY	Black Paint	0.9	=	0.9
812	STRMY CONE UPPER EXT	Black Anodization	0.86	=	0.86
813	STRMY CONE UPPER EXT	Black Anodization	0.86	=	0.86
814	STRMY CONE UPPER EXT	Black Anodization	0.86	=	0.86
815	STRMY CONE UPPER EXT	Black Anodization	0.86	=	0.86
816	STRMY CONE UPPER EXT	Black Anodization	0.86	=	0.86
817	STRMY CONE LOWER EXT	Black Anodization	0.86	=	0.86
820	STRMY CONE LOWER MLI	Carbon Filled Kapton	0.92	=	0.86
831	STRPY BOX	Black Paint	0.9	=	0.9
832	STRMY CONE UPPER EXT	Black Anodization	0.86	=	0.86
833	STRMY CONE UPPER EXT	Black Anodization	0.86	=	0.86
834	STRMY CONE UPPER EXT	Black Anodization	0.86	=	0.86
835	STRMY CONE UPPER EXT	Black Anodization	0.86	=	0.86
836	STRMY CONE UPPER EXT	Black Anodization	0.86	=	0.86
837	STRMY CONE LOWER EXT	Black Anodization	0.86	=	0.86
840	STRMY CONE LOWER MLI	Carbon Filled Kapton	0.92	=	0.86
1000	SVM Bot +Z MLI	Carbon Filled Kapton	0.92	=	0.86
1001	SVM Bot +Y+Z MLI	Carbon Filled Kapton	0.92	=	0.86
1002	SVM Bot +Y MLI	Carbon Filled Kapton	0.92	=	0.86
1003	SVM Bot +Y-Z MLI	Carbon Filled Kapton	0.92	=	0.86
1004	SVM Bot -Z MLI	Carbon Filled Kapton	0.92	=	0.86
1005	SVM Bot -Z-Y MLI	Carbon Filled Kapton	0.92	=	0.86
1006	SVM Bot -Y MLI	Carbon Filled Kapton	0.92	=	0.86
1007	SVM Bot -Y+Z MLI	Carbon Filled Kapton	0.92	=	0.86
2000	Launch Adapter Cone Ext +Z	Cromic Acid Anodization	0.5	=	0.5
2001	Launch Adapter Cone Ext +Z+Y	Cromic Acid Anodization	0.5	=	0.5
2002	Launch Adapter Cone Ext +Y	Cromic Acid Anodization	0.5	=	0.5
2003	Launch Adapter Cone Ext +Y-Z	Cromic Acid Anodization	0.5	=	0.5
2004	Launch Adapter Cone Ext –Z	Cromic Acid Anodization	0.5	=	0.5
2005	Launch Adapter Cone Ext –Z-Y	Cromic Acid Anodization	0.5	=	0.5

NODE	LABEL	MATERILAS	Alpha		Epsilon
			BOL	EOL	
2006	Launch Adapter Cone Ext –Y	Cromic Acid Anodization	0.5	=	0.5
2007	Launch Adapter Cone Ext –Y+Z	Cromic Acid Anodization	0.5	=	0.5
2010	Launch Adapter Edge Ext +Z	Cromic Acid Anodization	0.5	=	0.5
2011	Launch Adapter Edge Ext +Z+Y	Cromic Acid Anodization	0.5	=	0.5
2012	Launch Adapter Edge Ext +Y	Cromic Acid Anodization	0.5	=	0.5
2013	Launch Adapter Edge Ext +Y-Z	Cromic Acid Anodization	0.5	=	0.5
2014	Launch Adapter Edge Ext –Z	Cromic Acid Anodization	0.5	=	0.5
2015	Launch Adapter Edge Ext –Z-Y	Cromic Acid Anodization	0.5	=	0.5
2016	Launch Adapter Edge Ext –Y	Cromic Acid Anodization	0.5	=	0.5
2017	Launch Adapter Edge Ext –Y+Z	Cromic Acid Anodization	0.5	=	0.5
2021	Launch Adapter Cyl Ext +Z+Y	Cromic Acid Anodization	0.5	=	0.5
2022	Launch Adapter Cyl Ext +Y	Cromic Acid Anodization	0.5	=	0.5
2023	Launch Adapter Cyl Ext +Y-Z	Cromic Acid Anodization	0.5	=	0.5
2024	Launch Adapter Cyl Ext –Z	Cromic Acid Anodization	0.5	=	0.5
2025	Launch Adapter Cyl Ext –Z-Y	Cromic Acid Anodization	0.5	=	0.5
2026	Launch Adapter Cyl Ext –Y	Cromic Acid Anodization	0.5	=	0.5
2027	Launch Adapter Cyl Ext –Y+Z	Cromic Acid Anodization	0.5	=	0.5
2050	Adapter Cone Covered Ext +Z	Cromic Acid Anodization	0.5	=	0.5
2051	Adapter Cone Covered Ext +Z+Y	Cromic Acid Anodization	0.5	=	0.5
2052	Adapter Cone Covered Ext +Y	Cromic Acid Anodization	0.5	=	0.5
2053	Adapter Cone Covered Ext +Y-Z	Cromic Acid Anodization	0.5	=	0.5
2054	Adapter Cone Covered Ext –Z	Cromic Acid Anodization	0.5	=	0.5
2055	Adapter Cone Covered Ext –Z-Y	Cromic Acid Anodization	0.5	=	0.5
2056	Adapter Cone Covered Ext –Y	Cromic Acid Anodization	0.5	=	0.5
2057	Adapter Cone Covered Ext –Y+Z	Cromic Acid Anodization	0.5	=	0.5
2200	RCS Panel MLI +Z	Carbon Filled Kapton	0.92	=	0.86
2201	RCS Panel MLI +Z+Y	Carbon Filled Kapton	0.92	=	0.86
2202	RCS Panel MLI +Y	Carbon Filled Kapton	0.92	=	0.86
2203	RCS Panel MLI +Y-Z	Carbon Filled Kapton	0.92	=	0.86
2204	RCS Panel MLI –Z	Carbon Filled Kapton	0.92	=	0.86
2205	RCS Panel MLI –Z-Y	Carbon Filled Kapton	0.92	=	0.86
2206	RCS Panel MLI –Y	Carbon Filled Kapton	0.92	=	0.86
2207	RCS Panel MLI –Y+Z	Carbon Filled Kapton	0.92	=	0.86
2208	RCS Panel Central MLI	Carbon Filled Kapton	0.92	=	0.86
2250	Adapter Cone MLI +Z	Carbon Filled Kapton	0.92	=	0.86
2251	Adapter Cone MLI +Z+Y	Carbon Filled Kapton	0.92	=	0.86
2252	Adapter Cone MLI +Y	Carbon Filled Kapton	0.92	=	0.86
2253	Adapter Cone MLI +Y-Z	Carbon Filled Kapton	0.92	=	0.86
2254	Adapter Cone MLI –Z	Carbon Filled Kapton	0.92	=	0.86
2255	Adapter Cone MLI –Z-Y	Carbon Filled Kapton	0.92	=	0.86
2256	Adapter Cone MLI –Y	Carbon Filled Kapton	0.92	=	0.86
2257	Adapter Cone MLI –Y+Z	Carbon Filled Kapton	0.92	=	0.86
3001-72	OSR Rad +Z	OSR	0.1	0.18	0.78
3101-48	OSR Rad +Y+Z	OSR	0.1	0.18	0.78
3201-72	OSR Rad +Y	Electrodag 501	0.95	=	0.78
3301-48	OSR Rad +Y-Z	Electrodag 501	0.95	=	0.78
3401-72	OSR Rad –Z	Electrodag 501	0.95	=	0.78
3501-48	OSR Rad -Y-Z	Electrodag 501	0.95	=	0.78
3601-72	OSR Rad –Y	Electrodag 501	0.95	=	0.78

NODE	LABEL	MATERILAS	Alpha		Epsilon
			BOL	EOL	
3701-48	OSR Rad -Y+Z	OSR	0.1	0.18	0.78
4001-72	MLI Rad +Z	Carbon Filled Kapton	0.92	=	0.86
4101-48	MLI Rad +Y+Z	Carbon Filled Kapton	0.92	=	0.86
4201-72	MLI Rad +Y	Carbon Filled Kapton	0.92	=	0.86
4301-48	MLI Rad +Y-Z	Carbon Filled Kapton	0.92	=	0.86
4401-72	MLI Rad –Z	Carbon Filled Kapton	0.92	=	0.86
4501-48	MLI Rad -Y-Z	Carbon Filled Kapton	0.92	=	0.86
4601-72	MLI Rad –Y	Carbon Filled Kapton	0.92	=	0.86
4701-48	MLI Rad -Y+Z	Carbon Filled Kapton	0.92	=	0.86
4902	AAD MLI	Carbon Filled Kapton	0.92	=	0.86
4904	VMC MLI	Carbon Filled Kapton	0.92	=	0.86
4905	SAS BRK +Z MLI	Carbon Filled Kapton	0.92	=	0.86
4906	SAS +Z MLI	Carbon Filled Kapton	0.92	=	0.86
4946	SAS –Z MLI	Carbon Filled Kapton	0.92	=	0.86
4947	SAS BRK –Z MLI	Carbon Filled Kapton	0.92	=	0.86
4948	SREM MLI	Carbon Filled Kapton	0.92	=	0.86
7000	SVM Top MLI +Z	Kapton Aluminized	0.15	=	0.05
7001	SVM Top MLI +Y+Z	Kapton Aluminized	0.15	=	0.05
7002	SVM Top MLI +Y	Kapton Aluminized	0.15	=	0.05
7003	SVM Top MLI +Y-Z	Kapton Aluminized	0.15	=	0.05
7004	SVM Top MLI -Z	Kapton Aluminized	0.15	=	0.05
7005	SVM Top MLI -Z-Y	Kapton Aluminized	0.15	=	0.05
7006	SVM Top MLI -Y	Kapton Aluminized	0.15	=	0.05
7007	SVM Top MLI -Y+Z	Kapton Aluminized	0.15	=	0.05
7200	SVM Top Disc MLI +Z	Kapton Aluminized	0.15	=	0.05
7201	SVM Top Disc MLI +Z+Y	Kapton Aluminized	0.15	=	0.05
7202	SVM Top Disc MLI +Y	Kapton Aluminized	0.15	=	0.05
7203	SVM Top Disc MLI +Y-Z	Kapton Aluminized	0.15	=	0.05
7204	SVM Top Disc MLI –Z	Kapton Aluminized	0.15	=	0.05
7205	SVM Top Disc MLI –Z-Y	Kapton Aluminized	0.15	=	0.05
7206	SVM Top Disc MLI –Y	Kapton Aluminized	0.15	=	0.05
7207	SVM Top Disc MLI –Y+Z	Kapton Aluminized	0.15	=	0.05

Table 3.1.1-2 HERSCHEL – Payload Module Geometrical Nodes List

NODE	LABEL	Alpha		Epsilon
		BOL	EOL	
10000	Cryocooler middle	0.15	=	0.05
10010	Cryocooler lower	0.15	=	0.05
10011	Cryocooler lower	0.15	=	0.05
10012	Cryocooler lower	0.15	=	0.05
10013	Cryocooler lower	0.15	=	0.05
18001	Top Shield +Z	0.15	=	0.05
18002	Top Shield +Y	0.15	=	0.05
18003	Top Shield –Z	0.15	=	0.05
18004	Top Shield –Y	0.15	=	0.05
18101	Top Shield +Z	0.15	=	0.05

NODE	LABEL	Alpha		Epsilon
		BOL	EOL	
18102	Top Shield +Y	0.15	=	0.05
18103	Top Shield –Z	0.15	=	0.05
18104	Top Shield –Y	0.15	=	0.05
18501	Frontal Shield -Y+Z	0.72	=	0.82
18502	Frontal Shield -Y+Z	0.72	=	0.82
18503	Frontal Shield +Z	0.72	=	0.82
18504	Frontal Shield +Z	0.72	=	0.82
18505	Frontal Shield +Y+Z	0.72	=	0.82
18506	Frontal Shield +Y+Z	0.72	=	0.82
18510	MLI Closure SVM -Y	0.17	0.55	0.87
18512	MLI Closure SVM -Y+Z	0.17	0.55	0.87
18514	MLI Closure SVM +Z	0.17	0.55	0.87
18516	MLI Closure SVM +Y+Z	0.17	0.55	0.87
18518	MLI Closure SVM +Y	0.17	0.55	0.87
18601	Frontal Shield -Y+Z	0.9	=	0.9
18602	Frontal Shield -Y+Z	0.9	=	0.9
18603	Frontal Shield +Z	0.9	=	0.9
18604	Frontal Shield +Z	0.9	=	0.9
18605	Frontal Shield +Y+Z	0.9	=	0.9
18606	Frontal Shield +Y+Z	0.9	=	0.9
18610	MLI Closure SVM -Y	0.17	0.55	0.87
18612	MLI Closure SVM -Y+Z	0.17	0.55	0.87
18614	MLI Closure SVM +Z	0.17	0.55	0.87
18616	MLI Closure SVM +Y+Z	0.17	0.55	0.87
18618	MLI Closure SVM +Y	0.17	0.55	0.87
19000	MLI Struct Braces	0.15	=	0.05
19005	MLI Struct Braces	0.15	=	0.05
19010	MLI Struct Braces	0.15	=	0.05
19015	MLI Struct Braces	0.15	=	0.05
19020	MLI Struct Braces	0.15	=	0.05
19025	MLI Struct Braces	0.15	=	0.05
19030	MLI Struct Braces	0.15	=	0.05
19035	MLI Struct Braces	0.15	=	0.05
19040	MLI Struct Braces	0.15	=	0.05
19045	MLI Struct Braces	0.15	=	0.05
19050	MLI Struct Braces	0.15	=	0.05
19055	MLI Struct Braces	0.15	=	0.05
19060	MLI Struct Braces	0.15	=	0.05
19065	MLI Struct Braces	0.15	=	0.05
19070	MLI Struct Braces	0.15	=	0.05
19075	MLI Struct Braces	0.15	=	0.05
19080	MLI Struct Braces Front	0.15	=	0.05
19081	MLI Struct Braces Front	0.15	=	0.05
19082	MLI Struct Braces Front	0.15	=	0.05
19083	MLI Struct Braces Front	0.15	=	0.05
19084	MLI Struct Braces Front	0.15	=	0.05

NODE	LABEL	Alpha		Epsilon
		BOL	EOL	
19085	MLI Struct Braces Front	0.15	=	0.05
19086	MLI Struct Braces Front	0.15	=	0.05
19087	MLI Struct Braces Front	0.15	=	0.05
19088	MLI Struct Braces Front	0.15	=	0.05
19089	MLI Struct Braces Front	0.15	=	0.05
19090	MLI Struct Braces Front	0.15	=	0.05
19091	MLI Struct Braces Front	0.15	=	0.05
19092	MLI Struct Braces Front	0.15	=	0.05
19093	MLI Struct Braces Front	0.15	=	0.05
19094	MLI Struct Braces Front	0.15	=	0.05
19095	MLI Struct Braces Front	0.15	=	0.05

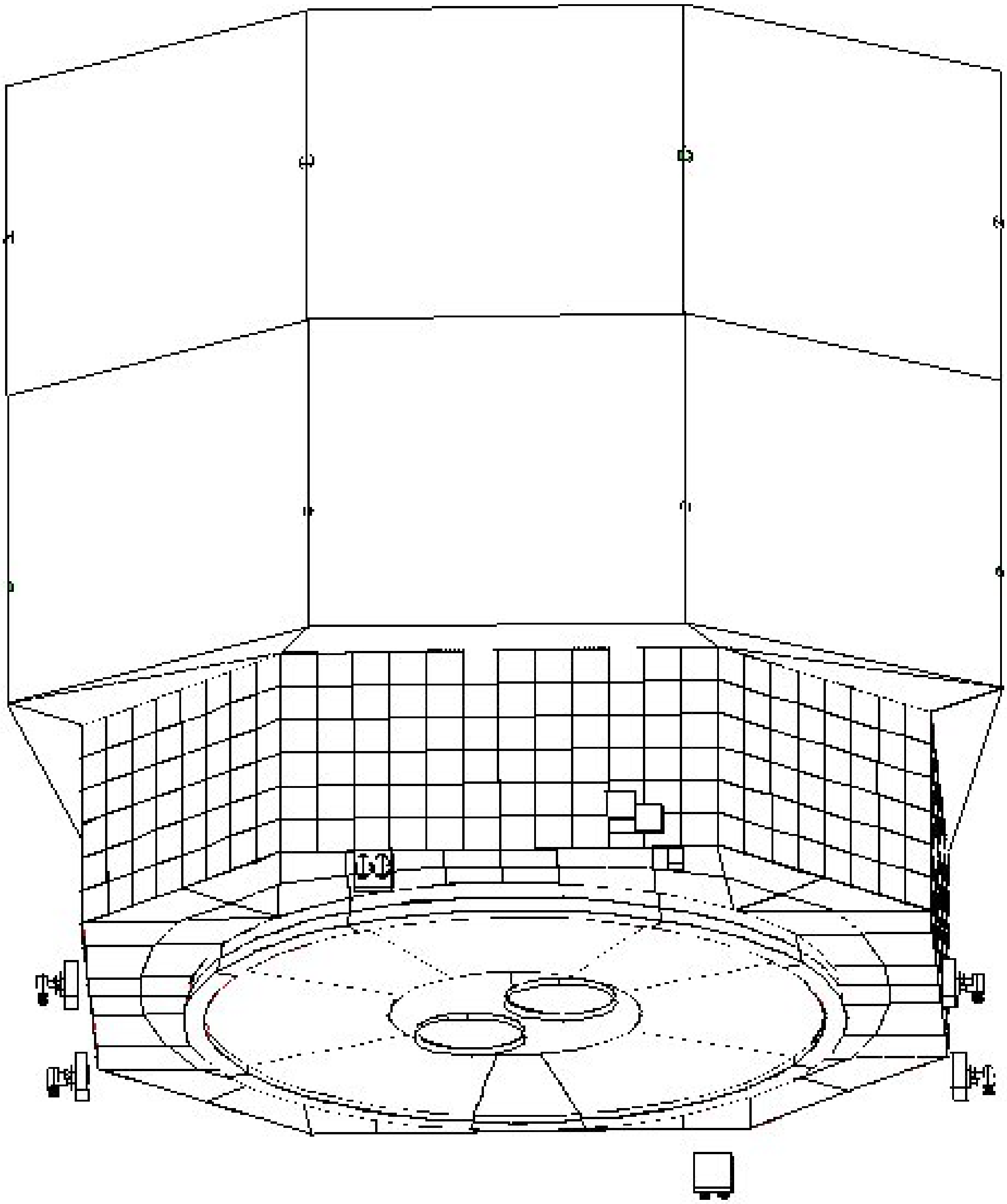

Figure 3.1.1-1 HERSCHEL – Overall view

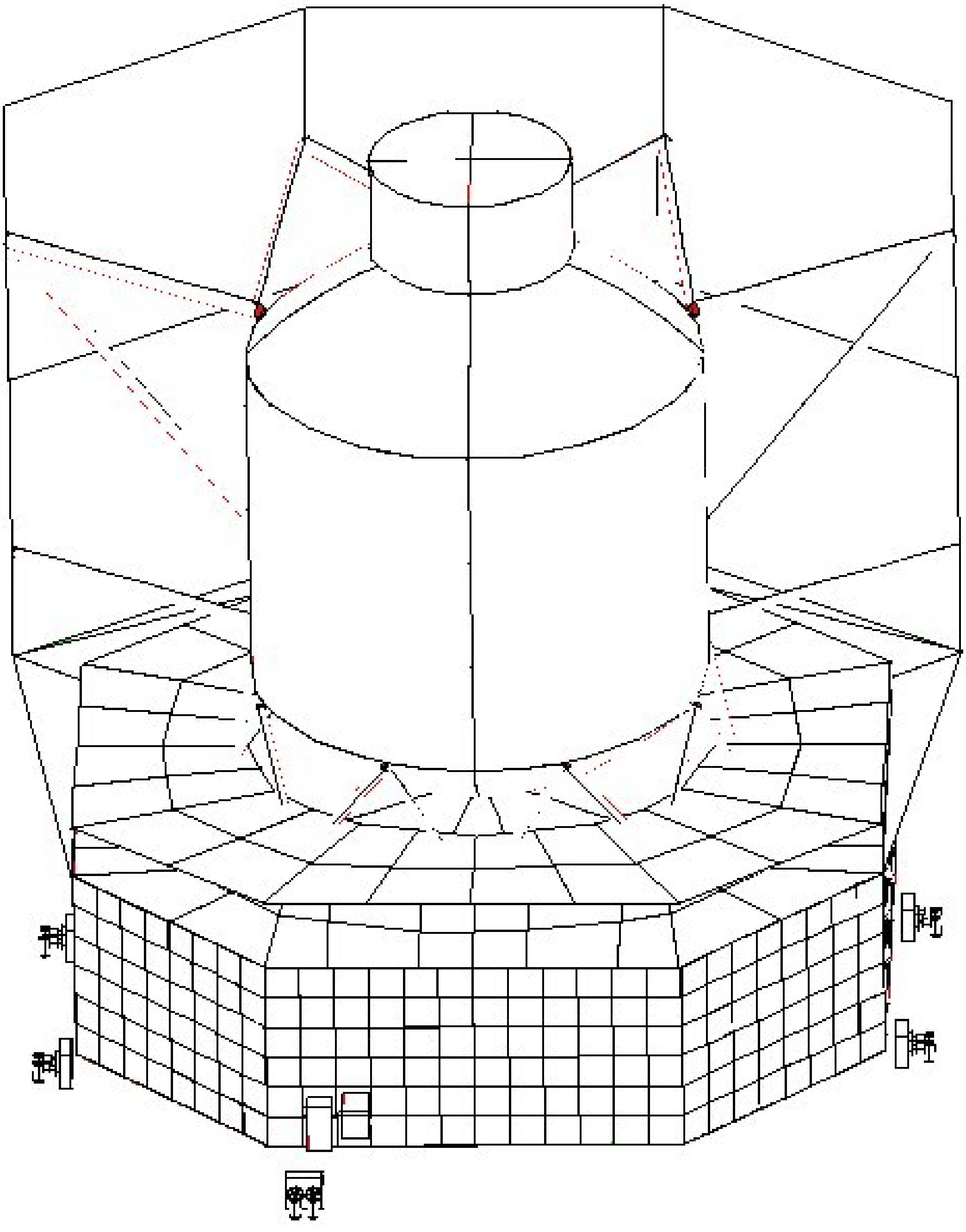

Figure 3.1.1-2 HERSCHEL – Overall View

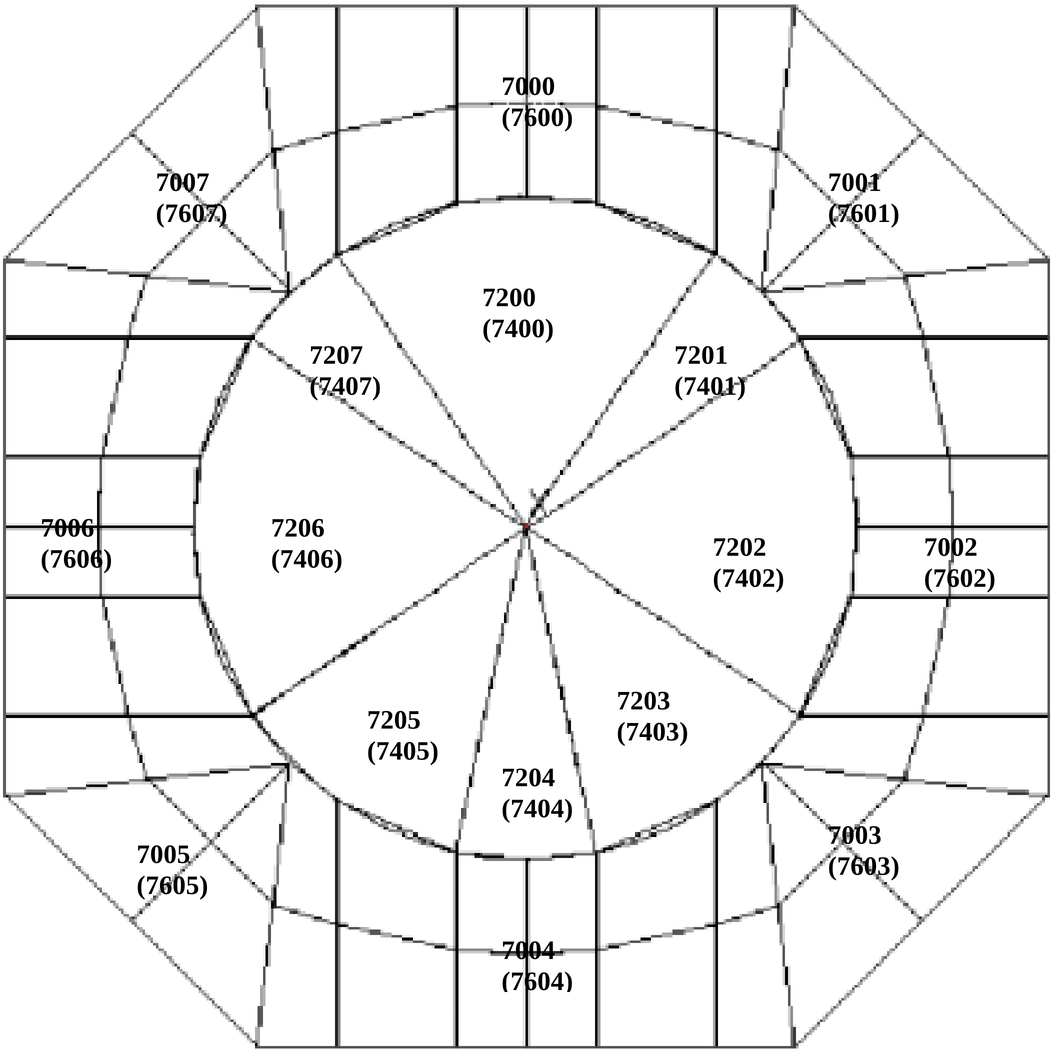

Figure 3.1.1-3 HERSCHEL – SVM Upper Closure and Payload Subplatform +X View

7000÷7: SVM Upper Closure MLI nodes
7600÷7: SVM Upper Closure Structural nodes
7200÷7: Payload Subplatform MLI nodes
7400÷7: Payload Subplatform Structural nodes

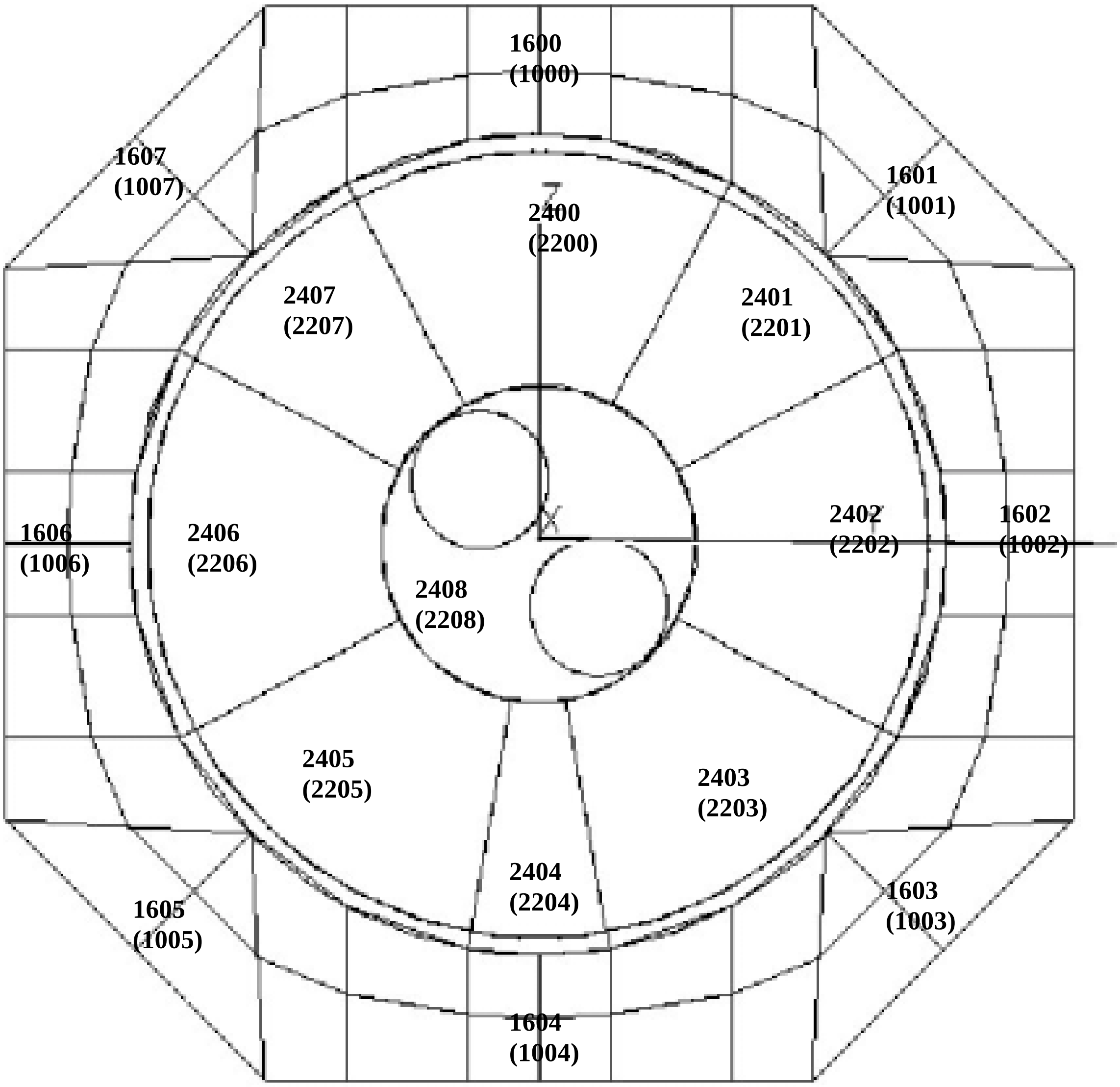

Figure 3.1.1-4 HERSCHEL – SVM Bottom Closure and Bottom Closure Platform -X View
1000÷7: SVM Bottom Closure MLI nodes
1600÷7: SVM Bottom Closure Structural nodes
2200÷8: Bottom Closure Platform MLI nodes
2400÷8 Bottom Closure Platform Structural nodes

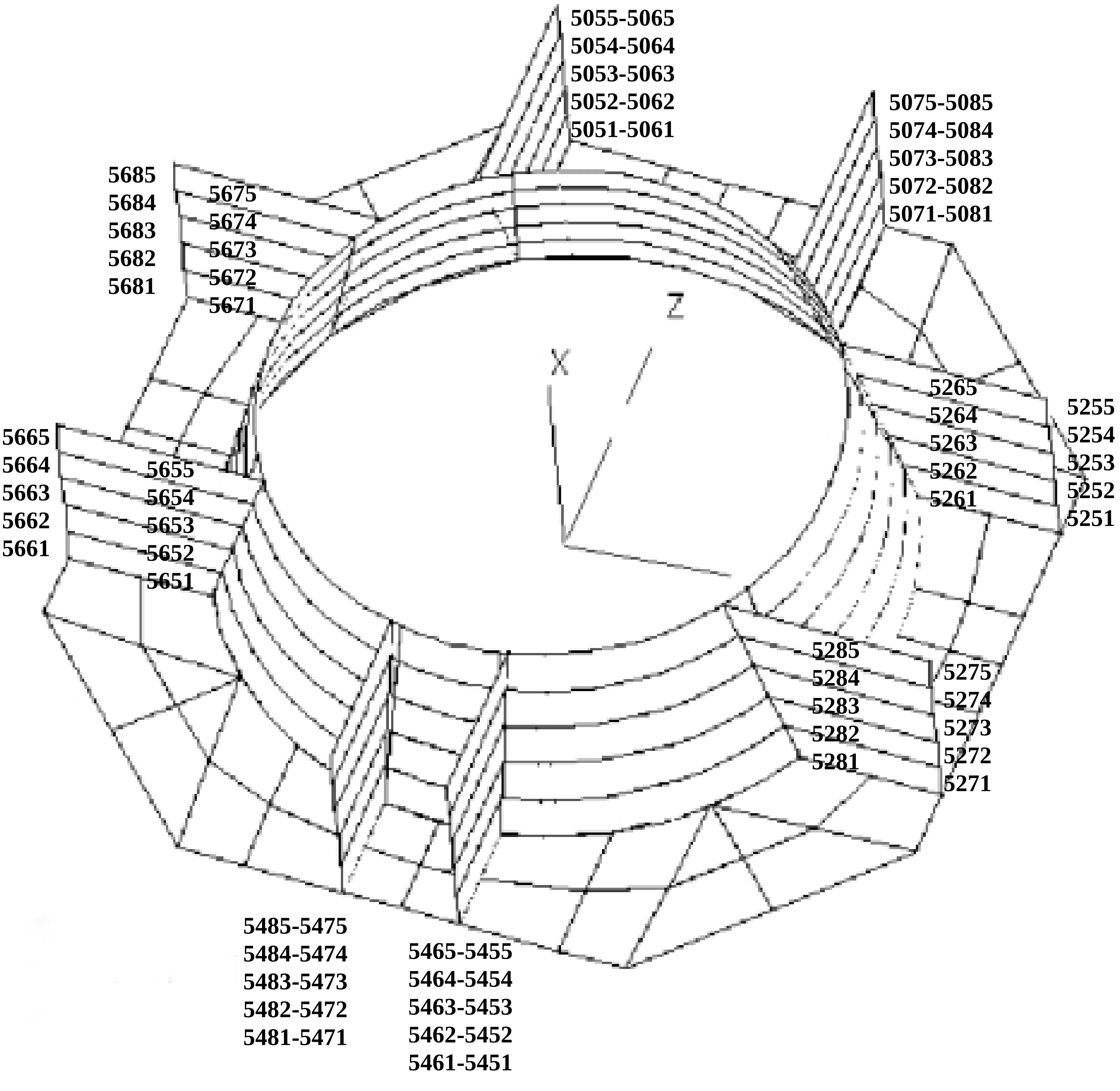

Figure 3.1.1-5 HERSCHEL – Shear PanelsView
50X1÷5: Shear +Z nodes
52X1÷5: Shear +Y nodes
54X1÷5: Shear -Z nodes
56X1÷5: Shear -Y nodes

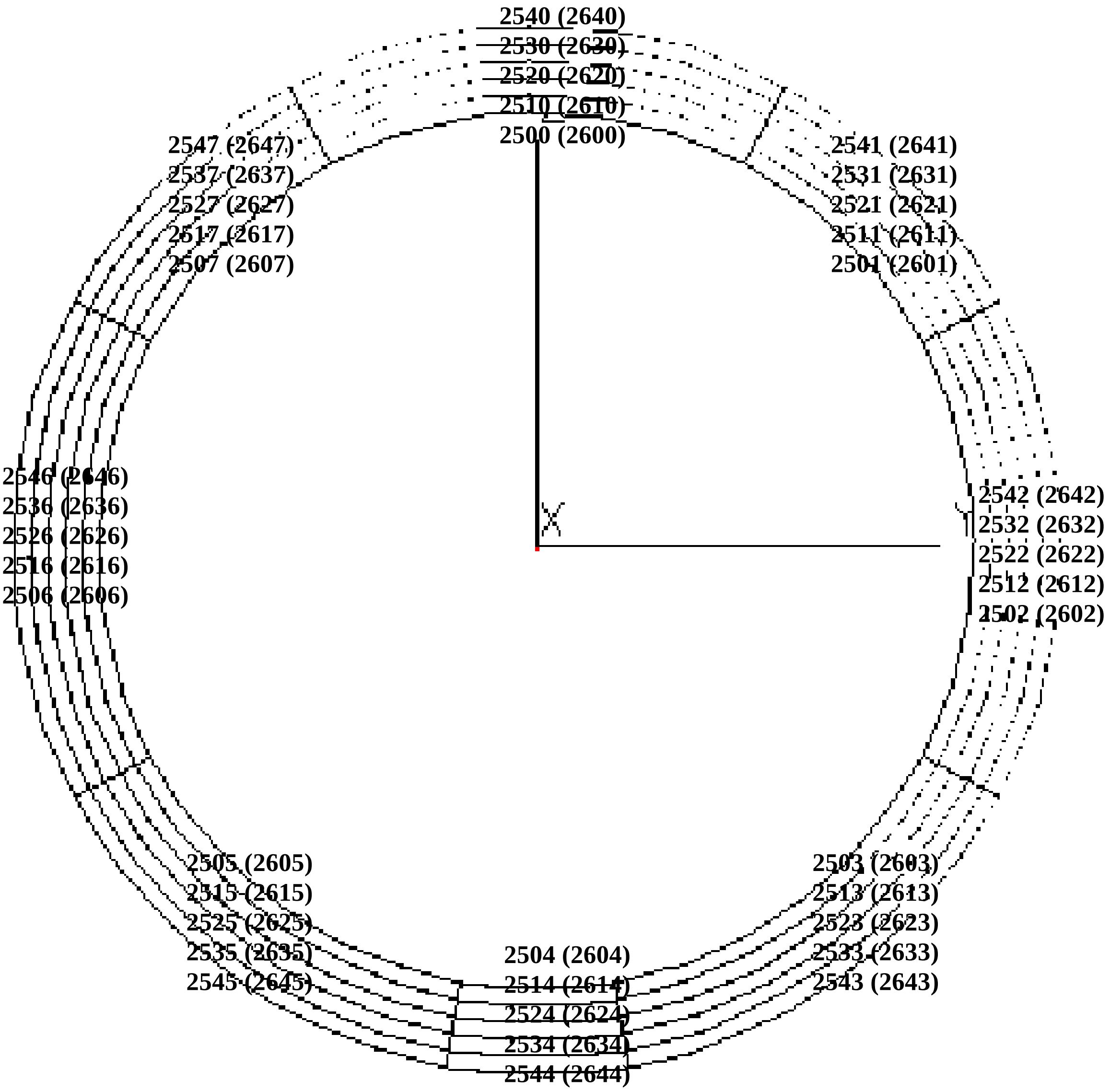

Figure 3.1.1-6 HERSCHEL – Cone: Viwe
25X0-7: Internal Cone nodes.
26X0-7: External Cone nodes.

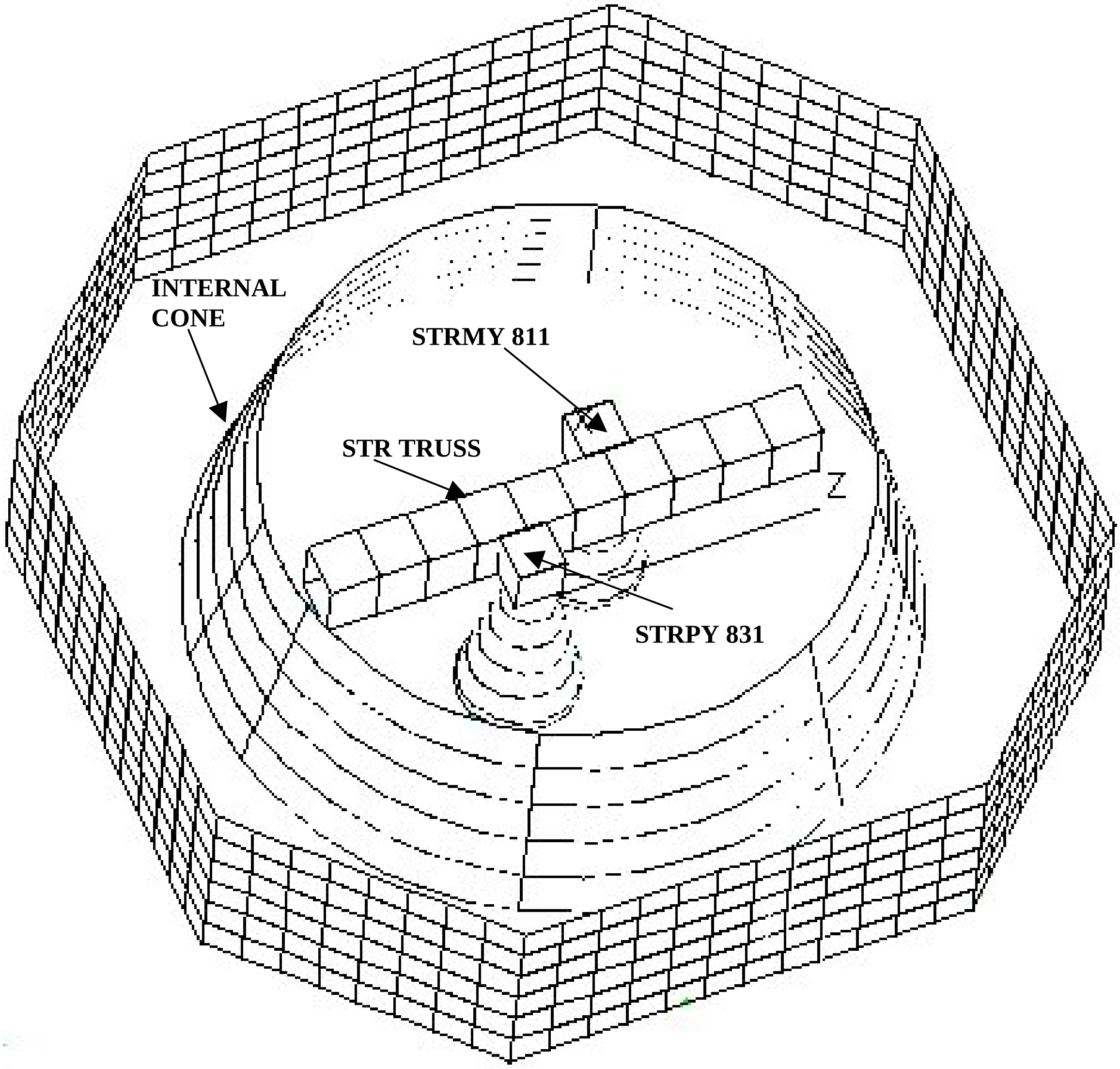

Figure 3.1.1-7 HERSCHEL – Location of STR and truss.

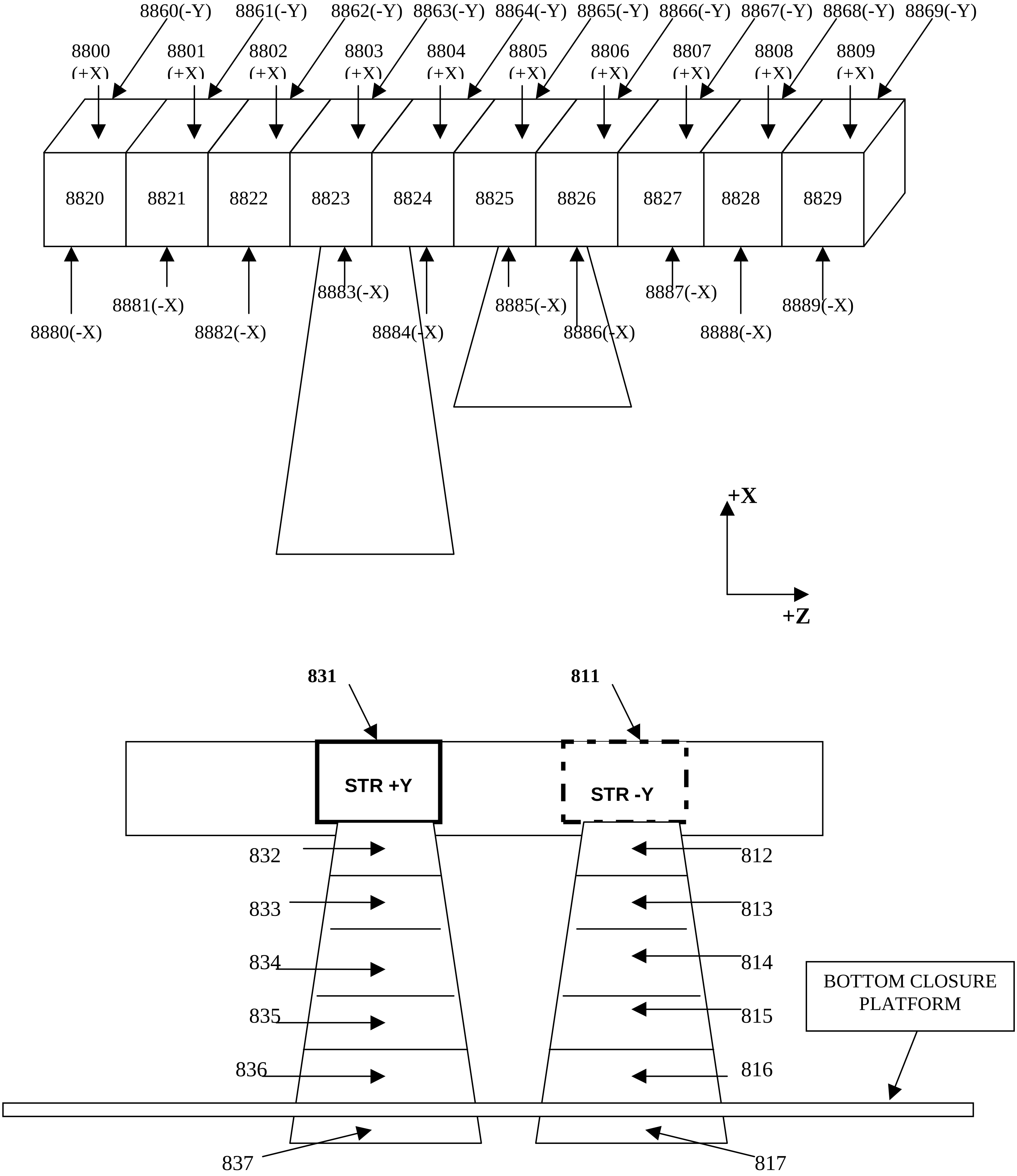

Figure 3.1.1-8 HERSCHEL –STR and truss nodal breakdown.

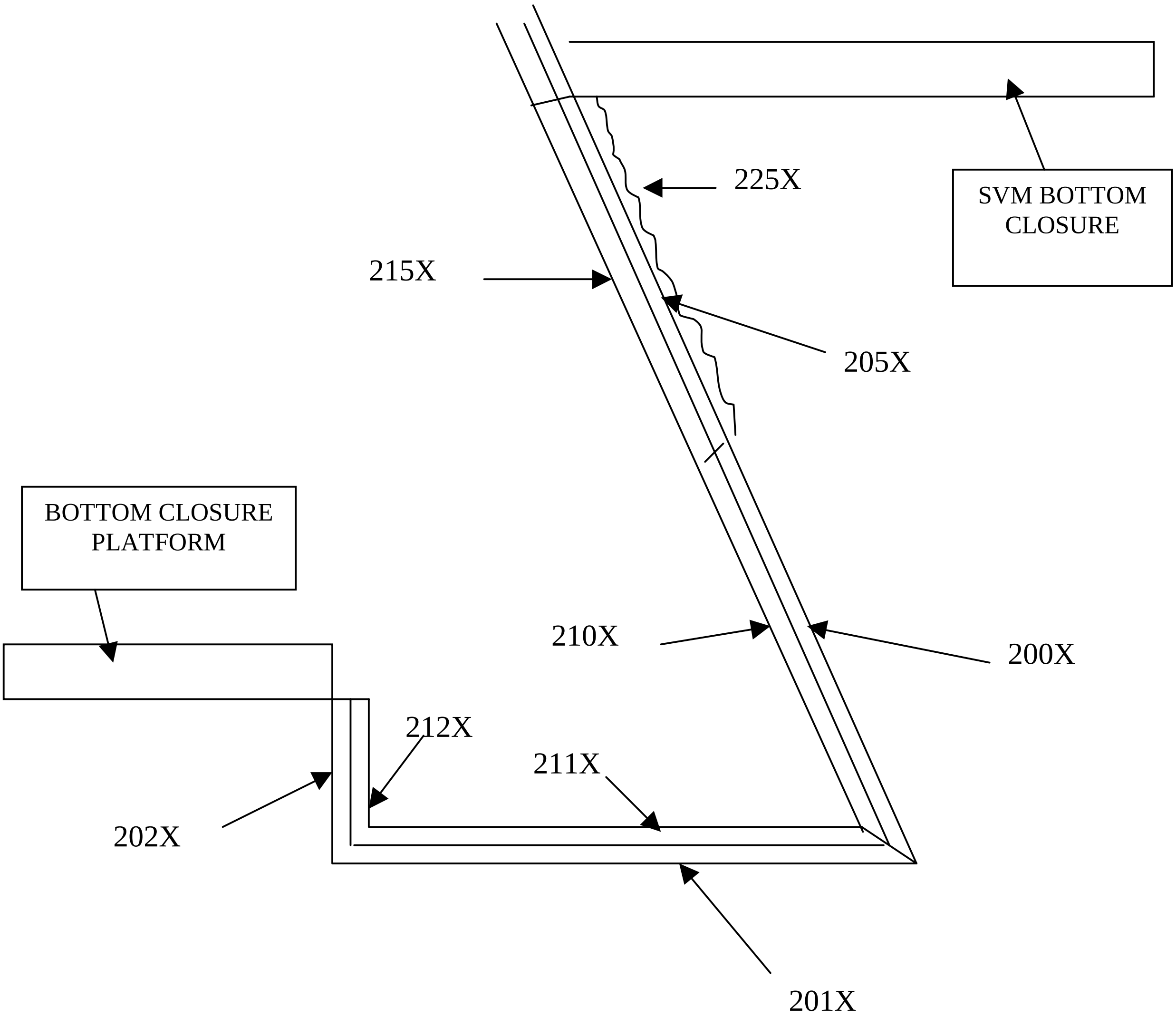

Figure 3.1.1-9 HERSCHEL – Detailed Adapter Ring nodal breakdown.

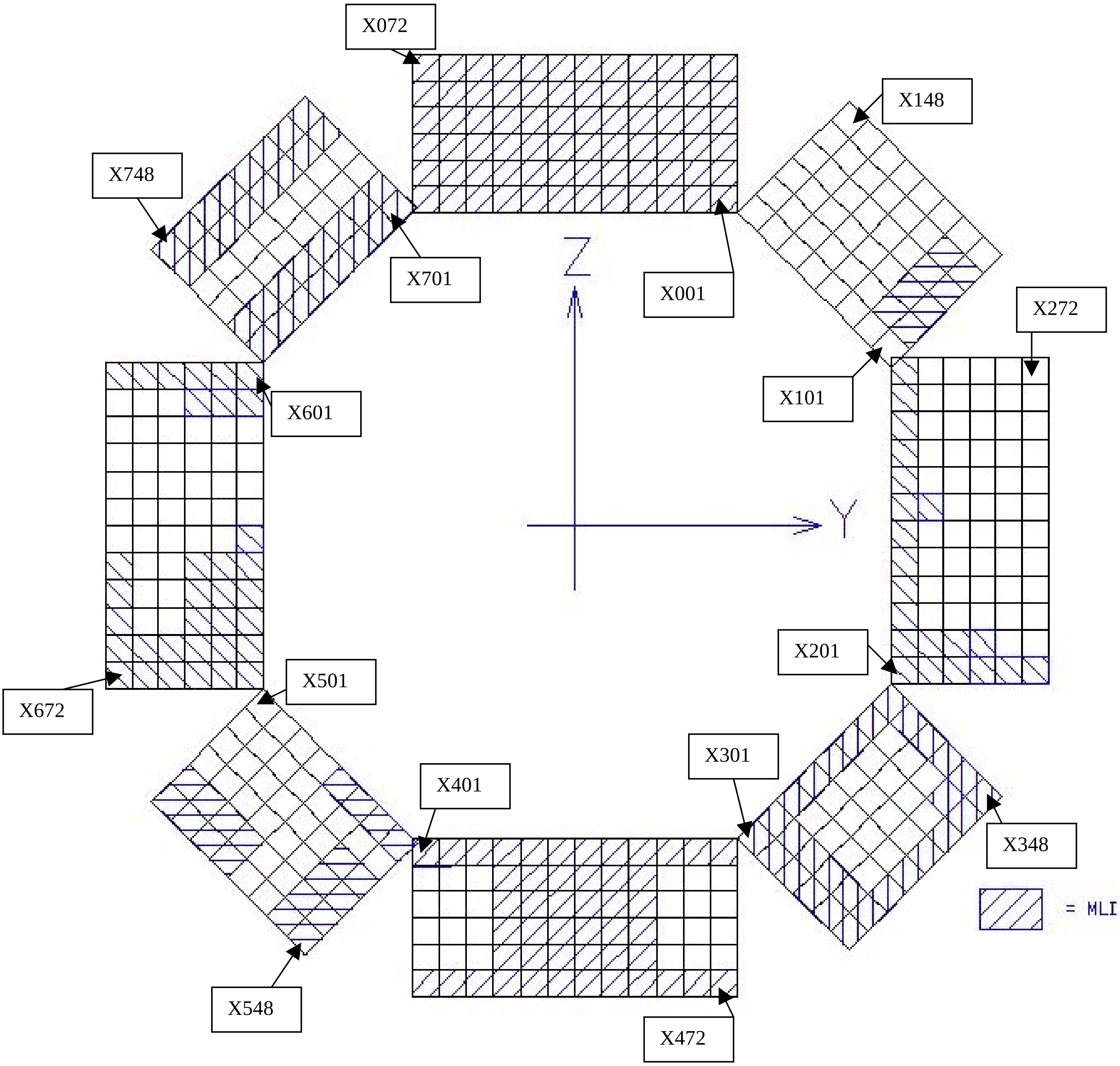

Figure 3.1.1-10 HERSCHEL – Lateral Panel Internal View
Internal Lateral Panels nodes: 6XXX
External Lateral Panels OSR nodes: 3XXX
External Lateral Panels MLI nodes: 4XXX

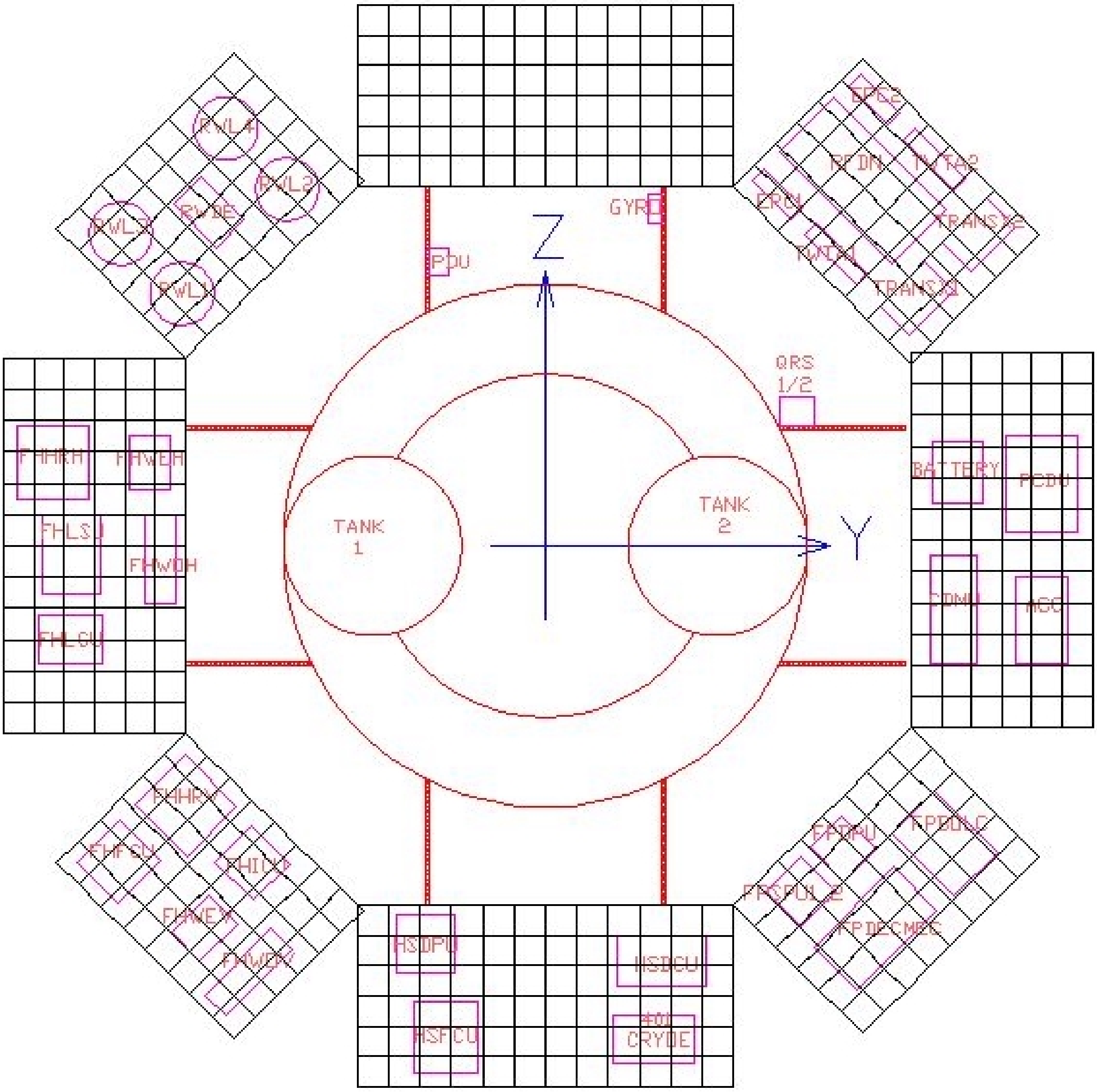

Figure 3.1.1-11 HERSCHEL – Lateral Panel & Units Internal View

3.1.2 Radiator Panels OSR / MLI Area

The radiative areas obtained from the thermal analysis are shown in Fig. 3.1.1-10 and the amounts of MLI and OSR areas are reported in the Table 3.1.2-1.

Table 3.1.2-1 HERSCHEL – Radiative and MLI Areas

Panel	**Total Panel Area [m²]**	**MLI Area [m²]**	**OSR Area [m²]**	**OSR Area / Total panel %**
+Z	1.462	1.462	0.0	0 %
+Y +Z	0.974	0.162	0.812	83%
+Y	1.462	0.427	1.035	70%
+Y -Z	0.974	0.588	0.386	40%
-Z	1.462	0.975	0.487	33%
-Y –Z	0.974	0.406	0.568	58%
-Y	1.462	0.691	0.771	53%
-Y +Z	0.974	0.649	0.325	33%
Total	9.744	5.359	4.385	

3.1.3 Thermal Mathematical Model (TMM)

The Thermal Mathematical Model (TMM) has been prepared with Esatan software and contains the thermal node description, the thermal conductivity network and the unit and heater dissipation. It is composed by 2126 nodes describing the Service Module and 113 nodes for the Payload Module, for a total of 2239 nodes.

3.1.3.1 Thermal Mathematical Nodes

- ***<u>ADDITIONAL NODES (Tanks, Units)</u>***

The following thermal mathematical nodes have been included in the TMM in addition to the GMM nodes.
They represent:

- external units
- tanks
- HIFI units

that are completely covered by MLI. In the GMM only the MLI node has been modelled to account for the correct radiative coupling. In the TMM an equivalent conductive coupling (non linear) to the external surface of the MLI is provided, accounting for the effective MLI thermal conductance.

Table 3.1.3.1-1 HERSCHEL – Units Thermal Nodes List

UNIT/TANK ADDITIONAL THERMAL NODE	MLI EXTERNAL SURFACE NODE (GMM & TMM)	LABEL
2	4902	AAD
4	4904	VMC
5	4905	SASZ_BRK
6	4906	SASZ
46	4946	SAS
47	4947	SAS_BRK
48	4948	SREM
950	900	TANK1
960	910	TANK2
501	9591	FHWOV
502	9592	FHHRV
503	9593	FHICU
504	9594	FHFCU
506	9596	FHWEV
507	9597	FH3DV
601	9691	FHWOH
602	9692	FHWEH
603	9693	FHHRH
604	9694	FHLCU
605	9695	FHLSU
606	9696	FH3DH

- ***<u>ADDITIONAL NODES (Interface to HPLM)</u>***

12 nodes representing the I/F HPLM points are connected to the Upper Payload Subplatform, the Upper Closure Panel and the Upper Cone (Internal and External) with a linear conductor. They are listed and shown hereafter:

Table 3.1.3.1-2 HERSCHEL – PLM I/F Thermal Nodes List

NODE	LABEL
2701	I/F Cone – Top Floor
2702	I/F Cone – Top Floor
2703	I/F Cone – Top Floor
2704	I/F Cone – Top Floor
2705	I/F Cone – Top Floor
2706	I/F Cone – Top Floor
2707	I/F Cone – Top Floor
2708	I/F Cone – Top Floor
2709	I/F Cone – Top Floor
2710	I/F Cone – Top Floor
2711	I/F Cone – Top Floor
2712	I/F Cone – Top Floor

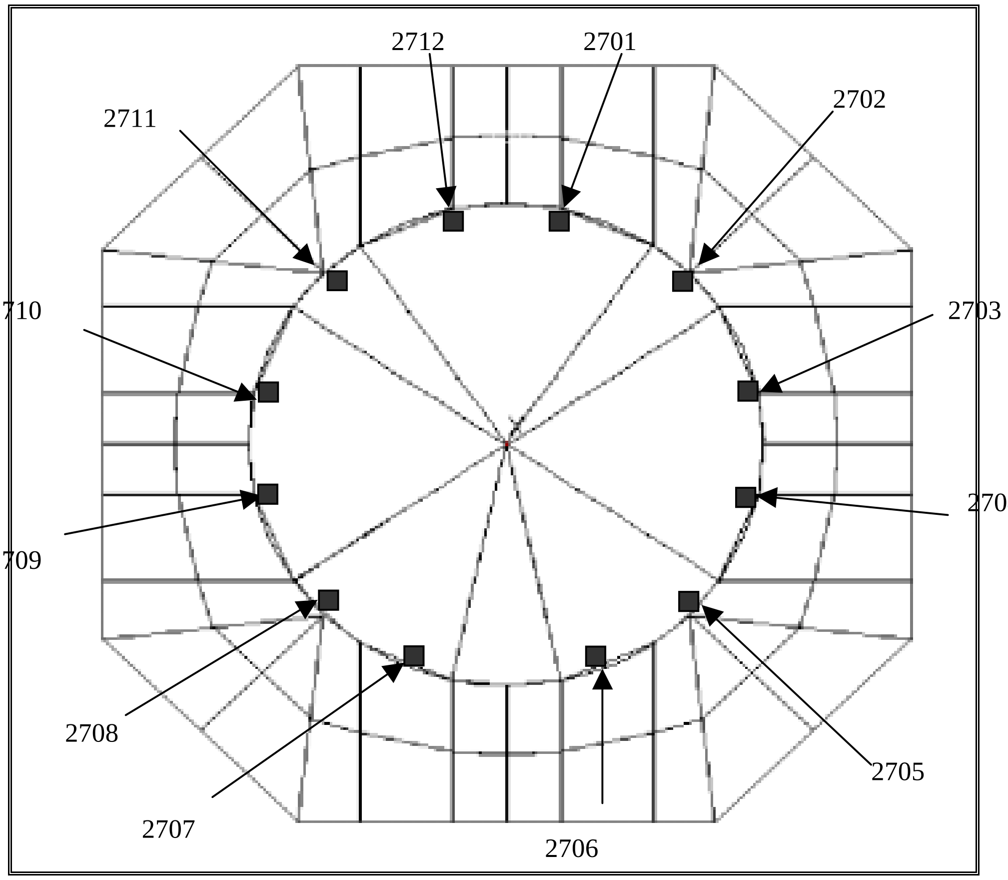

Figure 3.1.3.1-1 HERSCHEL – PLM I/F Thermal Nodes Location

- ***NODES (SPACE)***

Node 99999 defines the space with a temperature of –269 °C.

3.1.3.2 Conductive Couplings

- **MLI conductivity**

A temperature variable Conductive Coupling (non linear) array simulates the MLI blanket behaviour.
The different arrays used in the TMM, applicable to different MLI compositions are given in the following Table.
They are part of Alenia Spazio heritage. They are calculated with a semi-empirical curve derived from test data on Spacelab program (RD-2.2) and extensively used on several programs (Italsat, Artemis, Integral, MPLM, Atlantic Bird-1, Columbus, Nodes).
The used semi-empirical correlation was substantially confirmed through the Thermal Balance Tests performed on the above programs and by a dedicated test on a MPLM MLI sample.
By the way, Alenia used formula is in good agreement with the empirical correlation proposed in the RD-2.3.

MLI thermal conductivity is depending on the different number of layers. Application is:

- 20 layers MLI composition is used on the Top of the Satellite facing to HPLM
- 10 layers MLI composition is used on all the other external surfaces:
- 7 layers MLI composition is used on HIFI units, internal –Y –Z Panel, Internal –Y Panel, STR baffle and on the Tanks

Table 3.1.3.2-1 HERSCHEL – MLI Thermal Conductivity for different number of layers

Temperature [°C]	**20 Layers [W/m2°C]**	**10 Layers [W/m2°C]**	**7 Layers [W/m2°C]**
-100	0.0175	0.0233	0.0314
-90	0.0212	0.0275	0.0362
-80	0.0251	0.0320	0.0413
-70	0.0292	0.0366	0.0468
-60	0.0334	0.0416	0.0527
-50	0.0378	0.0469	0.0590
-40	0.0424	0.0524	0.0659
-30	0.0473	0.0584	0.0733
-20	0.0523	0.0647	0.0812
-10	0.0577	0.0714	0.0898
0	0.0633	0.0785	0.0990
10	0.0692	0.0861	0.1088
25	0.0786	0.0984	0.1250
30	0.0819	0.1027	0.1308
40	0.0888	0.1118	0.1430
50	0.0960	0.1214	0.1560
60	0.1036	0.1317	0.1699
70	0.1116	0.1425	0.1848
80	0.1200	0.1540	0.2006
90	0.1288	0.1661	0.2174
100	0.1381	0.1789	0.2352

- **Unit-Panel Conductivity**

Conductive coupling between unit and panel with graphite interfiller (like Sigraflex) is calculated as follows:

$$GL\ [W/°C] = Gc * Ac$$

where:

$Gc = 50000 * Cc^{-0.9}$ (Cc contact area in cm^2)
Ac = contact area in m^2. Applicability range of the formula: $30\ cm^2 < Cc < 1000\ cm^2$

where:

$Gc = 100$
Ac = contact area in m^2. Applicability range of the formula: $1000\ cm^2 < Cc$

No contact areas smaller than 30 cm^2 are present.
The above formula is based on data from dedicated test performed on Olympus program (1988) and successfully used in the Alenia programs since then.
Thermal Balance Test correlations of Italsat-1/2, SAX, TSS-1/2, Artemis, Integral, Atlantic Bird-1, confirmed the applicability of the used formula.
Further discussion was provided in RD-2.4.

- Spreading effect:

If the unit is mounted on several panel nodes and the ratio between the unit contact area and the mounting nodes area is ≤ 0.45 ($Ac/An \leq 0.45$) the spreading effect is taken into account and calculated as follows:

$$GL=Gc*Ac*[(Ac/An)/0.45]$$

according to Alenia Spazio Thermal Balance Test correlation findings (RD-2.4).

Details of Unit – Panel Contact Conductances (including spreading effect if applicable) are given in Table 3.1.3-2

Table 3.1.3-2 HERSCHEL – Unit-Panel Contact Conductances

UNIT	NODE	PANEL	CONTACT AREA [CM2]	MOUNTING NODES TOTAL AREA [CM2]	AC/AN	FILLER YES=1 NO=0	GL Ac <1000CM2 [W/°C]	GL Ac >1000CM2 [W/°C]	GL (WITH SPREADING EFFECT) [W/°C]
RFDN	101	+ Y + Z	2634.24	3654	0.72	1		26.34	26.34
EPC1	102	+ Y + Z	224.00	1218	0.18	1	8.59		3.51
EPC2	103	+ Y + Z	224.00	609	0.37	1	8.59		7.02
TRANSX1	104	+ Y + Z	373.00	812	0.46	1	9.04		9.04
TRANSX2	105	+ Y + Z	373.00	812	0.46	1	9.04		9.04
TWTA1	106	+ Y + Z	306.00	1624	0.19	1	8.86		3.71
TWTA2	107	+ Y + Z	306.00	812	0.38	1	8.86		7.42
PCDU	201	+ Y	1779.57	2436	0.73	1		17.80	17.80
CDMU	202	+ Y	1171.60	2436	0.48	1		11.72	11.72
ACC	203	+ Y	937.28	1827	0.51	1	9.91		9.91
BATT	204	+ Y	725.00	1827	0.40	1	9.66		8.52
FPSPU1-2	301	+ Y - Z	492.00	812	0.61	1	9.29		9.29
FPDPU	303	+ Y - Z	664.00	1218	0.55	1	9.58		9.58
FPBOLC	304	+ Y - Z	1105.00	1827	0.60	1		11.05	11.05
FPMECDEC	305	+ Y - Z	1792.00	3045	0.59	1		17.92	17.92
CRYOE	401	- Z	925.00	1827	0.51	1	9.90		9.90
HSDCU	404	- Z	1130.00	1624	0.70	1		11.30	11.30
HSDPU	405	- Z	644.00	1218	0.53	1	9.55		9.55
HSFCU	406	- Z	965.00	1218	0.79	1	9.94		9.94
FHWOV	501	- Y - Z	520.00	1624	0.32	1	9.34		6.65
FHHRV	502	- Y - Z	1102.50	1827	0.60	1		11.03	11.03
FHICU	503	- Y - Z	644.00	1827	0.35	1	9.55		7.48
FHFCU	504	- Y - Z	778.00	1827	0.43	1	9.73		9.21
FHWEV	506	- Y - Z	696.00	812	0.86	1	9.62		9.62
FH3DV	507	- Y - Z	49.00	406	0.12	1	7.38		1.98
FHWOH	601	- Y	520.00	1218	0.43	1	9.34		8.87
FHWEH	602	- Y	696.00	1218	0.57	1	9.62		9.62
FHHRH	603	- Y	1102.50	1827	0.60	1		11.03	11.03
FHLCU	604	- Y	750.00	1218	0.62	1	9.69		9.69
FHLSU	605	- Y	970.00	1827	0.53	1	9.95		9.95
FH3DH	606.0	- Y	49.00	406	0.12	1	7.38		1.98
RWS1	701	- Y + Z	961.63	0					GL of RW assumed from Integral data (TBC)
RWS2	702	- Y + Z	961.63	0					
RWS3	703	- Y + Z	961.63	0					
RWS4	704	- Y + Z	961.63	0					
RWDE	705	- Y + Z	761.52	1624	0.47	1	9.71		9.71
QRS1	706	- Y + Z	297.00	1200	0.25	1	8.84		4.86
QRS2	707	- Y + Z	297.00	2400	0.12	1	8.84		2.43
GYRO	801	+ Z	532.00	3600	0.15	1	9.37		3.08
PDU	802	+ Z	225.00	2400	0.09	1	8.59		1.79

- **Honeycomb Panel Conductivity**

- Conductive couplings across honeycomb panel (identified as “Z” direction) are calculated by multiplying the effective thermal conductivity Kz and the cross section between two thermal nodes (panel internal / external sides):

GL(int,ext) = KZ * A(node) / d

where
KZ = thermal conductivity across the honeycomb [W/m°C]
A(node) = node area [m2]
d = overall thickness of the honeycomb panel [m]

- Lateral thermal conductance of honeycomb panel (identifeied as “XY” direction) is calculated by multiplying the effective thermal conductivity Kxy by the cross section and dividing it by the distance between the two thermal nodes.

GL(xxx,yyy) = KXY * A(cross section) / d

where
KXY = in plane conductivity of the honeycomb
A(cross section) = cross section between the two nodes
d = distance of the center of mass of the two adjacent nodes

Structural characteristcs and thermal conductivity (Kz, Kxy) of the panels are hereafter reported (Remark: the conductivity evaluation has been made as per RD.2-1).

Table 3.1.3.2-3 HERSCHEL – SVM Honeycomb panels thermal properties

LOCATION	H/C TYPE	SKIN TYPE	SKIN CONDUCTIVITY [W/MK]	THICK. SKIN [MM]	THICK. CORE[MM]	KXY [W/MK]	KZ [W/MK]
Upper and Lower Closure	3/16-5056-.0007	M18/G801	20	0.4	20	1.21	1.19
Lateral	3/16-5056-.0007	AA7075T6	130	0.3	35	2.64	1.17
Equipment Platform	3/16-5056-.0007	M18/G801	20	0.3	20	1.03	1.18
Shear Web	3/16-5056-.001	M18/G969	20	0.76	15	2.43	1.78
Cone	3/16-5056-.001	M40/914	20	0.54	15	1.95	1.74
Reinforced Cone	1/8-5056-.002	M40/914	20	1.08	13.92	4.39	5.32

- **Interfaces between different panels and platforms**

The interface conductances between different panels are calculated taking into account the serial of the panel conductance from the center of the node to the interface device (cleats, brackets, …) and the conductance of the interface device itself.

- **Interfaces between external items / thrusters and spacecraft**

The external items (AAD, VMC, SAS and SREM) and the thrusters are considered thermally decoupled from the spacecraft.
An overall conductance of 0.2 W/Km is currently assumed.

Remark:
The thrusters GMM and the TMM are currently derived from the INTEGRAL program.

3.2 SVM INTERFACE REQUIREMENTS

The HERSCHEL SVM interface requirements are listed below:

REQUIR.	DESCRIPTION	RESULT	STATUS
ITP-020-H	CVV MLI Ext. layer temp. < 140 K	Boundary in theTMM	C
ITS-020-H	MLI Closure Ext. layer temp. on H-PLM side = 250 K (TBC)	Boundary in theTMM	C
ITP-030-H	CVV total negative conductive loads of 1 W	Boundary in theTMM	C
ITS-021-H	Sunshield total positive loads onto SVM of 15 W (TBC)	Boundary in theTMM	C
ITP-040-H	SVM shield total neg. loads onto SVM of 1 W	Boundary in theTMM	C
ITP-050-H	Total negative loads onto FHLSU via wave-guides of 1 W	Boundary in theTMM	C
ITP-060-H	Wawe Guide negative heat loads onto SVM < 1 W	Boundary in theTMM	C
ITP-090-H	MLI on top SVM max decoupling	Low Emissivity used	C
ITP-100-H	MLI on top SVM Exter. layer temp. < 220 K	Average 214°C	C
ITP-120-H	CVV truss attachement points temp < 293 K	303 K	N C
ITP-130-H	SVM shield attach. point temp. < 293 K	303 K	N C
ITI-020-H	Temp. design range and stability req.	See Analysis Results and discussion	C
ITL-010-H	ARIANE 5 interfaces	N A	N A

3.3 HERSCHEL - THERMAL ANALYSIS

3.3.1 Thermal Analysis Sizing Cases

Two fins on the +Y and –Y Panel have been designed to eliminate the Solar Flux on the two Panels as described in the Design Report AD-2.7.
Due to the use of these fins, the difference on the Temperature results between the case with a rotation of +1deg. and –1deg.° around X-axis, is lower then 1 °C.
For this reason, the Cold Cases were performed using only one position (Rot X= –1°).

According to AD-2.10, the following sizing cases have been performed:
Case 7= Hot Case in worst Attitude (-30° around the Yaxis and +/- 1° on the Xaxis) and in various operating Modes

- Mode 1 (sizing for HIFI units)
- Mode 2 (sizing for PACS units)

Case 2 = Cold Case in worst Attitude, (+30° around the Yaxis) and in various operating Modes

- Mode 1 (sizing for HIFI)
- Mode 3 (sizing for SPIRE)
- Survival = all warm units are Switched-Off

Solar constant values are defined in AD-2.10.

Table 3.3.1-1 HERSCHEL – Steady State Analysis Cases

CASE	BOL/EOL	SUN ON PANEL	SOLAR ASPECT ANGLE [DEG]	ATTITUDE	SOLAR CONSTANT [W/M²]	DISSIPATION MODE
7A	EOL	+X+Y	30	Rot X = +1 Rot Y = -30	1405	Telecom / MODE1
7A	EOL	+X+Y	30	Rot X = +1 Rot Y = -30	1405	Telecom / MODE2 Photometry
7A	EOL	+X+Y	30	Rot X = +1 Rot Y = -30	1405	Telecom / MODE2 Spectroscopy
7B	EOL	+X-Y	30	Rot X = -1 Rot Y = -30	1405	Telecom / MODE1
7B	EOL	+X-Y	30	Rot X = -1 Rot Y = -30	1405	Telecom / MODE2 Photometry
7B	EOL	+X-Y	30	Rot X = -1 Rot Y = -30	1405	Telecom / MODE2 Spectroscopy
2B	BOL	+X-Y	30	Rot X = -1 Rot Y = +30	1285	Scientific / MODE3
2B	BOL	+X-Y	30	Rot X = -1 Rot Y = +30	1285	Scientific / MODE1
2B	BOL	+X-Y	30	Rot X = -1 Rot Y = +30	1285	Survival
2B	EOL	+X-Y	30	Rot X = -1 Rot Y = +30	1285	Survival

3.3.2 Power Dissipation

Herschel Payload Operating Modes are the following (as per AD-2.10):

MODE	HIFI	PACS	SPIRE	COMMENTS
1	Prime	Standby	Standby	
2	Standby	Prime	Standby	Photometry / Spectrometry in PACS Prime
3	Standby	Standby	Prime	

Power dissipations used in the analysis cases are shown in Table 3.3.2-1.

Cold Case analyses have been performed considering the Equipment units in Scientific Observations mode, the Warm Units in MODE1 and MODE3.
Hot Case analyses (EOL7A, EOL7B) have been performed considering the Equipment units in Telecom phase mode, the Warm Units in MODE1 or MODE2 and within the MODE2, Photometry and Spectroscopy.

Table 3.3.2-1 HERSCHEL - Units Power Dissipations

		Scientific Observation	Scientific Observation	Telecom Phase	Telecom Phase	Telecom Phase	Survival
		MODE3 SPIRE Prime	MODE1 HIFI Prime	MODE1 HIFI Prime	MODE2 / Photometry PACS Prime	MODE2 / Spectroscopy PACS Prime	
NODE	LABEL	BOL Case	BOL Case	EOL Case	EOL Case	EOL Case	
		[W]	[W]	[W]	[W]	[W]	[W]
PANEL +Z+Y							
101	RFDN	0	0	8	8	8	8
102	EPC1	9	9	9	9	9	9
103	EPC2	0	0	0	0	0	0
104	TRANSX1	7	7	13	13	13	13
105	TRANSX2	7	7	7	7	7	7
106	TWTA1	0	0	38	38	38	38
107	TWTA2	0	0	0	0	0	0
PANEL +Y							
201	PCDU	153	153	127	127	127	97
202	CMDU	36	36	36	36	36	36
203	ACC	24	24	24	24	24	24
204	BATT	2.1	2.1	2.1	2.1	2.1	7.9
PANEL +Y-Z							
PACS							
301	FPSPU1_2	30.3	30.3	30.3	30.3	30.3	0
303	FPDPU	24	24	24	24	24	0
304	FPBOLC	6.6	6.6	6.6	*48.6*	*6.6*	0
305	FPMECDEC	20.9	20.9	20.9	*21.6*	*65*	0
PANEL –Z							
401	CRYOE	15	15	15	15	15	0
SPIRE							
404	HSDCU	37	37	37	37	37	0
405	HSDPU	15.3	15.3	15.3	15.3	15.3	0
406	HSFCU	42.9	42.9	42.9	42.9	42.9	0
PANEL –Y-Z							

HIFI							
501	FHWOV	2.2	2.2	2.2	2.2	2.2	0
502	FHHRV	63.3	63.3	63.3	63.3	63.3	0
503	FHICU	29.6	29.6	29.6	29.6	29.6	0
504	FHFCU	13	13	13	13	13	0
506	FHWEV	26.9	26.9	26.9	26.9	26.9	0
PANEL –Y							
HIFI							
601	FHWOH	2.2	2.2	2.2	2.2	2.2	0
602	FHWEH	26.9	26.9	26.9	26.9	26.9	0
603	FHHRH	63.3	63.3	63.3	63.3	63.3	0
604	FHLCU	26	35.4	35.4	*26*	*26*	0
605	FHLSU	5	45.8	45.8	*5*	*5*	0
PANEL –Y+Z							
701	RWL1_C	7.3	7.3	7.3	7.3	7.3	0
702	RWL2_C	7.3	7.3	7.3	7.3	7.3	0
703	RWL3_C	7.3	7.3	7.3	7.3	7.3	0
704	RWL4_C	0	0	0	0	0	0
705	RWDE	23.1	23.1	23.1	23.1	23.1	0
SHEAR +Y							
706	QRS1	8	8	8	8	8	0
707	QRS2	8	8	8	8	8	0
SHEAR +Z							
801	GYRO	21	21	21	21	21	0
802	PDU	10	10	10	10	10	0
CENTRAL TRUSS							
42	STRMY	13	13	13	13	13	0

3.3.3 Heater Sizing and Breakdown

An optimized heater definition approach was followed in order to define the minimum heater power needed by the TCS. It included the following major steps:

a) selection of the minimum applicable temperature limits
b) addition of +3°C to the minimum limits (i.e. to achieve the minimum heater control threshold)
c) addition of the defined uncertainty (+9°C/ +11°C as applicable) to obtain a new set of temperatures
d) computation of the needed heater power to maintain units at the those temperature levels in steady state conditions
e) definition of the upper threshold at +5°C above the minimum threshold
f) transient analysis with automatic heater control routines within the defined thresholds
g) verification of the results and local adjustement of heater power as necessary to achieve a proper variation of the equipment temperatures between thersholds (with a heater duty cycle < 100%)

The Heater circuit breakdown with the heater power impressed on the TMM nodes is shown in Table 3.3.3-1

Table 3.3.3-1 HERSCHEL – Heater Circuits Breakdown and Temperature Thresholds

HEATER LINE IDENTIFICATION			PURPOSE	Heater Node	Heater node power [W]	Threshold [°C] (com. on unit)	PURPOSE	Heater Node	Heater node power [W]	Threshold [°C] (com. on unit)
	Main	**Red.**								
HTR-	MA1	RA1	Nominal	6107	5.0	-7/-2 (TWTA1)	Survival	6107	5.0	-7/-2 (TWTA1)
				6115	5.0			6115	5.0	
				6104	7.0			6104	7.0	
				6105	7.0			6105	7.0	
				6112	7.0			6112	7.0	
				6113	7.0			6113	7.0	
				6109	2.5			6109	2.5	
				6110	2.5			6110	2.5	
				6117	2.5			6117	2.5	
				6118	2.5			6118	2.5	
HTR-	MA2	RA2	Nominal	6147	5.0	-7/-2 (TWTA2)	Survival	6147	5.0	-7/-2 (TWTA2)
				6148	5.0			6148	5.0	
				6144	14.0			6144	14.0	
				6145	14.0			6145	14.0	
				6125	2.5			6125	2.5	
				6126	2.5			6126	2.5	
				6133	2.5			6133	2.5	
				6134	2.5			6134	2.5	
HTR-	MB1	RB1	Nominal	6208	5.0	5/10 (BATT.)	Survival	6208	5.0	5/10 (BATT.)
				6209	5.0			6209	5.0	
				6210	5.0			6210	5.0	
				6220	15.0			6220	15.0	
				6222	15.0			6222	15.0	
				6232	5.0			6232	5.0	
				6233	5.0			6233	5.0	
HTR-	MB2	RB2					Survival	6227	7.5	-7/-2 (CDMU)
								6228	7.5	
								6229	7.5	
								6230	7.5	
HTR-	MC1	RC1	Nominal	6324	6.0	-12/-7 (FPBOLC)				
				6332	6.0					
				6340	6.0					
				6342	3.3					
				6343	3.3					
				6344	3.3					
HTR-	MC2	RC2					Survival	6324	6.0	-27/-22 (FPBOLC)
								6332	6.0	
								6340	6.0	
								6342	3.3	
								6343	3.3	
								6344	3.3	
HTR-	MC3	RC3					Survival	6302	8.0	-22/-17 (FPDPU)
								6304	8.0	
								6318	8.0	
								6339	8.0	
								6333	8.0	
								6334	8.0	
								6345	8.0	
HTR-	MD1	RD1	Nominal	6403	2.0	-12/-7 (CRYOE)				
				6404	2.0					
				6428	2.0					
				6457	2.0					
				6470	2.0					
HTR-	MD2	RD2					Survival	6414	10.0	-22/-17 (CRYOE)
								6402	10.0	
								6416	10.0	

HEATER LINE IDENTIFICATION			**PURPOSE**	**Heater Node**	**Heater node power [W]**	**Threshold [°C] (com. on unit)**	**PURPOSE**	**Heater Node**	**Heater node power [W]**	**Threshold [°C] (com. on unit)**
	Main	**Red.**								
HTR-	MD3	RD3					Survival	6409	7.5	-32/-27 (HSDPU)
								6411	7.5	
								6452	7.5	
								6464	7.5	
								6469	7.5	
								6471	7.5	
HTR-	ME1	RE1	Nominal	6531	5.0	ATC (FHWOV)				
				6532	5.0					
				6539	5.0					
				6540	5.0					
HTR-	ME2	RE2					Survival	6505	15.0	-22/-17 (FHICU)
								6506	15.0	
								6524	5.0	
HTR-	ME3	RE3					Survival	6501	15.0	-22/-17 (FHHRV)
								6517	15.0	
								6519	10.0	
								6533	5.0	
								6535	10.0	
								6537	10.0	
								6538	9.0	
								6531	1.5	
								6532	1.5	
								6539	1.5	
								6540	1.5	
HTR-	MF1	RF1	Nominal	6608	10.0	ATC (FHWOH)				
				6619	10.0					
HTR-	MF2	RF2	Nominal	6604	9.0	ATC (FHWEH)				
				6615	9.0					
HTR-	MF3	RF3	Nominal	6639	6.0	ATC (FHHRH)				
				6640	6.0					
				6641	6.0					
				6653	6.0					
				6663	6.0					
				6664	6.0					
HTR-	MF4	RF4	Nominal	6645	3.5	ATC (FHLCU)				
				6657	3.5					
				6646	3.5					
				6658	3.5					
HTR-	MF5	RF5	Nominal	6654	10.0	ATC (FHLSU)				
				6655	10.0					
HTR-	MF6	RF6					Survival	6618	10.0	-22/-17 (FHWOH)
								6619	10.0	
HTR-	MF7	RF7					Survival	6605	10.0	-22/-17 (FHWEH)
								6603	10.0	
								6617	10.0	
HTR-	MF8	RF8					Survival	6658	10.0	-22/-17 (FHHRH)
								6656	10.0	
								6653	10.0	
								6655	10.0	
								6663	10.0	
								6664	10.0	
								6665	10.0	
HTR-	MF9	RF9					Survival	6632	10.0	-22/-17 (FHLSU)
								6634	10.0	
								6641	10.0	
								6644	10.0	

HEATER LINE IDENTIFICATION			PURPOSE	Heater Node	Heater node power [W]	Threshold [°C] (com. on unit)	PURPOSE	Heater Node	Heater node power [W]	Threshold [°C] (com. on unit)
	Main	Red.								
HTR-	MG1	RG1	Nominal	6715	10.0	3/8 (RW1)	Survival	6715	10.0	3/8 (RW1)
				6710	10.0			6710	10.0	
HTR-	MG2	RG2	Nominal	6734	10.0	3/8 (RW3)	Survival	6734	10.0	3/8 (RW3)
				6739	10.0			6739	10.0	
HTR-	MG3	RG3					Survival	6715	17.0	-7/-2 (RWDE)
								6710	17.0	
								6734	17.0	
								6739	17.0	
HTR-	MH1	RH1	Nominal	950	5.0	13/18 (TANK1)	Survival	950	5.0	13/18 (TANK1)
HTR-	MH2	RH2	Nominal	960	5.0	13/18 (TANK2)	Survival	960	5.0	13/18 (TANK2)
HTR-	MH3	RH3	Nominal	8133	2.0	13/18 (RCT1 m)	Survival	8133	2.0	13/18 (T8133)
				8134	2.0			8134	2.0	
HTR-	MH4	RH4	Nominal	8233	2.0	13/18 (RCT2 m)	Survival	8233	2.0	13/18 (T8233)
				8234	2.0			8234	2.0	
HTR-	MH5	RH5	Nominal	8333	2.0	13/18 (RCT3 m)	Survival	8333	2.0	13/18 (T8333)
				8334	2.0			8334	2.0	
HTR-	MH6	RH6	Nominal	8433	2.0	13/18 (RCT4 m)	Survival	8433	2.0	13/18 (T8433)
				8434	2.0			8434	2.0	
HTR-	MH7	RH7	Nominal	8533	2.0	13/18 (RCT5 m)	Survival	8533	2.0	13/18 (T8533)
				8534	2.0			8534	2.0	
HTR-	MH8	RH8	Nominal	8633	2.0	13/18 (RCT6 m)	Survival	8633	2.0	13/18 (T8633)
				8634	2.0			8634	2.0	
HTR-	MH9	RH9	Nominal	TBD		13/18 (T TBD)	Survival	TBD		13/18 (T TBD)
HTR-	MH10	RH10	Nominal	TBD		13/18 (T TBD)	Survival	TBD		13/18 (T TBD)
HTR-	MH11	RH11	Nominal	TBD		13/18 (T TBD)	Survival	TBD		13/18 (T TBD)
HTR-	MI1	RI1	Nominal	811	5.0	-17/-12 (STRMY)	Survival	811	5.0	-17/-12 (STRMY)
HTR-	MI2	RI2	Nominal	831	5.0	-17/-12 (STRPY)	Survival	831	5.0	-17/-12 (STRPY)
HTR-	MI3	RI3	Nominal		5.0	TBD	Survival		5.0	TBD
HTR-	MI4	RI4	Nominal		5.0	TBD	Survival		5.0	TBD

3.3.4 Thermal stability

As reported in AD-2.7, in order to meet the stabilty requirement on HIFI and SPIRE Warm Units (+/- 3k/hour), no active thermal control is requested; but on units having an heater control (501 FHWOV, 601 FHWOH, 605 FHLSU) this requirement is met using an adequate heater power sizing.

A dedicated set of thermal analyses has been performed in order to verify the stability goal on the HIFI Units. The only possibilty to satisfy it, is to improve an active thermal control using an adequate control law as described hereafter.
The critical Units must to be mantained not only at the minimum operative limit, but also at the maximum temperature level achieved on the hot cases.

The comparison in term of extra heater power is reported in the results 3.4.5 paragraphs

3.3.4.1 Active Control Law

The use of an active thermal control was deemed necessary in order to satisfy the very stringent requirements of thermal stability applied to the HIFI units of the Payload carried on the Service Module of the HERSCHEL satellite. The development of the active thermal control algorithm dedicated to the HIFI units started after the finalization of the global TMM used to define the thermal design in his main aspects.

Due to the high level of definition of the global TMM, approximately 150 thermal nodes for each HIFI panel (2000 thermal nodes globally), the first task was to reduce the model in order to have a more suitable thermal network good for the development of the algorithm.
The reduced model has been tested with ESATAN in order to keep a good correlation ($|T_{detailed} - T_{reduced}| \leq 3$ °C) between the detailed model and the reduced one.
The thermal network has been written in his characteristic differential equation.
The non-linear terms (e.g. radiative conductors) have been linearized around his equilibrium point using Taylor expansion.
The obtained linear system has been transformed into the state-space form, well suited for control analysis.

$$dx/dt = Ax + Bu + Md$$
$$y = Cx + Du$$

with

x = […] state vector (all the temperatures considered in the system)
u = […] command vector (heater power applied on the panel)
d = […] disturb vector (unit power, boundary condition)
y = […] output vector (unit temperature to be controlled)

At the beginning of the analysis, the system has been considered as a MIMO (=Multi Input Multi Output) but doing a RGA analysis (=Relative Gain Array) it was clear that for the control purpose the 5 outputs (=y) could be considered as 5 SISO (=Single Input Single Output) respectively.
After that for each SISO has been found the appropriate PI regulator and then discretized with the TUSTIN method with a sampling time of 10 seconds (the sampling characteristic of the data acquisition system).
The specifications applied to this system are :

$e_\infty = 0$
cutting frequency = 0.001 Hz

The algorithm is:
$P_k = P_{k-1} + \text{alpha}\,(T_{ref} - T_k) + \text{beta}\,(T_{ref} - T_{k-1})$

With:

k = regulation cycle (cycle period = 10 seconds)
P_k = heating power at discrete time k
T_k = measured temperature at discrete time k
T_{ref} = set point temperature
alpha = first term of PI corrector coefficient
beta = second term of PI corrector coefficient

The algorithm has been applied to the following units with the following parameters (coefficient of the regulator and temperature set points):

- FHWOV (T501) alpha = 7.003 beta = -6.997 Temp. set point = 12 °C
- FHWOH (T601) alpha = 15.01 beta = -14.99 Temp. set point = 12 °C
- FHWEH (T602) alpha = 15.01 beta = -14.99 Temp. set point = 21 °C
- FHHRH (T603) alpha = 25.01 beta = -24.99 Temp. set point = 37 °C
- FHLCU (T604) alpha = 25.01 beta = -24.99 Temp. set point = 37 °C
- FHLSU (T605) alpha = 30.01 beta = -29.99 Temp. set point = 32 °C

3.3.5 Thermal Analysis Cases with Attitude Change

Two Cases with an Attitude Change have been performed with the HIFI Units in Prime Mode.
Here only the analysis results devoted to meet the stability goal are presented, as far as this is a conservative situation.

The stability goal is reached with the active control law implemented on the –Y Panel Units (FHWOH, FHWEH, FHHRH, FHLCU, FHLSU) and on the -Y-Z Unit (FHWOV).
Justification is:

- all units belonging to –Y panel require an active control during the attitude change (otherwise stability requirement is exceeded for about 7 hrs following the attitude change due to some solar heating and reflection effects from HPLM interface MLI)
- FHWOV belonging to –Y-Z panel requires a dedicated heater power, consequently the active control law is needed.

The analysed cases are:

- Cold Transient (Case 1):
  Starting from S/S case BOL2B: Sun on +X -Y axis, SAA=+30°/-1°
  Ending to case S/S case BOL7B: Sun on -X +Y axis, SAA=-30°/-1°
  Power units dissipation: constant (see value corresponding to BOL Cases in Table 3.2.2-2, Scientific Observation and Warm Units in MODE1 with HIFI in Prime Mode)
  Heater dissipation: Active Control Law on HIFI Units (nodes 501, 601, 602, 603, 604, 605).
  Duration of change of attitude: 1200s (20 min) at the 139600s
  Overall duration of transient case: 432000s (96 hours)

- Hot Transient (Case 2):
  Starting from S/S case EOL7A: Sun on -X +Y axis, SAA=-30°/+1°
  Ending to S/S case EOL2A: Sun on +X -Y axis, SAA=+30°/+1°
  Power units dissipation: constant (see value corresponding to EOL Cases in Table 3.2.2-2, Telecom Phase and Warm Units in MODE1 with HIFI in Prime Mode)
  Heater dissipation: Active Control Law on HIFI Units (noded 501, 601, 602, 603, 604, 605).
  Duration of change of attitude: 1200s (20 min) at the 139600s
  Overall duration of transient case: 432000s (96 hours)

3.3.6 Emergency Mode Cases and Results

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3.4 HERSCHEL – THERMAL ANALYSIS RESULTS

3.4.1 Results of Sizing Cases

The temperature results hereafter presented (Tables 3.4.1-1 to 4) refer to the Sizing Cases reported in paragraph 3.3.1. The values are inclusive of 11°C of uncertainty for the HIFI Units and 9°C of uncertainty for all the other Units according to the uncertainty analysis.

Table 3.4.1-1 HERSCHEL - Units Temperature results: Sizing Case BOL Nominal.

		Operative Temperatures Limits		Not Operative Temperatures Limits		BOL2B Scientific MODE1	BOL2B Scientific MODE3
		MIN	**MAX**	**MIN**	**MAX**	**T-UFP**	**T-UFP**
NODE	**LABEL**	**[°C]**	**[°C]**	**[°C]**	**[°C]**	**[°C]**	**[°C]**
6	**SASZ**	**-70**	**80**	**-70**	**80**	-1.9	-1.9
46	**SAS-Z**	**-70**	**80**	**-70**	**80**	-24.4	-24.6
101	**RFDN**	**-40**	**70**	**-50**	**80**	-22.5	-22.5
102	**EPC1**	**-15**	**45**	**-25**	**55**	(*) -6.6	(*) -6.6
103	**EPC2**	**-15**	**45**	**-25**	**55**	(*) -12.1	(*) -12.1
104	**TRANSX1**	**-10**	**50**	**-20**	**60**	(*) -2.7	(*) -2.7
105	**TRANSX2**	**-10**	**50**	**-20**	**60**	(*) -5.5	(*) -5.5
106	**TWTA1**	**-15**	**50**	**-25**	**60**	(*) –10	(*) –10
107	**TWTA2**	**-15**	**50**	**-25**	**60**	(*) –10	(*) –10
201	**PCDU**	**-10**	**45**	**-20**	**55**	12.7	12.7
202	**CMDU**	**-10**	**45**	**-20**	**55**	-10.7	-10.7
203	**ACC**	**-20**	**55**	**-30**	**65**	-14.4	-14.4
204	**BATT**	**0**	**35**			(*) 2	(*) 2
301	**FPSPU1_2**	**-15**	**45**	**-30**	**60**	1.4	1.4
303	**FPDPU**	**-15**	**45**	**-30**	**60**	-4	-4
304	**FPBOLC**	**-15**	**45**	**-30**	**60**	(*) –15	(*) –15
305	**FPMECDEC**	**-15**	**45**	**-30**	**60**	(*) -12.1	(*) -12.1
401	**CRYOE**	**-15**	**45**	**-25**	**55**	(*) –15	(*) –15
404	**HSDCU**	**-15**	**45**	**-35**	**80**	-13.9	-14.1
405	**HSDPU**	**-15**	**45**	**-35**	**80**	(*) -10.8	(*) -10.9
406	**HSFCU**	**-15**	**45**	**-35**	**80**	-5.4	-5.4
501	**FHWOV**	**0**	**15**	**-25**	**55**	(*) 0	(*) 0
502	**FHHRV**	**-10**	**40**	**-25**	**55**	10.1	10
503	**FHICU**	**-25**	**45**	**-30**	**60**	-6.8	-6.9
504	**FHFCU**	**-10**	**40**	**-25**	**55**	-10.5	-10.7
506	**FHWEV**	**0**	**25**	**-25**	**55**	-2.8	-2.8
507	**FH3DV**	**-10**	**40**	**-25**	**55**	-22.9	-23.1
601	**FHWOH**	**0**	**15**	**-25**	**55**	(*) 0	(*) 0
602	**FHWEH**	**0**	**25**	**-25**	**55**	(*) 0	(*) 0
603	**FHHRH**	**-10**	**40**	**-25**	**55**	1.2	0.7
604	**FHLCU**	**-10**	**40**	**-25**	**55**	7.8	1.6
605	**FHLSU**	**-10**	**40**	**-25**	**55**	0.9	(*) –10
606	**FH3DH**	**-10**	**40**	**-25**	**55**	-3.1	-6.1
701	**RWL1_C**	**0**	**50**	**-10**	**60**	(*) 0	(*) 0
702	**RWL2_C**	**0**	**50**	**-10**	**60**	(*) 0.5	(*) 0.5
703	**RWL3_C**	**0**	**50**	**-10**	**60**	(*) 0	(*) 0
704	**RWL4_C**	**0**	**70**	**-10**	**60**	(*) -3.7	(*) –3.7
705	**RWDE**	**-10**	**50**	**-20**	**60**	-5.1	-5.1
706	**QRS1**	**-15**	**45**	**-35**	**65**	-6	-6
707	**QRS2**	**-15**	**45**	**-35**	**65**	-5.7	-5.7

		Operative Temperatures Limits		Not Operative Temperatures Limits		BOL2B	BOL2B
						Scientific	Scientific
						MODE1	MODE3
		MIN	MAX	MIN	MAX	T-UFP	T-UFP
NODE	LABEL	[°C]	[°C]	[°C]	[°C]	[°C]	[°C]
801	GYRO	-15	45	-25	55	-2.6	-2.7
802	PDU	-15	45	-25	55	-3.7	-3.7
811	STRMY	-20	30	-30	50	-15.2	-15.3
831	STRPY	-20	30	-30	50	(not op)-25.6	(not op) -25.7
950	TANK1	10	40	10	40	(*) 10	(*) 10
960	TANK2	10	40	10	40	(*) 10	(*) 10

(*) Units with dedicated heater control properly sized; relevant applied uncertainty is 3°C, corresponding to the automatic control chain uncertainty.

Table 3.4.1-2 HERSCHEL - Units Temperature results: Sizing Case BOL Survival.

		Operative Temperatures Limits		Not Operative Temperatures Limits		BOL2B	EOL2B
						Survival	Survival
		MIN	MAX	MIN	MAX	T+UFP	T+UFP
NODE	LABEL	[°C]	[°C]	[°C]	[°C]	[°C]	[°C]
6	SASZ	-70	80	-70	80	-7.5	-7
46	SAS-Z	-70	80	-70	80	-32.6	-32.6
101	RFDN	-40	70	-50	80	-21.8	-17.5
102	EPC1	-15	45	-25	55	(*) –10	(*) –10
103	EPC2	-15	45	-25	55	(*) -10	(*) –10
104	TRANSX1	-10	50	-20	60	(*) -3	(*) –2
105	TRANSX2	-10	50	-20	60	(*) -5.5	(*) -7.2
106	TWTA1	-15	50	-25	60	(*) 5.8	(*) 11.3
107	TWTA2	-15	50	-25	60	(*) 0.1	(*) -12.7
201	PCDU	-10	45	-20	55	-5.4	-5.2
202	CMDU	-10	45	-20	55	(*) –10	(*) -10
203	ACC	-20	55	-30	65	-23	-22.8
204	BATT	0	35			(*) 2	(*) 2
301	FPSPU1_2	-15	45	-30	60	(*) -24.7	(*) –24.5
303	FPDPU	-15	45	-30	60	(*) –30	(*) –30
304	FPBOLC	-15	45	-30	60	(*) –30	(*) –30
305	FPMECDEC	-15	45	-30	60	(*) -28.4	(*) -28.3
401	CRYOE	-15	45	-25	55	(*) -25	(*) –25
404	HSDCU	-15	45	-35	80	(*) -28.6	(*) -28.5
405	HSDPU	-15	45	-35	80	(*) –35	(*) –35
406	HSFCU	-15	45	-35	80	(*) -27.9	(*) -27.8
501	FHWOV	0	15	-25	55	(*) -19.4	(*) -19.4
502	FHHRV	-10	40	-25	55	(*) –25	(*) –25
503	FHICU	-25	45	-30	60	(*) -25	(*) –25
504	FHFCU	-10	40	-25	55	(*) -21.5	(*) -21.5
506	FHWEV	0	25	-25	55	(*) -24.3	(*) -24.3
507	FH3DV	-10	40	-25	55	(*) -33.9	(*) -33.9
601	FHWOH	0	15	-25	55	(*) -25	(*) –25
602	FHWEH	0	25	-25	55	(*) -25	(*) –25
603	FHHRH	-10	40	-25	55	(*) -25	(*) –25
604	FHLCU	-10	40	-25	55	(*) -21.7	(*) -21.8

		Operative Temperatures Limits		Not Operative Temperatures Limits		BOL2B Survival	EOL2B Survival
		MIN	MAX	MIN	MAX	T+UFP	T+UFP
NODE	LABEL	[°C]	[°C]	[°C]	[°C]	[°C]	[°C]
605	FHLSU	-10	40	-25	55	(*) -25	(*) –25
606	FH3DH	-10	40	-25	55	(*) -23.5	(*) -23.3
701	RWL1_C	0	50	-10	60	(*) 0	(*) 0
702	RWL2_C	0	50	-10	60	(*) 0.4	(*) 1.2
703	RWL3_C	0	50	-10	60	(*) 0	(*) 0
704	RWL4_C	0	70	-10	60	(*) 1	(*) 1.2
705	RWDE	-10	50	-20	60	(*) –10	(*) –10
706	QRS1	-15	45	-35	65	-17.1	-16.5
707	QRS2	-15	45	-35	65	-17.4	-17
801	GYRO	-15	45	-25	55	-19.2	-17.9
802	PDU	-15	45	-25	55	-17	-16.3
811	STRMY	-20	30	-30	50	(*) –20	(*) –20
831	STRPY	-20	30	-30	50	(*) –20	(*) –20
950	TANK1	10	40	10	40	(*) 10	(*) 10
960	TANK2	10	40	10	40	(*) 10	(*) 10

(*) Units with dedicated heater control properly sized; relevant applied uncertainty is 3°C, corresponding to the automatic control chain uncertainty.

Table 3.4.1-3 HERSCHEL - Units Temperature results: Sizing Case EOL Nominal

		Operative Temperatures Limits		Not Operative Temperatures Limits		EOL7A Telecom MODE1	EOL7A Telecom MODE2 Photometry	EOL7A Telecom MODE2 Spectrometry
		MIN	MAX	MIN	MAX	T+UFP	T+UFP	T+UFP
NODE	LABEL	[°C]	[°C]	[°C]	[°C]	[°C]	[°C]	[°C]
6	SASZ	-70	80	-70	80	49.7	50.3	50.3
46	SAS-Z	-70	80	-70	80	19.8	20.7	20.9
101	RFDN	-40	70	-50	80	29.3	30.2	30.1
102	EPC1	-15	45	-25	55	32.7	33.4	33.4
103	EPC2	-15	45	-25	55	29	29.8	29.7
104	TRANSX1	-10	50	-20	60	36.8	37.7	37.6
105	TRANSX2	-10	50	-20	60	35.5	36.5	36.4
106	TWTA1	-15	50	-25	60	46.6	47.2	47.2
107	TWTA2	-15	50	-25	60	30.2	31	30.9
201	PCDU	-10	45	-20	55	41	42.7	42.4
202	CMDU	-10	45	-20	55	25.8	28.6	28
203	ACC	-20	55	-30	65	22.1	25.1	24.4
204	BATT	0	35			18	19.8	19.6
301	FPSPU1_2	-15	45	-30	60	39.1	44.1	45.8
303	FPDPU	-15	45	-30	60	33.7	39.1	40.3
304	FPBOLC	-15	45	-30	60	17.9	34.4	24.6
305	FPMECDEC	-15	45	-30	60	20.5	27	35.1
401	CRYOE	-15	45	-25	55	27.3	28.3	28.5
404	HSDCU	-15	45	-35	80	29.8	30.8	31
405	HSDPU	-15	45	-35	80	22.3	27.1	28.5
406	HSFCU	-15	45	-35	80	34.6	39	39.8
501	FHWOV	0	15	-25	55	(*) 11	(*) 11	(*) 11

		Operative Temperatures Limits		Not Operative Temperatures Limits		EOL7A Telecom MODE1	EOL7A Telecom MODE2 Photometry	EOL7A Telecom MODE2 Spectrometry
		MIN	MAX	MIN	MAX	T+UFP	T+UFP	T+UFP
NODE	LABEL	[°C]	[°C]	[°C]	[°C]	[°C]	[°C]	[°C]
502	FHHRV	-10	40	-25	55	39	38.7	38.8
503	FHICU	-25	45	-30	60	22.4	22.5	22.5
504	FHFCU	-10	40	-25	55	21.2	20.6	20.7
506	FHWEV	0	25	-25	55	23.6	23.6	23.7
507	FH3DV	-10	40	-25	55	5	5	5
601	FHWOH	0	15	-25	55	(*) 11	(*) 11	(*) 11
602	FHWEH	0	25	-25	55	21	19.7	19.7
603	FHHRH	-10	40	-25	55	36.6	30.6	30.6
604	FHLCU	-10	40	-25	55	40.9	22.5	22.6
605	FHLSU	-10	40	-25	55	32.3	(*) 1	(*) 1
606	FH3DH	-10	40	-25	55	28.6	18.2	18.2
701	RWL1_C	0	50	-10	60	42.1	42.4	42.5
702	RWL2_C	0	50	-10	60	43.2	43.7	43.7
703	RWL3_C	0	50	-10	60	42	42.3	42.4
704	RWL4_C	0	70	-10	60	39.5	39.9	40
705	RWDE	-10	50	-20	60	42.8	43.2	43.2
706	QRS1	-15	45	-35	65	36.2	37.6	37.4
707	QRS2	-15	45	-35	65	36.5	38	37.8
801	GYRO	-15	45	-25	55	48.3	49.2	49.2
802	PDU	-15	45	-25	55	47.7	48.4	48.4
811	STRMY	-20	30	-30	50	44.3	45.5	45.5
831	STRPY	-20	30	-30	50	(not op) 35.5	(not op) 37.3	(not op) 37.4
950	TANK1	10	40	10	40	37.3	38.3	38.4
960	TANK2	10	40	10	40	35.3	37.2	37.2

(*) Units with dedicated heater control properly sized; relevant applied uncertainty is 3°C, corresponding to the automatic control chain uncertainty.

Table 3.4.1-4 HERSCHEL - Units Temperature results: Sizing Case EOL Nominal

		Operative Temperatures Limits		Not Operative Temperatures Limits		EOL7B Telecom MODE1	EOL7B Telecom MODE2 Photometry	EOL7B Telecom MODE2 Spectrometry
		MIN	MAX	MIN	MAX	T+UFP	T+UFP	T+UFP
NODE	LABEL	[°C]	[°C]	[°C]	[°C]	[°C]	[°C]	[°C]
6	SASZ	-70	80	-70	80	49.6	50.2	50.3
46	SAS-Z	-70	80	-70	80	19.8	20.7	20.9
101	RFDN	-40	70	-50	80	28.5	29.4	29.3
102	EPC1	-15	45	-25	55	31.9	32.6	32.6
103	EPC2	-15	45	-25	55	28.1	28.9	28.9
104	TRANSX1	-10	50	-20	60	36.1	37	36.9
105	TRANSX2	-10	50	-20	60	34.7	35.6	35.5
106	TWTA1	-15	50	-25	60	45.8	46.5	46.4
107	TWTA2	-15	50	-25	60	29.3	30	30
201	PCDU	-10	45	-20	55	40.4	42.1	41.8
202	CMDU	-10	45	-20	55	25.4	28.2	27.6

		Operative Temperatures Limits		Not Operative Temperatures Limits		EOL7B	EOL7B	EOL7B
						Telecom	Telecom	Telecom
						MODE1	MODE2 Photometry	MODE2 Spectrometry
		MIN	MAX	MIN	MAX	T+UFP	T+UFP	T+UFP
NODE	LABEL	[°C]	[°C]	[°C]	[°C]	[°C]	[°C]	[°C]
203	ACC	-20	55	-30	65	21.6	24.6	23.9
204	BATT	0	35			17.5	19.4	19.1
301	FPSPU1_2	-15	45	-30	60	38.9	43.9	45.6
303	FPDPU	-15	45	-30	60	33.5	38.9	40.1
304	FPBOLC	-15	45	-30	60	17.7	34.2	24.4
305	FPMECDEC	-15	45	-30	60	20.3	26.8	34.9
401	CRYOE	-15	45	-25	55	27.3	28.3	28.5
404	HSDCU	-15	45	-35	80	29.8	30.7	30.9
405	HSDPU	-15	45	-35	80	22.1	27	28.4
406	HSFCU	-15	45	-35	80	34.4	38.8	39.6
501	FHWOV	0	15	-25	55	(*) 11	(*) 11	(*) 11
502	FHHRV	-10	40	-25	55	39	38.7	38.8
503	FHICU	-25	45	-30	60	22.4	22.5	22.5
504	FHFCU	-10	40	-25	55	21.2	20.6	20.7
506	FHWEV	0	25	-25	55	23.6	23.6	23.7
507	FH3DV	-10	40	-25	55	5	5	5
601	FHWOH	0	15	-25	55	(*) 11	(*) 11	(*) 11
602	FHWEH	0	25	-25	55	21.3	19.9	19.9
603	FHHRH	-10	40	-25	55	37.4	31.3	31.3
604	FHLCU	-10	40	-25	55	41.2	22.6	22.6
605	FHLSU	-10	40	-25	55	32.8	(*) 1	(*) 1
606	FH3DH	-10	40	-25	55	28.7	18.2	18.2
701	RWL1_C	0	50	-10	60	42.4	42.7	42.7
702	RWL2_C	0	50	-10	60	43.5	43.9	43.9
703	RWL3_C	0	50	-10	60	42.3	42.6	42.6
704	RWL4_C	0	70	-10	60	39.7	40.2	40.2
705	RWDE	-10	50	-20	60	43.3	43.6	43.6
706	QRS1	-15	45	-35	65	35.7	37.1	36.9
707	QRS2	-15	45	-35	65	36	37.4	37.2
801	GYRO	-15	45	-25	55	48	48.9	48.8
802	PDU	-15	45	-25	55	47.7	48.4	48.4
811	STRMY	-20	30	-30	50	44.3	45.4	45.5
831	STRPY	-20	30	-30	50	(not op) 35.2	(not op) 37	(not op) 37.1
950	TANK1	10	40	10	40	37.3	38.2	38.3
960	TANK2	10	40	10	40	35	37	37

(*) Units with dedicated heater control properly sized; relevant applied uncertainty is 3°C, corresponding to the automatic control chain uncertainty.

3.4.2 Trade-off Analyses

Trade-off analysis was made with the scope to identify possible design improvements in the Hot case in terms of maximum temperature decrease and heater power budget optimization; the EOL7B- MODE1 case (without any heater operation) was chosen as reference analysis case for the trade off.
Major attention is focused on critical items such as Star Trackers and Gyro (data details in Table 3.4.2-1)

Cold case analysis was run to verify that minimum or no impacts are expected in cold cases; a temperature decrease of less than 1.5°C was detected even in the worst case (see case (d)).

Summary of impacts of different design solutions on temperature levels and mass budget is:

a) Use of the Aluminium Tape properties (EPS=0.05) on all Internal Bottom surfaces:
Units Temperatures decreasing 1÷2 °C.
Mass rising: 0.35 kg

b) Use of Beta-cloth properties (ALPHA=0.375, EPS=0.87) on the MLI external layer on the –X face:
Units Temperatures decrease of 2÷6 °C.
Mass rising: 3.3 kg

c) Use of the two previous options together:
Units Temperatures decrease of 2÷6 °C.
Mass rising: 3.65 kg

d) Use of the ITO properties (ALPHA=0.6, EPS=0.77) on the MLI external layers exposed to the Sun:
Units Temperatures decrease of 1÷4 °C.
Mass rising: negligeable

e) Use of the Beta-cloth properties on the MLI external layers exposed to the Sun:
Units Temperatures decrease of 2÷8 °C.
Mass rising: 4.3 kg

f) Use of the Beta-cloth properties on the MLI external layers on the +Z Panel:
Units Temperatures decrease of 0.5÷2.5°C.
Mass rising: 0.5 kg

A possible decrease in term of heaters power consumption will be investigated only for the potential in case that one of these options will be selected.

Table 3.4.2-1 HERSCHEL – Trade Offs results in Hot Case EOL7B MODE 1

NODE	**LABEL**	**NOM.**	**BETACLOTH -X (b)**		**Aluminum Tape on BOT (a)**		**BETACLOTH –X Aluminum Tape on BOT (c)**		**ITO on SUN PANELS (d)**		**BETA-CLOTH on SUN PANELS (e)**		**BETACLOTH on +Z (f)**	
				DELTA WITH NOM		DELTA WITH NOM		DELTA WITH NOM		DELTA WITH NOM		DELTA WITH NOM		DELTA WITH NOM
			[°C]	[°C]	[°C]	[°C]	[°C]	[°C]	[°C]	[°C]	[°C]	[°C]	[°C]	[°C]
6	SAS +Z	40.44	35.95	-4.49	39.77	-0.67	35.44	-5	33.46	-6.98	23.42	-17.02	36.82	-3.62
46	SAS -Z	10.46	6	-4.46	9.76	-0.7	5.95	-4.51	7.99	-2.47	4.84	-5.62	9.69	-0.77
101	RFDN	19.43	16.3	-3.13	18.77	-0.66	16.18	-3.25	17.22	-2.21	14.39	-5.04	18.1	-1.33
102	EPC1	22.81	19.79	-3.02	22.78	-0.03	19.99	-2.82	20.73	-2.08	18.06	-4.75	21.59	-1.22
103	EPC2	19.04	16.14	-2.9	18.32	-0.72	15.95	-3.09	17	-2.04	14.35	-4.69	17.7	-1.34
104	TRANSX1	26.94	23.69	-3.25	26.27	-0.67	23.42	-3.52	24.64	-2.3	21.66	-5.28	25.89	-1.05
105	TRANSX2	25.58	22.58	-3	24.87	-0.71	22.4	-3.18	23.37	-2.21	20.57	-5.01	24.53	-1.05
106	TWTA1	36.69	33.97	-2.72	36.59	-0.1	34.08	-2.61	34.87	-1.82	32.54	-4.15	35.73	-0.96
107	TWTA2	20.16	17.47	-2.69	19.48	-0.68	17.29	-2.87	18.31	-1.85	15.83	-4.33	19.09	-1.07
201	PCDU	31.31	28.45	-2.86	30.81	-0.5	28.43	-2.88	29.59	-1.72	27.46	-3.85	30.57	-0.74
202	CMDU	16.27	12.52	-3.75	15.63	-0.64	12.39	-3.88	14.15	-2.12	11.45	-4.82	15.53	-0.74
203	ACC	12.48	9.08	-3.4	11.84	-0.64	9.01	-3.47	10.52	-1.96	8.06	-4.42	11.74	-0.74
204	BATT	8.41	4.87	-3.54	7.99	-0.42	4.88	-3.53	6.33	-2.08	3.73	-4.68	7.6	-0.81
301	FPSPU1_2	29.75	25.89	-3.86	30.41	0.66	27.06	-2.69	27.64	-2.11	25	-4.75	29.15	-0.6
303	FPDPU	24.35	20.49	-3.86	24.67	0.32	21.32	-3.03	22.23	-2.12	19.58	-4.77	23.74	-0.61
304	FPBOLC	8.54	4.39	-4.15	7.48	-1.06	4.02	-4.52	6.24	-2.3	3.33	-5.21	7.83	-0.71
305	FPMECDEC	11.16	7.17	-3.99	10.65	-0.51	7.33	-3.83	8.96	-2.2	6.18	-4.98	10.49	-0.67
401	CRYOE	17.87	13.03	-4.84	17.13	-0.74	13.09	-4.78	15.21	-2.66	11.8	-6.07	17.04	-0.83
404	HSDCU	20.38	15.89	-4.49	19.78	-0.6	16.14	-4.24	17.86	-2.52	14.68	-5.7	19.57	-0.81
405	HSDPU	12.96	9.02	-3.94	12.49	-0.47	9.23	-3.73	10.77	-2.19	8.02	-4.94	12.29	-0.67
406	HSFCU	25.28	21.17	-4.11	25.69	0.41	22.21	-3.07	23.03	-2.25	20.19	-5.09	24.63	-0.65
501	FHWOV	1.39	-1.08	-2.47	1.03	-0.36	-1.13	-2.52	-0.02	-1.41	-1.81	-3.2	0.96	-0.43
502	FHHRV	27.76	26.45	-1.31	27.54	-0.22	26.13	-1.63	27.05	-0.71	26.12	-1.64	27.56	-0.2
503	FHICU	10.82	9.19	-1.63	10.51	-0.31	8.74	-2.08	9.93	-0.89	8.8	-2.02	10.57	-0.25
504	FHFCU	9.86	8.08	-1.78	9.59	-0.27	8.03	-1.83	8.87	-0.99	7.57	-2.29	9.56	-0.3
506	FHWEV	11.46	10.02	-1.44	11.25	-0.21	9.95	-1.51	10.66	-0.8	9.6	-1.86	11.23	-0.23
507	FH3DV	-4.75	-6.73	-1.98	-5.03	-0.28	-6.71	-1.96	-5.87	-1.12	-7.35	-2.6	-5.06	-0.31
601	FHWOH	-2.18	-4.55	-2.37	-3.03	-0.85	-5.78	-3.6	-3.59	-1.41	-5.35	-3.17	-2.67	-0.49
602	FHWEH	9.02	7.07	-1.95	8.44	-0.58	6.19	-2.83	7.78	-1.24	6.25	-2.77	8.53	-0.49
603	FHHRH	25.88	24.57	-1.31	25.6	-0.28	24.43	-1.45	24.92	-0.96	23.8	-2.08	25.55	-0.33
604	FHLCU	29.17	27.3	-1.87	28.78	-0.39	27.06	-2.11	28.04	-1.13	26.63	-2.54	28.79	-0.38
605	FHLSU	20.5	19.09	-1.41	20.19	-0.31	18.88	-1.62	19.63	-0.87	18.54	-1.96	20.2	-0.3

NODE	LABEL	NOM.	BETACLOTH -X (b)		Aluminum Tape on BOT (a)		BETACLOTH –X Aluminum Tape on BOT (c)		ITO on SUN PANELS (d)		BETA-CLOTH on SUN PANELS (e)		BETACLOTH on +Z (f)	
				DELTA WITH NOM		DELTA WITH NOM		DELTA WITH NOM		DELTA WITH NOM		DELTA WITH NOM		DELTA WITH NOM
			[°C]	[°C]	[°C]	[°C]	[°C]	[°C]	[°C]	[°C]	[°C]	[°C]	[°C]	[°C]
606	FH3DH	18.78	16.39	-2.39	18.3	-0.48	16	-2.78	17.37	-1.41	15.61	-3.17	18.33	-0.45
701	RWL1_C	33.13	28.32	-4.81	31.87	-1.26	27.85	-5.28	29.54	-3.59	24.94	-8.19	31.52	-1.61
702	RWL2_C	34.24	29.38	-4.86	33.2	-1.04	29.16	-5.08	30.46	-3.78	25.59	-8.65	32.23	-2.01
703	RWL3_C	33.03	28.4	-4.63	31.6	-1.43	27.85	-5.18	29.51	-3.52	25.02	-8.01	31.36	-1.67
704	RWL4_C	30.48	25.74	-4.74	29.23	-1.25	25.36	-5.12	26.7	-3.78	21.83	-8.65	28.38	-2.1
705	RWDE	34.04	29.96	-4.08	33.03	-1.01	29.64	-4.4	30.75	-3.29	26.66	-7.38	32.48	-1.56
706	QRS1	26.53	22.86	-3.67	25.61	-0.92	22.6	-3.93	24.18	-2.35	21.17	-5.36	25.4	-1.13
707	QRS2	26.83	23.26	-3.57	26	-0.83	23.08	-3.75	24.51	-2.32	21.55	-5.28	25.66	-1.17
801	GYRO	38.83	34.38	-4.45	37.69	-1.14	33.97	-4.86	35.4	-3.43	30.96	-7.87	36.29	-2.54
802	PDU	38.5	33.66	-4.84	37.14	-1.36	33.19	-5.31	34.67	-3.83	29.7	-8.8	35.85	-2.65
811	STRMY	35.13	30.01	-5.12	33.48	-1.65	29.29	-5.84	31.97	-3.16	28.17	-6.96	33.75	-1.38
831	STRPY	26.02	20.87	-5.15	24.55	-1.47	20.35	-5.67	23.03	-2.99	19.1	-6.92	24.82	-1.2
950	TANK1	28.08	22.27	-5.81	26.81	-1.27	22.11	-5.97	24.62	-3.46	20.2	-7.88	26.74	-1.34
960	TANK2	25.92	20.56	-5.36	24.9	-1.02	20.5	-5.42	22.78	-3.14	18.75	-7.17	24.68	-1.24

3.4.3 Results of Transient Cases

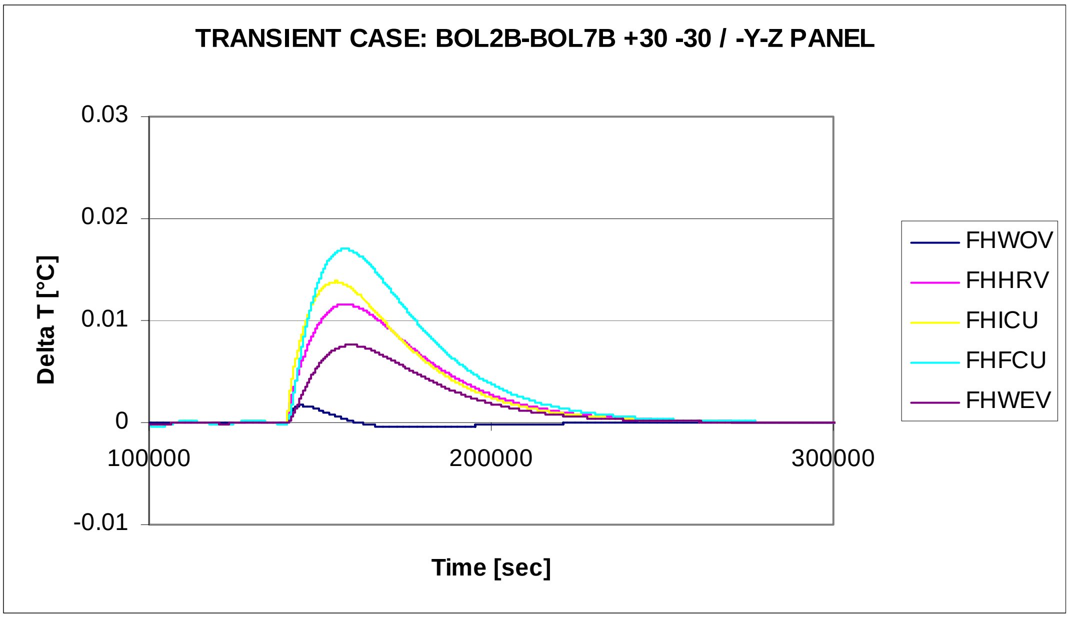
Transient analysis cases were run to assess the thermal behaviour of the SVM when subjected to attitude change (sun from +30 deg to –30 deg on –X side and vice-versa). Main purpose was to verify the capability of the design to meet the stability requirements and in particular the stability goal.

The list of stability goal is:

NODE	UNIT	Stability Requirement Delta T
501	FHWOV	+/- 0.03/100s
502	FHHRV	+/- 0.03/100s
503	FHICU	+/-0.14/100s
504	FHFCU	+/- 0.14/100s
506	FHWEV	+/- 0.03/100s
601	FHWOH	+/- 0.03/100s
602	FHWEH	+/- 0.03/100s
603	FHHRH	+/- 0.03/100s
604	FHLCU	+/- 0.03/100s
605	FHLSU	+/- 0.03/100s

Plots of Temperature variations over 100 sec for the HIFI units are shown hereunder for:

- transient case 1 (+30 / -30) (Figure 3.4.3-1)
- transient case 2 (-30 / + 30) (Figure 3.4.3-2)



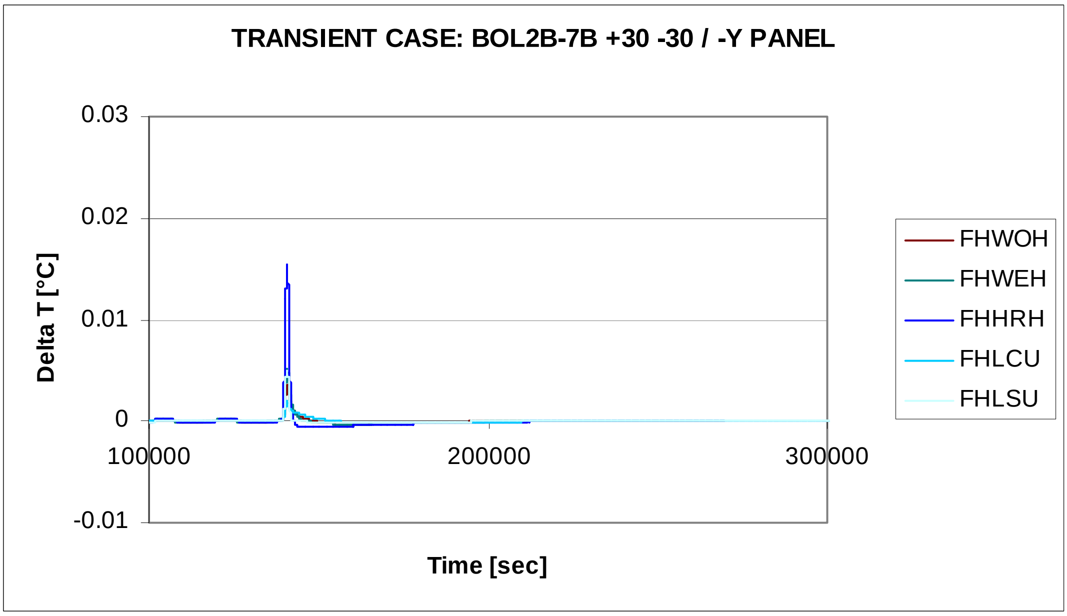
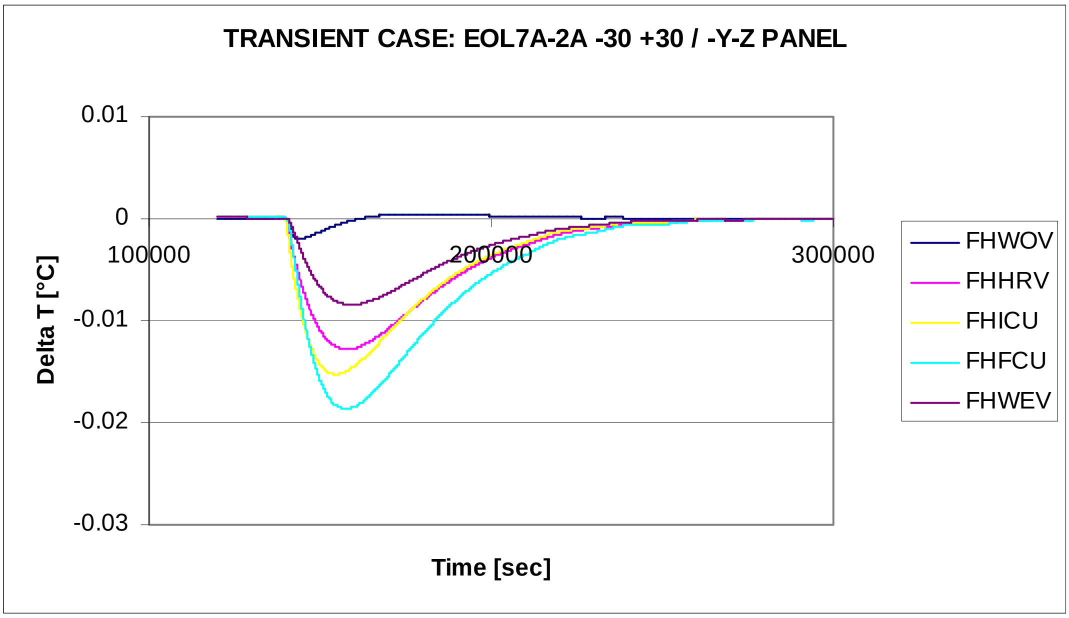


Figure 3.4.3-1 HERSCHEL – HIFI units Transient Case 1: DeltaT on 100s.



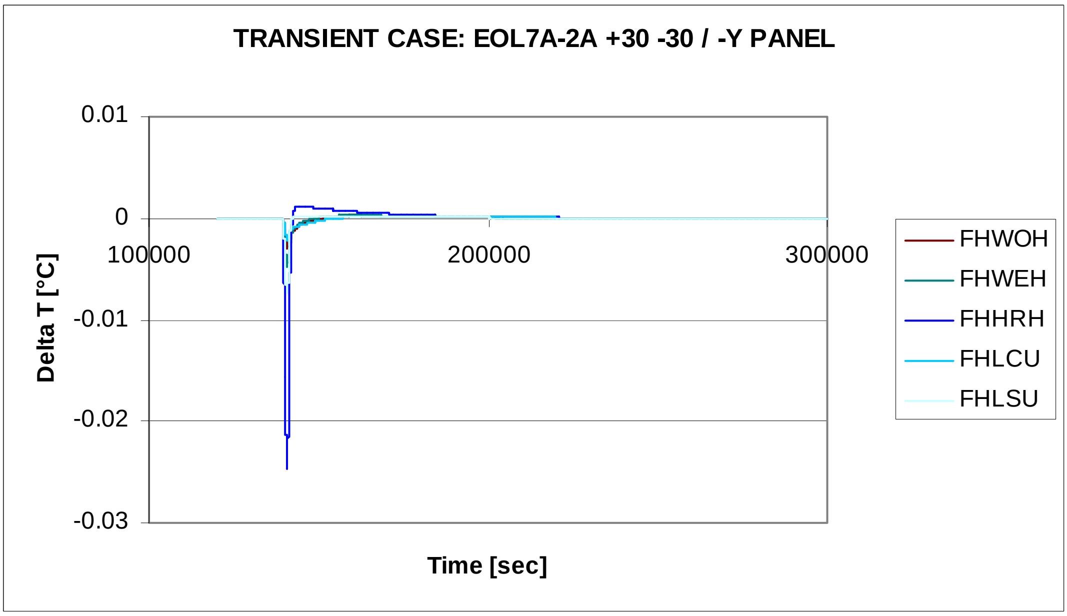


Figure 3.4.3-2 HERSCHEL – HIFI units Transient Case 2: DeltaT on 100s.

3.4.4 Heater Power Summary

The following tables provide the heater power consumption in the various analysed cases.
Data of EOL sizing cases are shown in Table 3.4.4-1
Data of BOL sizing cases are shown in Table 3.4.4-2
Data of BOL Survival cases are shown in Table 3.4.4-3

Table 3.4.4-1 HERSCHEL – Heater Power Consumption in Nominal Hot Case (without uncertainty)

			EOL7B	EOL7B	EOL7B	EOL7A	EOL7A	EOL7A
			Telecom	Telecom	Telecom	Telecom	Telecom	Telecom
			MODE1 HIFI Prime	MODE2 / Photometry PACS Prime	MODE2 / Spectroscopy PACS Prime	MODE1 HIFI Prime	MODE2 / Photometry PACS Prime	MODE2 / Spectroscopy PACS Prime
NODE	LABEL	HTR	[W]	[W]	[W]	[W]	[W]	[W]
HTR106	TWTA1	HTR-MA1	0	0	0	0	0	0
HTR107	TWTA2	HTR-MA2	0	0	0	0	0	0
HTR204	BATT	HTR-MB1	1.24	0.87	0.89	1.1	0.75	0.87
HTR304	FPBOLC	HTR-MC1	0	0	0	0	0	0
HTR401	CRYOE	HTR-MD1	0	0	0	0	0	0
HTR501	FHWOV	HTR-ME1	1.77	1.53	1.53	1.77	1.55	1.46
HTR601	FHWOH	HTR-MF1	5.28	11.59	11.57	5.45	11.63	11.62
HTR602	FHWEH	HTR-MF2	0	0	0	0	0	0
HTR603	FHHRH	HTR-MF3	0	0	0	0	0	0
HTR604	FHLCU	HTR-MF4	0	0	0	0	0	0
HTR605	FHLSU	HTR-MF5	0	9.08	9.05	0	10.03	9.96
HTR701	RWL1	HTR-MG1	0	0	0	0	0	0
HTR703	RWL3	HTR-MG2	0	0	0	0	0	0
HTR950	TANK1	HTR-MH1	0.21	0.19	0.19	0.21	0.19	0.19
HTR960	TANK2	HTR-MH2	0.21	0	0	0.21	0	0
HTR811	STRMY	HTR-MI1	0	0	0	0	0	0
HTR831	STRPY	HTR-MI2	0	0	0	0	0	0
HTR8133	THR1-MAIN	HTR-MH3	0	0	0	0	0	0
HTR8134	THR1-RED	HTR-MH3	0	0	0	0	0	0
HTR8233	THR2-MAIN	HTR-MH4	0.01	0	0.01	0.01	0	0
HTR8234	THR2-RED	HTR-MH4	0.01	0	0.01	0.01	0	0
HTR8333	THR3-MAIN	HTR-MH5	0.01	0	0	0.01	0	0
HTR8334	THR3-RED	HTR-MH5	0.01	0	0	0.01	0	0
HTR8433	THR4-MAIN	HTR-MH6	0.01	0.01	0.01	0.01	0.01	0.01
HTR8434	THR4-RED	HTR-MH6	0.01	0.01	0.01	0.01	0.01	0.01
HTR8533	THR5-MAIN	HTR-MH7	0	0	0	0	0	0
HTR8534	THR5-RED	HTR-MH7	0	0	0	0	0	0
HTR8633	THR6-MAIN	HTR-MH8	0	0	0	0	0	0
HTR8634	THR6-RED	HTR-MH8	0	0	0	0	0	0
	PIPE LINES	HTR-MH9	5.5	5.5	5.5	5.5	5.5	5.5
	PIPE LINES	HTR-MH10	5.5	5.5	5.5	5.5	5.5	5.5
	PIPE LINES	HTR-MH11	5.5	5.5	5.5	5.5	5.5	5.5
	SAS +Z	HTR-MI3	2.5	2.5	2.5	2.5	2.5	2.5
	SAS-Z	HTR-MI4	2.5	2.5	2.5	2.5	2.5	2.5
	Tot. Heater consumption (nominal):		**30.27**	**44.78**	**44.77**	**30.3**	**45.67**	**45.62**

Table 3.4.4-2 HERSCHEL – Heater Power Consumption in Nominal Cold Case (without uncertainty)

			BOL2B	BOL2B
			Scientific	Scientific
			MODE3 SPIRE Prime	MODE1 HIFI Prime
NODE	LABEL	HTR	[W]	[W]
HTR106	TWTA1	HTR-MA1	39.11	38.99
HTR107	TWTA2	HTR-MA2	29.5	29.43
HTR204	BATT	HTR-MB1	40.95	40.79
HTR304	FPBOLC	HTR-MC1	15.09	14.76
HTR401	CRYOE	HTR-MD1	0	0
HTR501	FHWOV	HTR-ME1	8.57	8.45
HTR601	FHWOH	HTR-MF1	18.48	16.28
HTR602	FHWEH	HTR-MF2	5.3	5.17
HTR603	FHHRH	HTR-MF3	0	0
HTR604	FHLCU	HTR-MF4	0	0
HTR605	FHLSU	HTR-MF5	38.41	0
HTR701	RWL1	HTR-MG1	10.79	10.4
HTR703	RWL3	HTR-MG2	11.7	11.15
HTR950	TANK1	HTR-MH1	3.11	3.09
HTR960	TANK2	HTR-MH2	2.96	2.9
HTR811	STRMY	HTR-MI1	0	0
HTR831	STRPY	HTR-MI2	0	0
HTR8133	THR1-MAIN	HTR-MH3	0	0
HTR8134	THR1-RED	HTR-MH3	0	0
HTR8233	THR2-MAIN	HTR-MH4	0	0
HTR8234	THR2-RED	HTR-MH4	0	0
HTR8333	THR3-MAIN	HTR-MH5	0	0
HTR8334	THR3-RED	HTR-MH5	0	0
HTR8433	THR4-MAIN	HTR-MH6	0	0
HTR8434	THR4-RED	HTR-MH6	0	0
HTR8533	THR5-MAIN	HTR-MH7	0	0
HTR8534	THR5-RED	HTR-MH7	0	0
HTR8633	THR6-MAIN	HTR-MH8	0	0
HTR8634	THR6-RED	HTR-MH8	0	0
	PIPE LINES	HTR-MH9	5.5	5.5
	PIPE LINES	HTR-MH10	5.5	5.5
	PIPE LINES	HTR-MH11	5.5	5.5
	SAS +Z	HTR-MI3	2.5	2.5
	SAS-Z	HTR-MI4	2.5	2.5
	Tot. Heater consumption (nominal):		**245.47**	**202.91**

Table 3.4.4-3 HERSCHEL – Heater Power Consumption in Survival mode (without uncertainty)

			BOL2B	EOL2B
			SURVIVAL	SURVIVAL
NODE	LABEL	HTR	[W]	[W]
HTR106	TWTA1	HTR-MA1	18.76	0.34
HTR107	TWTA2	HTR-MA2	48	33.96
HTR202	CDMU	HTR-MB2	18.12	17.06
HTR204	BATT	HTR-MB1	54.9	54.9
HTR303	FPDPU	HTR-MC3	54.65	54.64
HTR304	FPBOLC	HTR-MC2	0.95	0.93
HTR401	CRYOE	HTR-MD2	26.49	25.96
HTR405	HSDPU	HTR-MD3	43.93	43.92
HTR502	FHICU	HTR-ME2	72.39	72.37
HTR503	FHHRV	HTR-ME3	26.95	26.94
HTR601	FHWOH	HTR-MF6	9.89	9.88
HTR602	FHWEH	HTR-MF7	24.34	24.3
HTR603	FHHRH	HTR-MF8	69.27	69.27
HTR605	FHLSU	HTR-MF9	20.8	20.59
HTR701	RWL1	HTR-MG1-MG3	42.81	35.46
HTR703	RWL3	HTR-MG2-MG3	46.09	39.04
HTR950	TANK1	HTR-MH1	3.77	3.74
HTR960	TANK2	HTR-MH2	3.27	3.18
HTR811	STRMY	HTR-MI1	5	5
HTR831	STRPY	HTR-MI2	5	5
HTR8133	THR1-MAIN	HTR-MH3	0.68	0.64
HTR8134	THR1-RED	HTR-MH3	0.68	0.64
HTR8233	THR2-MAIN	HTR-MH4	1.14	1.11
HTR8234	THR2-RED	HTR-MH4	1.14	1.11
HTR8333	THR3-MAIN	HTR-MH5	1.51	1.5
HTR8334	THR3-RED	HTR-MH5	1.51	1.5
HTR8433	THR4-MAIN	HTR-MH6	2	2
HTR8434	THR4-RED	HTR-MH6	2	2
HTR8533	THR5-MAIN	HTR-MH7	1.47	1.46
HTR8534	THR5-RED	HTR-MH7	1.47	1.46
HTR8633	THR6-MAIN	HTR-MH8	1.06	1.05
HTR8634	THR6-RED	HTR-MH8	1.06	1.05
	PIPE LINES	HTR-MH9	11	11
	PIPE LINES	HTR-MH10	11	11
	PIPE LINES	HTR-MH11	11	11
	SAS +Z	HTR-MI3	5	5
	SAS-Z	HTR-MI4	5	5
	Tot. Heater consumption (nominal):		**654.1**	**605.00**

3.4.5 Active Control law heater power impacts

To respect the stability goal in the cases with the HIFI in Prime Mode (MODE1), it is necessary to keep the temperatures of critical units at the maximum value reached in the hot cases or very close to it.
The critical units and the set point are:

FHWOV 501= 12°C
FHWOH 601= 12°C
FHWEH 602 = 21°C
FHHRH 603 = 37°C
FHLCU 604 = 37°C
FHLSU 605 = 32°C

The impacts on heater power (additional heater power demand) in the Hot Case EOL7B MODE1, EOL7A MODE1 and Cold case BOL2B MODE1 are listed in the following Table 3.4.5-1.
The considered cases are those relevant to HIFI in Prime Mode where stability goal is applicable.

Table 3.4.5-1 HERSCHEL – Heater Power Consumption in Survival mode (without uncertainty)

			EOL7B	EOL7A	BOL2B
			Telecom	Telecom	Scientific
			MODE1 HIFI Prime	MODE1 HIFI Prime	MODE1 HIFI Prime
NODE	LABEL	HTR	[W]	[W]	[W]
HTR106	TWTA1	HTR-MA1	0	0	38.61
HTR107	TWTA2	HTR-MA2	0	0	29.17
HTR204	BATT	HTR-MB1	2.26	2.21	40.3
HTR304	FPBOLC	HTR-MC1	0	0	12.27
HTR401	CRYOE	HTR-MD1	0	0	0
HTR501	FHWOV	HTR-ME1	5.45	5.44	11.34
HTR601	FHWOH	HTR-MF1	6.54	6.56	12.43
HTR602	FHWEH	HTR-MF2	7.34	7.42	14.5
HTR603	FHHRH	HTR-MF3	11.92	13.11	29.44
HTR604	FHLCU	HTR-MF4	2.52	2.62	10.14
HTR605	FHLSU	HTR-MF5	9.62	10.01	15.9
HTR701	RWL1	HTR-MG1	0	0	7.09
HTR703	RWL3	HTR-MG2	0	0	7.02
HTR950	TANK1	HTR-MH1	0.42	0.42	2.99
HTR960	TANK2	HTR-MH2	0.42	0.42	2.92
HTR811	STRMY	HTR-MI1	0	0	0
HTR831	STRPY	HTR-MI2	0	0	0
HTR8133	THR1-MAIN	HTR-MH3	0	0	0
HTR8134	THR1-RED	HTR-MH3	0	0	0
HTR8233	THR2-MAIN	HTR-MH4	0.02	0.02	0
HTR8234	THR2-RED	HTR-MH4	0.02	0.02	0
HTR8333	THR3-MAIN	HTR-MH5	0.02	0.02	0
HTR8334	THR3-RED	HTR-MH5	0.02	0.02	0
HTR8433	THR4-MAIN	HTR-MH6	0.02	0.02	0
HTR8434	THR4-RED	HTR-MH6	0.02	0.02	0
HTR8533	THR5-MAIN	HTR-MH7	0	0	0
HTR8534	THR5-RED	HTR-MH7	0	0	0
HTR8633	THR6-MAIN	HTR-MH8	0	0	0
HTR8634	THR6-RED	HTR-MH8	0	0	0
	PIPE LINES	HTR-MH9	5.5	5.5	5.5
	PIPE LINES	HTR-MH10	5.5	5.5	5.5
	PIPE LINES	HTR-MH11	5.5	5.5	5.5
	SAS +Z	HTR-MI3	2.5	2.5	2.5
	SAS-Z	HTR-MI4	2.5	2.5	2.5
	Tot. Heater need:		**68.11**	**69.83**	**255.62**

3.5 HERSCHEL CONCLUSION

Sizing cases Analyses

All the units are maintained within their temperature limits with the exclusion of the following:

COLD CASES

❑ **CDMU:**	case BOL2B	-10.7°C vs -10.0°C
❑ **FHFCU:**	case BOL2B	-10.7°C vs -10.0°C
❑ **FHWEV:**	case BOL2B	-2.8 °C vs -0.0°C
❑ **ACC:**	case BOL2B	-23.0 °C vs -20.0°C

HOT CASES

❑ **FPSPU1/2:**	case EOL7A	45.8°C vs 45.0°C
❑ **FHLCU:**	case EOL7A	41.2°C vs 40.0°C
❑ **GYRO:**	case EOL7A	49.2°C vs 45.0°C
❑ **PDU:**	case EOL7A	48.4°C vs 45.0°C
❑ **STR:**	case EOL7A	45.5°C vs 30.0°C

Remark: In addition, the temperature of the switch unit FH3DV (-23.1°C in cold case BOL2B), is out of specification versus the operative limits (-10°C) but are within respect to the not-operative temperature (-25°C); clarification on the requirement is necessary.
Design will be trimmed based on the above.

COLD CASES RECOVERY ACTIONS:

All the out of specification in the Cold Cases are recoverable with a fine re-design of the MLI/OSR and a re-distribution of the heater already foreseen that will be done as part of normal work, so that they are not considered on issue.

HOT COLD CASES RECOVERY ACTIONS:

FPSPU1/2 & FHLCU: Action on the MLI/OSR trimming is possible to recover this out of spec.
GYRO: Change of position moving from +Z shear panel to one of lateral radiator (excluded +Z lateral panel) or used of different MLI external layer (see para 3.4.2)
PDU: The unit has been recently removed from the SVM with an implementation of an electronic card (and consequently increasing of the power dissipation) inside the ACC; this also leads a benefit for the ACC out of spec. during cold case.
STR: See AD(2.7 para.4.11)

Transient Analyses
The temperature stability requirement (± 3°C) on the warm units (HI-FI and SPIRE) is always met.
Concerning the stability GOAL on HI-FI unit, it is always met only through a use of an active thermal control based on dedicated control laws. The used of this PI alghoritm is based on the concept to maintain always the HI-FI units at the maximum temperature level also in cold cases with a consequent increase of power budget as shown in para 3.4.5 of this documents

4. PLANCK – MODEL DESCRIPTION AND THERMAL ANALYSIS

4.1 PLANCK - PRESENTATION OF THE MODEL

Herschel and Planck are two satellites dedicated to the observation of the universe.

- Planck mission objective is to provide major source of information relevant to several cosmological and astrophysical issues such as the testing theories of the early universe and the origin of cosmic structure.

The spacecraft is planned to operate from Lissajous orbits around the Langragian point L2 of the Sun / Earth system. This point is aligned with the Earth and the Sun and located at 1.5 10^6 Km from the Earth.

Both satellites are planned to be launched by ARIANE 5 dual launch.

The main modules are:

- The Service Module (SVM)
- The Payload Module (PLM), carrying the scientific instruments and telescopes and relevant electronic units
- The Sunshields, protecting the Payload or the S/C and used also as Solar Arrays.

4.1.1 Geometric Mathematical Model (GMM)

The Geometric models detail all the satellite surfaces and their thermo-optical properties, in order to evaluate the radiative exchange factors among nodes and, only for the external nodes, the fluxes (solar, albedo and Earth shine) on spacecraft surfaces during the orbit. Due to the huge distance of the PLANCK orbit from the Earth, only solar fluxes have been considerate in the thermal analysis.

The Geometric Mathematical Model (GMM) of PLANCK satellite has been built using Esarad (ver. 4.3) software and it is composed by two models, the first describe the external environment comprensive of some components of the Payload Module in order to evaluate the radiative impact on the PLANCK Service Module.
The second one describe the internal enclosures of the spacecraft.

The thermo-optical properties of the material used in theGMM/TMM are listed in Table 4.1.1-1. and Table 4.1.1-2
The geometrical nodes of PLANCK Service Module and Groove Shield and the thermal properties of each node are reported in Table 4.1.1-3.

The only thermal property assumed to change during the satellite life is the solar absorptivity of the OSR (Alenia experience) and of the MLI closure between the SVM and PLM (input data from AD-2.6).
In addition to the previous list, the nodal breakdown of the Geometric Model, both internal and external nodes, is shown on Fig 4.1.1-1 to Fig. 4.1.1-10.

SURFACES	MATERIALS	Alpha	Alpha	Epsilon	Ref.
		BOL	EOL		
External model					
Radiators	Black Paint (Electrodag)	0.95	=	0.80	Alenia test data
Top/Bottom MLI	VDA Kapton	0.15	=	0.05	Supplier data sheet
External lateral panels MLI	Carbon Filled Kapton	0.92	=	0.86	Supplier data sheet
Solar Array External		-	-	-	See Figure 4.1.1-1
Solar Array Central		-	-	-	See Figure 4.1.1-1
External STR Baffle	Black Anodization	0.86	=	0.86	Assumption based on Alenia test data
External Launcher Adaptor Ring	Chromic Acid Anodization	0.5	=	0.5	Test data derived from Integral program

Table 4.1.1-1 PLANCK – Service Module External Thermo-optical properties

SURFACES	MATERIALS	Alpha	Alpha	Epsilon	Ref.
		BOL	EOL		
Internal model					
CFRP internal surfaces (cone)	CFRP	0.9	=	0.9	Assumption (TBC)
High emissivity Aluminum int. surf. (panels & units)	Black Paint	0.9	=	0.9	Alenia test data (worst case)
Internal MLI (tanks, SCC and SCE panels, central SA (back side) ,	VDA Kapton (Aluminized side)	0.15	=	0.05	Supplier data sheet
Internal Launcher Adaptor Ring	Alumnium tape	0.15	=	0.05	Supplier data sheet

Table 4.1.1-2 PLANCK – Service Module Internal Thermo-optical properties

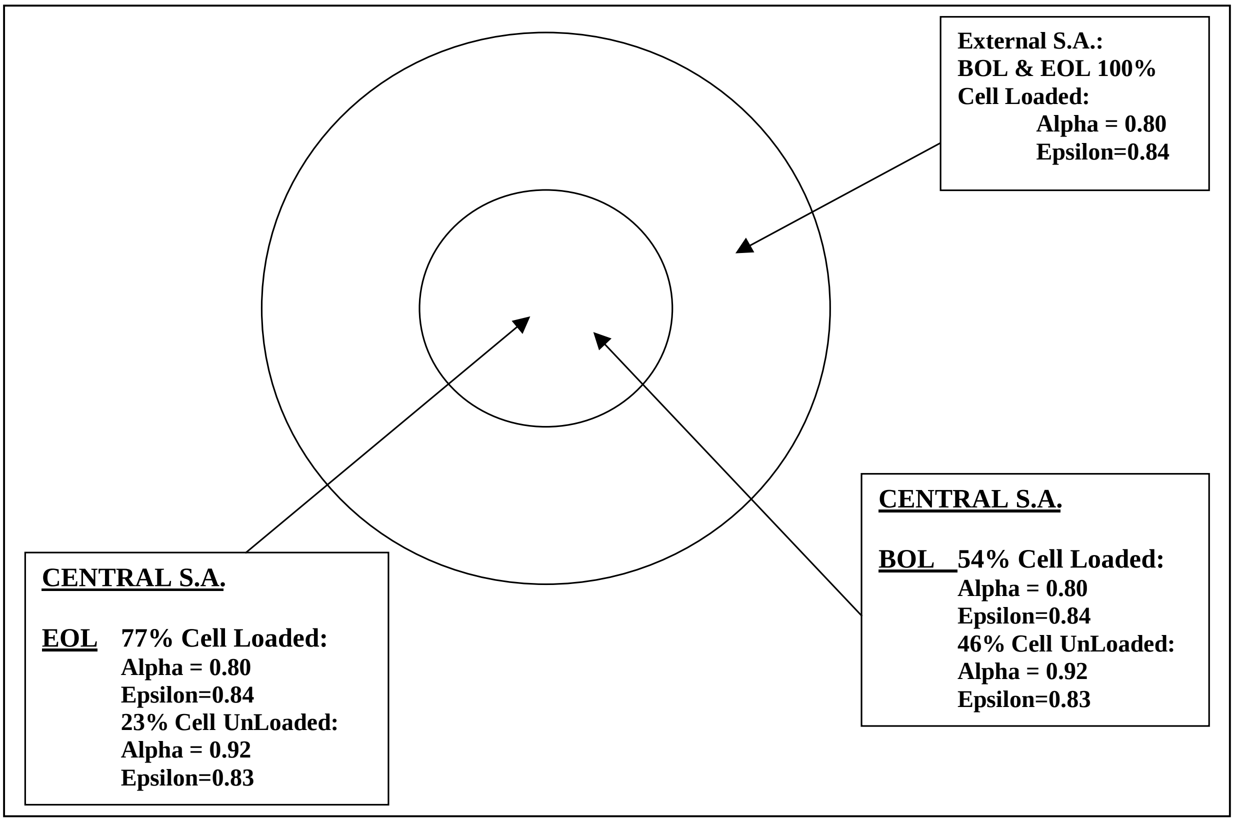


Figure 4.1.1 -1 PLANCK – Solar Array Thermo-optical roperties

Table 4.1.1-3 PLANCK – Service Module Geometrical Nodes List

NODE	DESCRIPTION	MATERIALS	Alpha		Epsilon
			BOL	EOL	
11	STR1	Black Paint	0.9	=	0.9
12	STR2	Black Paint	0.9	=	0.9
13	DPU1	Black Paint	0.9	=	0.9
14	DPU2	Black Paint	0.9	=	0.9
15	REU	Black Paint	0.9	=	0.9
101	DCCU	Black Paint	0.9	=	0.9
102	REBA1	Black Paint	0.9	=	0.9
103	REBA2	Black Paint	0.9	=	0.9
201	4 CCU	Black Paint	0.9	=	0.9
202	4 CAU	Black Paint	0.9	=	0.9
203	4 PRE-REG	Black Paint	0.9	=	0.9
204	CEU	Black Paint	0.9	=	0.9
401	SCE1	Black Paint	0.9	=	0.9
402	SCE2	Black Paint	0.9	=	0.9
521	BEU	Black Paint	0.9	=	0.9
522	PAU	Black Paint	0.9	=	0.9
525	DAE POWER BOX	Black Paint	0.9	=	0.9
551	QRS3	Black Paint	0.9	=	0.9
601	XPND_1	Black Paint	0.9	=	0.9
602	XPND_2	Black Paint	0.9	=	0.9
603	TWTA_1	Black Paint	0.9	=	0.9
604	TWTA_2	Black Paint	0.9	=	0.9
605	RFDN	Black Paint	0.9	=	0.9
606	EPC1	Black Paint	0.9	=	0.9
607	EPC2	Black Paint	0.9	=	0.9
701	CDMU	Black Paint	0.9	=	0.9
702	ACC	Black Paint	0.9	=	0.9
703	BATT	Black Paint	0.9	=	0.9
704	PCDU	Black Paint	0.9	=	0.9
705	QRS1	Black Paint	0.9	=	0.9
706	QRS2	Black Paint	0.9	=	0.9
707	PDU	Black Paint	0.9	=	0.9
1001	MLI SVM Bot +Z	Kapton Aluminized	0.15	=	0.5
1002	MLI SVM Bot +Z+Y	Kapton Aluminized	0.15	=	0.5
1003	MLI SVM Bot +Y	Kapton Aluminized	0.15	=	0.5
1004	MLI SVM Bot -Z-Y	Kapton Aluminized	0.15	=	0.5
1005	MLI SVM Bot -Z	Kapton Aluminized	0.15	=	0.5
1006	MLI SVM Bot -Z-Y	Kapton Aluminized	0.15	=	0.5
1007	MLI SVM Bot -Y	Kapton Aluminized	0.15	=	0.5
1008	MLI SVM Bot +Z-Y	Kapton Aluminized	0.15	=	0.5
1601	SVM Bot +Z	Black Paint	0.9	=	0.9
1602	SVM Bot +Z+Y	Black Paint	0.9	=	0.9
1603	SVM Bot +Y	Black Paint	0.9	=	0.9
1604	SVM Bot -Z-Y	Black Paint	0.9	=	0.9
1605	SVM Bot -Z	Black Paint	0.9	=	0.9

1606	SVM Bot -Z-Y	Black Paint	0.9	=	0.9
1607	SVM Bot -Y	Black Paint	0.9	=	0.9
1608	SVM Bot +Z-Y	Black Paint	0.9	=	0.9
1611	SVM Bot +Z	Black Paint	0.9	=	0.9
2001	Launcher Adapter Ring	Cromic Acid Anodization	0.5	=	0.5
2002	Launcher Adapter Ring	Cromic Acid Anodization	0.5	=	0.5
2003	Launcher Adapter Ring	Cromic Acid Anodization	0.5	=	0.5
2004	Launcher Adapter Ring	Cromic Acid Anodization	0.5	=	0.5
2005	Launcher Adapter Ring	Cromic Acid Anodization	0.5	=	0.5
2006	Launcher Adapter Ring	Cromic Acid Anodization	0.5	=	0.5
2007	Launcher Adapter Ring	Cromic Acid Anodization	0.5	=	0.5
2008	Launcher Adapter Ring	Cromic Acid Anodization	0.5	=	0.5
2011	Launcher Adapter Edge	Cromic Acid Anodization	0.5	=	0.5
2012	Launcher Adapter Edge	Cromic Acid Anodization	0.5	=	0.5
2013	Launcher Adapter Edge	Cromic Acid Anodization	0.5	=	0.5
2014	Launcher Adapter Edge	Cromic Acid Anodization	0.5	=	0.5
2015	Launcher Adapter Edge	Cromic Acid Anodization	0.5	=	0.5
2016	Launcher Adapter Edge	Cromic Acid Anodization	0.5	=	0.5
2017	Launcher Adapter Edge	Cromic Acid Anodization	0.5	=	0.5
2018	Launcher Adapter Edge	Cromic Acid Anodization	0.5	=	0.5
2021	Launcher Adapter Ring	Cromic Acid Anodization	0.5	=	0.5
2022	Launcher Adapter Ring	Cromic Acid Anodization	0.5	=	0.5
2023	Launcher Adapter Ring	Cromic Acid Anodization	0.5	=	0.5
2024	Launcher Adapter Ring	Cromic Acid Anodization	0.5	=	0.5
2025	Launcher Adapter Ring	Cromic Acid Anodization	0.5	=	0.5
2026	Launcher Adapter Ring	Cromic Acid Anodization	0.5	=	0.5
2027	Launcher Adapter Ring	Cromic Acid Anodization	0.5	=	0.5
2028	Launcher Adapter Ring	Cromic Acid Anodization	0.5	=	0.5
2101	Launcher Adapter Ring	Alumnium Tape	0.15	=	0.05
2102	Launcher Adapter Ring	Alumnium Tape	0.15	=	0.05
2103	Launcher Adapter Ring	Alumnium Tape	0.15	=	0.05
2104	Launcher Adapter Ring	Alumnium Tape	0.15	=	0.05
2105	Launcher Adapter Ring	Alumnium Tape	0.15	=	0.05
2106	Launcher Adapter Ring	Alumnium Tape	0.15	=	0.05
2107	Launcher Adapter Ring	Alumnium Tape	0.15	=	0.05
2108	Launcher Adapter Ring	Alumnium Tape	0.15	=	0.05
2111	Launcher Adapter Edge	Alumnium Tape	0.15	=	0.05
2112	Launcher Adapter Edge	Alumnium Tape	0.15	=	0.05
2113	Launcher Adapter Edge	Alumnium Tape	0.15	=	0.05
2114	Launcher Adapter Edge	Alumnium Tape	0.15	=	0.05
2115	Launcher Adapter Edge	Alumnium Tape	0.15	=	0.05
2116	Launcher Adapter Edge	Alumnium Tape	0.15	=	0.05
2117	Launcher Adapter Edge	Alumnium Tape	0.15	=	0.05
2118	Launcher Adapter Edge	Alumnium Tape	0.15	=	0.05
2121	Launcher Adapter Ring	Alumnium Tape	0.15	=	0.05
2122	Launcher Adapter Ring	Alumnium Tape	0.15	=	0.05
2123	Launcher Adapter Ring	Alumnium Tape	0.15	=	0.05
2124	Launcher Adapter Ring	Alumnium Tape	0.15	=	0.05
2125	Launcher Adapter Ring	Alumnium Tape	0.15	=	0.05

2126	Launcher Adapter Ring	Alumnium Tape	0.15	=	0.05
2127	Launcher Adapter Ring	Alumnium Tape	0.15	=	0.05
2128	Launcher Adapter Ring	Alumnium Tape	0.15	=	0.05
2251	MLI Launcher Adapter Ring	Kapton Aluminized	0.15	=	0.05
2252	MLI Launcher Adapter Ring	Kapton Aluminized	0.15	=	0.05
2253	MLI Launcher Adapter Ring	Kapton Aluminized	0.15	=	0.05
2254	MLI Launcher Adapter Ring	Kapton Aluminized	0.15	=	0.05
2255	MLI Launcher Adapter Ring	Kapton Aluminized	0.15	=	0.05
2256	MLI Launcher Adapter Ring	Kapton Aluminized	0.15	=	0.05
2257	MLI Launcher Adapter Ring	Kapton Aluminized	0.15	=	0.05
2258	MLI Launcher Adapter Ring	Kapton Aluminized	0.15	=	0.05
2501	SVM Cone +Z+Y	CFRP	0.9	=	0.9
2502	SVM Cone +Y	CFRP	0.9	=	0.9
2503	SVM Cone +Y-Z	CFRP	0.9	=	0.9
2504	SVM Cone -Z	CFRP	0.9	=	0.9
2505	SVM Cone -Z-Y	CFRP	0.9	=	0.9
2506	SVM Cone -Y	CFRP	0.9	=	0.9
2507	SVM Cone -Z+Y	CFRP	0.9	=	0.9
2508	SVM Cone +Z	CFRP	0.9	=	0.9
2511	SVM Cone +Z+Y	CFRP	0.9	=	0.9
2512	SVM Cone +Y	CFRP	0.9	=	0.9
2513	SVM Cone +Y-Z	CFRP	0.9	=	0.9
2514	SVM Cone -Z	CFRP	0.9	=	0.9
2515	SVM Cone -Z-Y	CFRP	0.9	=	0.9
2516	SVM Cone -Y	CFRP	0.9	=	0.9
2517	SVM Cone -Z+Y	CFRP	0.9	=	0.9
2518	SVM Cone +Z	CFRP	0.9	=	0.9
2521	SVM Cone +Z+Y	CFRP	0.9	=	0.9
2522	SVM Cone +Y	CFRP	0.9	=	0.9
2523	SVM Cone +Y-Z	CFRP	0.9	=	0.9
2524	SVM Cone -Z	CFRP	0.9	=	0.9
2525	SVM Cone -Z-Y	CFRP	0.9	=	0.9
2526	SVM Cone -Y	CFRP	0.9	=	0.9
2527	SVM Cone -Z+Y	CFRP	0.9	=	0.9
2528	SVM Cone +Z	CFRP	0.9	=	0.9
2531	SVM Cone +Z+Y	CFRP	0.9	=	0.9
2532	SVM Cone +Y	CFRP	0.9	=	0.9
2533	SVM Cone +Y-Z	CFRP	0.9	=	0.9
2534	SVM Cone -Z	CFRP	0.9	=	0.9
2535	SVM Cone -Z-Y	CFRP	0.9	=	0.9
2536	SVM Cone -Y	CFRP	0.9	=	0.9
2537	SVM Cone -Z+Y	CFRP	0.9	=	0.9
2538	SVM Cone +Z	CFRP	0.9	=	0.9
2541	SVM Cone +Z+Y	CFRP	0.9	=	0.9
2542	SVM Cone +Y	CFRP	0.9	=	0.9
2543	SVM Cone +Y-Z	CFRP	0.9	=	0.9
2544	SVM Cone -Z	CFRP	0.9	=	0.9
2545	SVM Cone -Z-Y	CFRP	0.9	=	0.9
2546	SVM Cone -Y	CFRP	0.9	=	0.9

2547	SVM Cone -Z+Y	CFRP	0.9	=	0.9
2548	SVM Cone +Z	CFRP	0.9	=	0.9
2601	SVM Cone +Z+Y	CFRP	0.9	=	0.9
2602	SVM Cone +Y	CFRP	0.9	=	0.9
2603	SVM Cone +Y-Z	CFRP	0.9	=	0.9
2604	SVM Cone -Z	CFRP	0.9	=	0.9
2605	SVM Cone -Z-Y	CFRP	0.9	=	0.9
2606	SVM Cone -Y	CFRP	0.9	=	0.9
2607	SVM Cone -Z+Y	CFRP	0.9	=	0.9
2608	SVM Cone +Z	CFRP	0.9	=	0.9
2611	SVM Cone +Z+Y	CFRP	0.9	=	0.9
2612	SVM Cone +Y	CFRP	0.9	=	0.9
2613	SVM Cone +Y-Z	CFRP	0.9	=	0.9
2614	SVM Cone -Z	CFRP	0.9	=	0.9
2615	SVM Cone -Z-Y	CFRP	0.9	=	0.9
2616	SVM Cone -Y	CFRP	0.9	=	0.9
2617	SVM Cone -Z+Y	CFRP	0.9	=	0.9
2618	SVM Cone +Z	CFRP	0.9	=	0.9
2621	SVM Cone +Z+Y	CFRP	0.9	=	0.9
2622	SVM Cone +Y	CFRP	0.9	=	0.9
2623	SVM Cone +Y-Z	CFRP	0.9	=	0.9
2624	SVM Cone -Z	CFRP	0.9	=	0.9
2625	SVM Cone -Z-Y	CFRP	0.9	=	0.9
2626	SVM Cone -Y	CFRP	0.9	=	0.9
2627	SVM Cone -Z+Y	CFRP	0.9	=	0.9
2628	SVM Cone +Z	CFRP	0.9	=	0.9
2631	SVM Cone +Z+Y	CFRP	0.9	=	0.9
2632	SVM Cone +Y	CFRP	0.9	=	0.9
2633	SVM Cone +Y-Z	CFRP	0.9	=	0.9
2634	SVM Cone -Z	CFRP	0.9	=	0.9
2635	SVM Cone -Z-Y	CFRP	0.9	=	0.9
2636	SVM Cone -Y	CFRP	0.9	=	0.9
2637	SVM Cone -Z+Y	CFRP	0.9	=	0.9
2638	SVM Cone +Z	CFRP	0.9	=	0.9
2641	SVM Cone +Z+Y	CFRP	0.9	=	0.9
2642	SVM Cone +Y	CFRP	0.9	=	0.9
2643	SVM Cone +Y-Z	CFRP	0.9	=	0.9
2644	SVM Cone -Z	CFRP	0.9	=	0.9
2645	SVM Cone -Z-Y	CFRP	0.9	=	0.9
2646	SVM Cone -Y	CFRP	0.9	=	0.9
2647	SVM Cone -Z+Y	CFRP	0.9	=	0.9
2648	SVM Cone +Z	CFRP	0.9	=	0.9
3001-48	Rad +Z	Black Paint (Electrodag)	0.95	=	0.8
3101-72	Rad +Y+Z	Black Paint (Electrodag)	0.95	=	0.8
3201-48	Rad +Y	Black Paint (Electrodag)	0.95	=	0.8
3301-48	Rad +Y-Z	Black Paint (Electrodag)	0.95	=	0.8
3401-54	Rad -Z	Black Paint (Electrodag)	0.95	=	0.8
3501-48	Rad -Y-Z	Black Paint (Electrodag)	0.95	=	0.8
3601-48	Rad -Y	Black Paint (Electrodag)	0.95	=	0.8

3701-72	Rad -Y+Z	Black Paint (Electrodag)	0.95	=	0.8
3901	INT. BAFFLE STR1	Black Anodization	0.86	=	0.86
3902	INT. BAFFLE STR2	Black Anodization	0.86	=	0.86
4001	MLI Rad +Z	Carbon Filled	0.92	=	0.86
4002	MLI Rad +Z	Carbon Filled	0.92	=	0.86
4003	MLI Rad +Z	Carbon Filled	0.92	=	0.86
4004	MLI Rad +Z	Carbon Filled	0.92	=	0.86
4005	MLI Rad +Z	Carbon Filled	0.92	=	0.86
4006	MLI Rad +Z	Carbon Filled	0.92	=	0.86
4007	MLI Rad +Z	Carbon Filled	0.92	=	0.86
4008	MLI Rad +Z	Carbon Filled	0.92	=	0.86
4011	MLI Rad +Z	Carbon Filled	0.92	=	0.86
4012	MLI Rad +Z	Carbon Filled	0.92	=	0.86
4019	MLI Rad +Z	Carbon Filled	0.92	=	0.86
4020	MLI Rad +Z	Carbon Filled	0.92	=	0.86
4027	MLI Rad +Z	Carbon Filled	0.92	=	0.86
4028	MLI Rad +Z	Carbon Filled	0.92	=	0.86
4101	MLI Rad +Y+Z	Carbon Filled	0.92	=	0.86
4102	MLI Rad +Y+Z	Carbon Filled	0.92	=	0.86
4103	MLI Rad +Y+Z	Carbon Filled	0.92	=	0.86
4104	MLI Rad +Y+Z	Carbon Filled	0.92	=	0.86
4105	MLI Rad +Y+Z	Carbon Filled	0.92	=	0.86
4106	MLI Rad +Y+Z	Carbon Filled	0.92	=	0.86
4107	MLI Rad +Y+Z	Carbon Filled	0.92	=	0.86
4108	MLI Rad +Y+Z	Carbon Filled	0.92	=	0.86
4109	MLI Rad +Y+Z	Carbon Filled	0.92	=	0.86
4110	MLI Rad +Y+Z	Carbon Filled	0.92	=	0.86
4111	MLI Rad +Y+Z	Carbon Filled	0.92	=	0.86
4112	MLI Rad +Y+Z	Carbon Filled	0.92	=	0.86
4113	MLI Rad +Y+Z	Carbon Filled	0.92	=	0.86
4114	MLI Rad +Y+Z	Carbon Filled	0.92	=	0.86
4115	MLI Rad +Y+Z	Carbon Filled	0.92	=	0.86
4116	MLI Rad +Y+Z	Carbon Filled	0.92	=	0.86
4117	MLI Rad +Y+Z	Carbon Filled	0.92	=	0.86
4118	MLI Rad +Y+Z	Carbon Filled	0.92	=	0.86
4119	MLI Rad +Y+Z	Carbon Filled	0.92	=	0.86
4120	MLI Rad +Y+Z	Carbon Filled	0.92	=	0.86
4121	MLI Rad +Y+Z	Carbon Filled	0.92	=	0.86
4122	MLI Rad +Y+Z	Carbon Filled	0.92	=	0.86
4123	MLI Rad +Y+Z	Carbon Filled	0.92	=	0.86
4124	MLI Rad +Y+Z	Carbon Filled	0.92	=	0.86
4125	MLI Rad +Y+Z	Carbon Filled	0.92	=	0.86
4126	MLI Rad +Y+Z	Carbon Filled	0.92	=	0.86
4127	MLI Rad +Y+Z	Carbon Filled	0.92	=	0.86
4128	MLI Rad +Y+Z	Carbon Filled	0.92	=	0.86
4129	MLI Rad +Y+Z	Carbon Filled	0.92	=	0.86
4130	MLI Rad +Y+Z	Carbon Filled	0.92	=	0.86
4135	MLI Rad +Y+Z	Carbon Filled	0.92	=	0.86
4136	MLI Rad +Y+Z	Carbon Filled	0.92	=	0.86

4137	MLI Rad +Y+Z	Carbon Filled	0.92	=	0.86
4138	MLI Rad +Y+Z	Carbon Filled	0.92	=	0.86
4139	MLI Rad +Y+Z	Carbon Filled	0.92	=	0.86
4140	MLI Rad +Y+Z	Carbon Filled	0.92	=	0.86
4141	MLI Rad +Y+Z	Carbon Filled	0.92	=	0.86
4142	MLI Rad +Y+Z	Carbon Filled	0.92	=	0.86
4147	MLI Rad +Y+Z	Carbon Filled	0.92	=	0.86
4148	MLI Rad +Y+Z	Carbon Filled	0.92	=	0.86
4149	MLI Rad +Y+Z	Carbon Filled	0.92	=	0.86
4150	MLI Rad +Y+Z	Carbon Filled	0.92	=	0.86
4151	MLI Rad +Y+Z	Carbon Filled	0.92	=	0.86
4152	MLI Rad +Y+Z	Carbon Filled	0.92	=	0.86
4153	MLI Rad +Y+Z	Carbon Filled	0.92	=	0.86
4154	MLI Rad +Y+Z	Carbon Filled	0.92	=	0.86
4155	MLI Rad +Y+Z	Carbon Filled	0.92	=	0.86
4156	MLI Rad +Y+Z	Carbon Filled	0.92	=	0.86
4159	MLI Rad +Y+Z	Carbon Filled	0.92	=	0.86
4160	MLI Rad +Y+Z	Carbon Filled	0.92	=	0.86
4161	MLI Rad +Y+Z	Carbon Filled	0.92	=	0.86
4162	MLI Rad +Y+Z	Carbon Filled	0.92	=	0.86
4163	MLI Rad +Y+Z	Carbon Filled	0.92	=	0.86
4164	MLI Rad +Y+Z	Carbon Filled	0.92	=	0.86
4165	MLI Rad +Y+Z	Carbon Filled	0.92	=	0.86
4166	MLI Rad +Y+Z	Carbon Filled	0.92	=	0.86
4167	MLI Rad +Y+Z	Carbon Filled	0.92	=	0.86
4168	MLI Rad +Y+Z	Carbon Filled	0.92	=	0.86
4169	MLI Rad +Y+Z	Carbon Filled	0.92	=	0.86
4170	MLI Rad +Y+Z	Carbon Filled	0.92	=	0.86
4171	MLI Rad +Y+Z	Carbon Filled	0.92	=	0.86
4172	MLI Rad +Y+Z	Carbon Filled	0.92	=	0.86
4239	MLI Rad +Y	Carbon Filled	0.92	=	0.86
4240	MLI Rad +Y	Carbon Filled	0.92	=	0.86
4241	MLI Rad +Y	Carbon Filled	0.92	=	0.86
4242	MLI Rad +Y	Carbon Filled	0.92	=	0.86
4243	MLI Rad +Y	Carbon Filled	0.92	=	0.86
4244	MLI Rad +Y	Carbon Filled	0.92	=	0.86
4245	MLI Rad +Y	Carbon Filled	0.92	=	0.86
4246	MLI Rad +Y	Carbon Filled	0.92	=	0.86
4247	MLI Rad +Y	Carbon Filled	0.92	=	0.86
4248	MLI Rad +Y	Carbon Filled	0.92	=	0.86
4601	MLI Rad -Y	Carbon Filled	0.92	=	0.86
4602	MLI Rad -Y	Carbon Filled	0.92	=	0.86
4609	MLI Rad -Y	Carbon Filled	0.92	=	0.86
4610	MLI Rad -Y	Carbon Filled	0.92	=	0.86
4611	MLI Rad -Y	Carbon Filled	0.92	=	0.86
4612	MLI Rad -Y	Carbon Filled	0.92	=	0.86
4617	MLI Rad -Y	Carbon Filled	0.92	=	0.86
4618	MLI Rad -Y	Carbon Filled	0.92	=	0.86
4619	MLI Rad -Y	Carbon Filled	0.92	=	0.86

4620	MLI Rad -Y	Carbon Filled	0.92	=	0.86
4621	MLI Rad -Y	Carbon Filled	0.92	=	0.86
4622	MLI Rad -Y	Carbon Filled	0.92	=	0.86
4623	MLI Rad -Y	Carbon Filled	0.92	=	0.86
4624	MLI Rad -Y	Carbon Filled	0.92	=	0.86
4625	MLI Rad -Y	Carbon Filled	0.92	=	0.86
4626	MLI Rad -Y	Carbon Filled	0.92	=	0.86
4627	MLI Rad -Y	Carbon Filled	0.92	=	0.86
4628	MLI Rad -Y	Carbon Filled	0.92	=	0.86
4629	MLI Rad -Y	Carbon Filled	0.92	=	0.86
4630	MLI Rad -Y	Carbon Filled	0.92	=	0.86
4631	MLI Rad -Y	Carbon Filled	0.92	=	0.86
4632	MLI Rad -Y	Carbon Filled	0.92	=	0.86
4633	MLI Rad -Y	Carbon Filled	0.92	=	0.86
4634	MLI Rad -Y	Carbon Filled	0.92	=	0.86
4635	MLI Rad -Y	Carbon Filled	0.92	=	0.86
4636	MLI Rad -Y	Carbon Filled	0.92	=	0.86
4641	MLI Rad -Y	Carbon Filled	0.92	=	0.86
4642	MLI Rad -Y	Carbon Filled	0.92	=	0.86
4709	MLI Rad +Y+Z	Carbon Filled	0.92	=	0.86
4710	MLI Rad +Y+Z	Carbon Filled	0.92	=	0.86
4711	MLI Rad +Y+Z	Carbon Filled	0.92	=	0.86
4712	MLI Rad +Y+Z	Carbon Filled	0.92	=	0.86
4721	MLI Rad +Y+Z	Carbon Filled	0.92	=	0.86
4722	MLI Rad +Y+Z	Carbon Filled	0.92	=	0.86
4723	MLI Rad +Y+Z	Carbon Filled	0.92	=	0.86
4724	MLI Rad +Y+Z	Carbon Filled	0.92	=	0.86
4733	MLI Rad +Y+Z	Carbon Filled	0.92	=	0.86
4734	MLI Rad +Y+Z	Carbon Filled	0.92	=	0.86
4735	MLI Rad +Y+Z	Carbon Filled	0.92	=	0.86
4736	MLI Rad +Y+Z	Carbon Filled	0.92	=	0.86
4747	MLI Rad +Y+Z	Carbon Filled	0.92	=	0.86
4748	MLI Rad +Y+Z	Carbon Filled	0.92	=	0.86
4762	MLI Rad +Y+Z	Carbon Filled	0.92	=	0.86
4771	MLI Rad +Y+Z	Carbon Filled	0.92	=	0.86
4901	MLI BAFFLE STR1	Carbon Filled	0.92	=	0.86
4902	MLI BAFFLE STR2	Carbon Filled	0.92	=	0.86
4921	MLI SAS1	Carbon Filled	0.92	=	0.86
4922	MLI LGA2	Carbon Filled	0.92	=	0.86
4961	MLI SREM	Carbon Filled	0.92	=	0.86
4962	MLI LGA3	Carbon Filled	0.92	=	0.86
4963	MLI VMC	Carbon Filled	0.92	=	0.86
4970	MLI SAS2	Carbon Filled	0.92	=	0.86
4971	MLI AAD	Carbon Filled	0.92	=	0.86
5051	Shear Web1 +Z-Y	CFRP	0.9	=	0.9
5052	Shear Web1 +Z-Y	CFRP	0.9	=	0.9
5053	Shear Web1 +Z-Y	CFRP	0.9	=	0.9
5054	Shear Web1 +Z-Y	CFRP	0.9	=	0.9
5055	Shear Web1 +Z-Y	CFRP	0.9	=	0.9

5061	Shear Web1 +Z-Y	CFRP	0.9	=	0.9
5062	Shear Web1 +Z-Y	CFRP	0.9	=	0.9
5063	Shear Web1 +Z-Y	CFRP	0.9	=	0.9
5064	Shear Web1 +Z-Y	CFRP	0.9	=	0.9
5065	Shear Web1 +Z-Y	CFRP	0.9	=	0.9
5071	Shear Web2 +Z-Y	CFRP	0.9	=	0.9
5072	Shear Web2 +Z-Y	CFRP	0.9	=	0.9
5073	Shear Web2 +Z-Y	CFRP	0.9	=	0.9
5074	Shear Web2 +Z-Y	CFRP	0.9	=	0.9
5075	Shear Web2 +Z-Y	CFRP	0.9	=	0.9
5081	Shear Web2 +Z-Y	CFRP	0.9	=	0.9
5082	Shear Web2 +Z-Y	CFRP	0.9	=	0.9
5083	Shear Web2 +Z-Y	CFRP	0.9	=	0.9
5084	Shear Web2 +Z-Y	CFRP	0.9	=	0.9
5085	Shear Web2 +Z-Y	CFRP	0.9	=	0.9
5151	Shear Web3 +Z+Y	CFRP	0.9	=	0.9
5152	Shear Web3 +Z+Y	CFRP	0.9	=	0.9
5153	Shear Web3 +Z+Y	CFRP	0.9	=	0.9
5154	Shear Web3 +Z+Y	CFRP	0.9	=	0.9
5155	Shear Web3 +Z+Y	CFRP	0.9	=	0.9
5161	Shear Web3 +Z+Y	CFRP	0.9	=	0.9
5162	Shear Web3 +Z+Y	CFRP	0.9	=	0.9
5163	Shear Web3 +Z+Y	CFRP	0.9	=	0.9
5164	Shear Web3 +Z+Y	CFRP	0.9	=	0.9
5165	Shear Web3 +Z+Y	CFRP	0.9	=	0.9
5171	Shear Web4 +Z+Y	CFRP	0.9	=	0.9
5172	Shear Web4 +Z+Y	CFRP	0.9	=	0.9
5173	Shear Web4 +Z+Y	CFRP	0.9	=	0.9
5174	Shear Web4 +Z+Y	CFRP	0.9	=	0.9
5175	Shear Web4 +Z+Y	CFRP	0.9	=	0.9
5181	Shear Web4 +Z+Y	CFRP	0.9	=	0.9
5182	Shear Web4 +Z+Y	CFRP	0.9	=	0.9
5183	Shear Web4 +Z+Y	CFRP	0.9	=	0.9
5184	Shear Web4 +Z+Y	CFRP	0.9	=	0.9
5185	Shear Web4 +Z+Y	CFRP	0.9	=	0.9
5251	Shear Web5 -Z+Y	CFRP	0.9	=	0.9
5252	Shear Web5 -Z+Y	CFRP	0.9	=	0.9
5253	Shear Web5 -Z+Y	CFRP	0.9	=	0.9
5254	Shear Web5 -Z+Y	CFRP	0.9	=	0.9
5255	Shear Web5 -Z+Y	CFRP	0.9	=	0.9
5261	Shear Web5 -Z+Y	CFRP	0.9	=	0.9
5262	Shear Web5 -Z+Y	CFRP	0.9	=	0.9
5263	Shear Web5 -Z+Y	CFRP	0.9	=	0.9
5264	Shear Web5 -Z+Y	CFRP	0.9	=	0.9
5265	Shear Web5 -Z+Y	CFRP	0.9	=	0.9
5271	Shear Web6 -Z+Y	CFRP	0.9	=	0.9
5272	Shear Web6 -Z+Y	CFRP	0.9	=	0.9
5273	Shear Web6 -Z+Y	CFRP	0.9	=	0.9
5274	Shear Web6 -Z+Y	CFRP	0.9	=	0.9

5275	Shear Web6 -Z+Y	CFRP	0.9	=	0.9
5281	Shear Web6 -Z+Y	CFRP	0.9	=	0.9
5282	Shear Web6 -Z+Y	CFRP	0.9	=	0.9
5283	Shear Web6 -Z+Y	CFRP	0.9	=	0.9
5284	Shear Web6 -Z+Y	CFRP	0.9	=	0.9
5285	Shear Web6 -Z+Y	CFRP	0.9	=	0.9
5351	Shear Web7 -Z-Y	CFRP	0.9	=	0.9
5352	Shear Web7 -Z-Y	CFRP	0.9	=	0.9
5353	Shear Web7 -Z-Y	CFRP	0.9	=	0.9
5354	Shear Web7 -Z-Y	CFRP	0.9	=	0.9
5355	Shear Web7 -Z-Y	CFRP	0.9	=	0.9
5361	Shear Web7 -Z-Y	CFRP	0.9	=	0.9
5362	Shear Web7 -Z-Y	CFRP	0.9	=	0.9
5363	Shear Web7 -Z-Y	CFRP	0.9	=	0.9
5364	Shear Web7 -Z-Y	CFRP	0.9	=	0.9
5365	Shear Web7 -Z-Y	CFRP	0.9	=	0.9
5371	Shear Web8 -Z-Y	CFRP	0.9	=	0.9
5372	Shear Web8 -Z-Y	CFRP	0.9	=	0.9
5373	Shear Web8 -Z-Y	CFRP	0.9	=	0.9
5374	Shear Web8 -Z-Y	CFRP	0.9	=	0.9
5375	Shear Web8 -Z-Y	CFRP	0.9	=	0.9
5381	Shear Web8 -Z-Y	CFRP	0.9	=	0.9
5382	Shear Web8 -Z-Y	CFRP	0.9	=	0.9
5383	Shear Web8 -Z-Y	CFRP	0.9	=	0.9
5384	Shear Web8 -Z-Y	CFRP	0.9	=	0.9
5385	Shear Web8 -Z-Y	CFRP	0.9	=	0.9
6001-48	Int Rad +Z	Black Paint	0.9	=	0.9
6101-72	Int Rad +Y+Z	Black Paint	0.9	=	0.9
6201-48	Int Rad +Y	Black Paint	0.9	=	0.9
6301-48	Int Rad +Y-Z	Black Paint	0.9	=	0.9
6401-54	Int Rad -Z	Black Paint	0.9	=	0.9
6501-48	Int Rad -Y-Z	Black Paint	0.9	=	0.9
6601-48	Int Rad -Y	Black Paint	0.9	=	0.9
6701-72	Int Rad -Y+Z	Black Paint	0.9	=	0.9
7001	MLI SVM Top +Z	Kapton Aluminized	0.15	=	0.05
7002	MLI SVM Top +Z+Y	Kapton Aluminized	0.15	=	0.05
7003	MLI SVM Top +Y	Kapton Aluminized	0.15	=	0.05
7004	MLI SVM Top -Z+Y	Kapton Aluminized	0.15	=	0.05
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7008	MLI SVM Top +Z-Y	Kapton Aluminized	0.15	=	0.05
7201	MLI SVM Top Disc +Y+Z	Kapton Aluminized	0.15	=	0.05
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7203	MLI SVM Top Disc +Y+Z	Kapton Aluminized	0.15	=	0.05
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7206	MLI SVM Top Disc +Y+Z	Kapton Aluminized	0.15	=	0.05
7207	MLI SVM Top Disc +Y+Z	Kapton Aluminized	0.15	=	0.05

7208	MLI SVM Top Disc +Y+Z	Kapton Aluminized	0.15	=	0.05
7209	MLI SVM Top Disc +Y+Z	Kapton Aluminized	0.15	=	0.05
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7211	MLI SVM Top Disc +Y+Z	Kapton Aluminized	0.15	=	0.05
7212	MLI SVM Top Disc +Y+Z	Kapton Aluminized	0.15	=	0.05
7213	MLI SVM Top Disc +Y+Z	Kapton Aluminized	0.15	=	0.05
7214	MLI SVM Top Disc +Y+Z	Kapton Aluminized	0.15	=	0.05
7215	MLI SVM Top Disc +Y+Z	Kapton Aluminized	0.15	=	0.05
7216	MLI SVM Top Disc +Y+Z	Kapton Aluminized	0.15	=	0.05
7217	MLI SVM Top Disc +Y+Z	Kapton Aluminized	0.15	=	0.05
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7220	MLI SVM Top Disc +Y+Z	Kapton Aluminized	0.15	=	0.05
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7222	MLI SVM Top Disc +Y+Z	Kapton Aluminized	0.15	=	0.05
7223	MLI SVM Top Disc +Y+Z	Kapton Aluminized	0.15	=	0.05
7224	MLI SVM Top Disc +Y+Z	Kapton Aluminized	0.15	=	0.05
7225	MLI SVM Top Disc +Y+Z	Kapton Aluminized	0.15	=	0.05
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7229	MLI SVM Top Disc +Y+Z	Kapton Aluminized	0.15	=	0.05
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7304	SVM Top Disc +Y+Z	Aluminium	-	=	0.05
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7309	SVM Top Disc +Y+Z	Aluminium	-	=	0.05
7310	SVM Top Disc +Y+Z	Aluminium	-	=	0.05
7311	SVM Top Disc +Y+Z	Aluminium	-	=	0.05
7312	SVM Top Disc +Y+Z	Aluminium	-	=	0.05
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7317	SVM Top Disc +Y+Z	Aluminium	-	=	0.05
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7331	SVM Top Disc +Y+Z	Aluminium	-	=	0.05
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7338	SVM Top Disc +Y+Z	Aluminium	-	=	0.05
7339	SVM Top Disc +Y+Z	Aluminium	-	=	0.05
7401	SVM Top Disc +Y+Z	Black Paint	0.9	=	0.9
7402	SVM Top Disc +Y+Z	Black Paint	0.9	=	0.9
7403	SVM Top Disc +Y+Z	Black Paint	0.9	=	0.9
7404	SVM Top Disc +Y+Z	Black Paint	0.9	=	0.9
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7411	SVM Top Disc +Y+Z	Black Paint	0.9	=	0.9
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7413	SVM Top Disc +Y+Z	Black Paint	0.9	=	0.9
7414	SVM Top Disc +Y+Z	Black Paint	0.9	=	0.9
7415	SVM Top Disc +Y+Z	Black Paint	0.9	=	0.9
7416	SVM Top Disc +Y+Z	Black Paint	0.9	=	0.9
7417	SVM Top Disc +Y+Z	Black Paint	0.9	=	0.9
7418	SVM Top Disc +Y+Z	Black Paint	0.9	=	0.9
7419	SVM Top Disc +Y+Z	Black Paint	0.9	=	0.9
7420	SVM Top Disc +Y+Z	Black Paint	0.9	=	0.9
7421	SVM Top Disc +Y+Z	Black Paint	0.9	=	0.9
7422	SVM Top Disc +Y+Z	Black Paint	0.9	=	0.9
7423	SVM Top Disc +Y+Z	Black Paint	0.9	=	0.9
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7427	SVM Top Disc +Y+Z	Black Paint	0.9	=	0.9
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7436	SVM Top Disc +Y+Z	Black Paint	0.9	=	0.9
7437	SVM Top Disc +Y+Z	Black Paint	0.9	=	0.9
7438	SVM Top Disc +Y+Z	Black Paint	0.9	=	0.9
7439	SVM Top Disc +Y+Z	Black Paint	0.9	=	0.9
7445	SVM Top Disc	Black Paint	0.9	=	0.9
7521	MLI on BEU	Carbon Filled	0.92	=	0.86
7522	MLI on PAU	Carbon Filled	0.92	=	0.86
7601	SVM Top +Z	Aluminium	0.9	=	0.9
7602	SVM Top +Z+Y	Aluminium	0.9	=	0.9
7603	SVM Top +Y	Aluminium	0.9	=	0.9
7604	SVM Top -Z+Y	Aluminium	0.9	=	0.9
7605	SVM Top -Z	Aluminium	0.9	=	0.9
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7607	SVM Top -Y	Aluminium	0.9	=	0.9
7608	SVM Top +Z-Y	Aluminium	0.9	=	0.9
8101	MLI Solar Array vs. sate	Kapton Aluminized	0.15	=	0.05
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8103	MLI Solar Array vs. sate	Kapton Aluminized	0.15	=	0.05
8104	MLI Solar Array vs. sate	Kapton Aluminized	0.15	=	0.05
8401	MLI Central Solar Array	Kapton Aluminized	0.15	=	0.05
8402	MLI Central Solar Array	Kapton Aluminized	0.15	=	0.05
8403	MLI Central Solar Array	Kapton Aluminized	0.15	=	0.05
8404	MLI Central Solar Array	Kapton Aluminized	0.15	=	0.05
9300	MLI on SCC1 Rad +Y-Z	Kapton Aluminized	0.15	=	0.05
9301	MLI Int Rad +Y-Z	Kapton Aluminized	0.15	=	0.05
9306	MLI Int Rad +Y-Z	Kapton Aluminized	0.15	=	0.05
9307	MLI Int Rad +Y-Z	Kapton Aluminized	0.15	=	0.05
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9318	MLI Int Rad +Y-Z	Kapton Aluminized	0.15	=	0.05
9319	MLI Int Rad +Y-Z	Kapton Aluminized	0.15	=	0.05
9324	MLI Int Rad +Y-Z	Kapton Aluminized	0.15	=	0.05
9325	MLI Int Rad +Y-Z	Kapton Aluminized	0.15	=	0.05
9330	MLI Int Rad +Y-Z	Kapton Aluminized	0.15	=	0.05
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9343	MLI Int Rad +Y-Z	Kapton Aluminized	0.15	=	0.05
9348	MLI Int Rad +Y-Z	Kapton Aluminized	0.15	=	0.05

9400	MLI Rad -Z	Kapton Aluminized	0.15	=	0.05
9500	MLI on SCC2 Rad -Y-Z	Kapton Aluminized	0.15	=	0.05
9501	MLI Int Rad -Y-Z	Kapton Aluminized	0.15	=	0.05
9506	MLI Int Rad -Y-Z	Kapton Aluminized	0.15	=	0.05
9507	MLI Int Rad -Y-Z	Kapton Aluminized	0.15	=	0.05
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9513	MLI Int Rad -Y-Z	Kapton Aluminized	0.15	=	0.05
9518	MLI Int Rad -Y-Z	Kapton Aluminized	0.15	=	0.05
9519	MLI Int Rad -Y-Z	Kapton Aluminized	0.15	=	0.05
9524	MLI Int Rad -Y-Z	Kapton Aluminized	0.15	=	0.05
9525	MLI Int Rad -Y-Z	Kapton Aluminized	0.15	=	0.05
9530	MLI Int Rad -Y-Z	Kapton Aluminized	0.15	=	0.05
9531	MLI Int Rad -Y-Z	Kapton Aluminized	0.15	=	0.05
9536	MLI Int Rad -Y-Z	Kapton Aluminized	0.15	=	0.05
9537	MLI Int Rad -Y-Z	Kapton Aluminized	0.15	=	0.05
9542	MLI Int Rad -Y-Z	Kapton Aluminized	0.15	=	0.05
9543	MLI Int Rad -Y-Z	Kapton Aluminized	0.15	=	0.05
9548	MLI Int Rad -Y-Z	Kapton Aluminized	0.15	=	0.05
9900	MLI Helium Tank +Z	Kapton Aluminized	0.15	=	0.05
9905	MLI Helium Tank +Y	Kapton Aluminized	0.15	=	0.05
9910	MLI Helium Tank -Z	Kapton Aluminized	0.15	=	0.05
9915	MLI Helium Tank -Y	Kapton Aluminized	0.15	=	0.05
9920	MLI P Tank +Y+Z Lower	Kapton Aluminized	0.15	=	0.05
9925	MLI P Tank -Z Lower	Kapton Aluminized	0.15	=	0.05
9930	MLI P Tank -Y+Z Lower	Kapton Aluminized	0.15	=	0.05
10001	Groove Shield	Aluminium	0.15	=	0.05
10002	Groove Shield	Aluminium	0.15	=	0.05

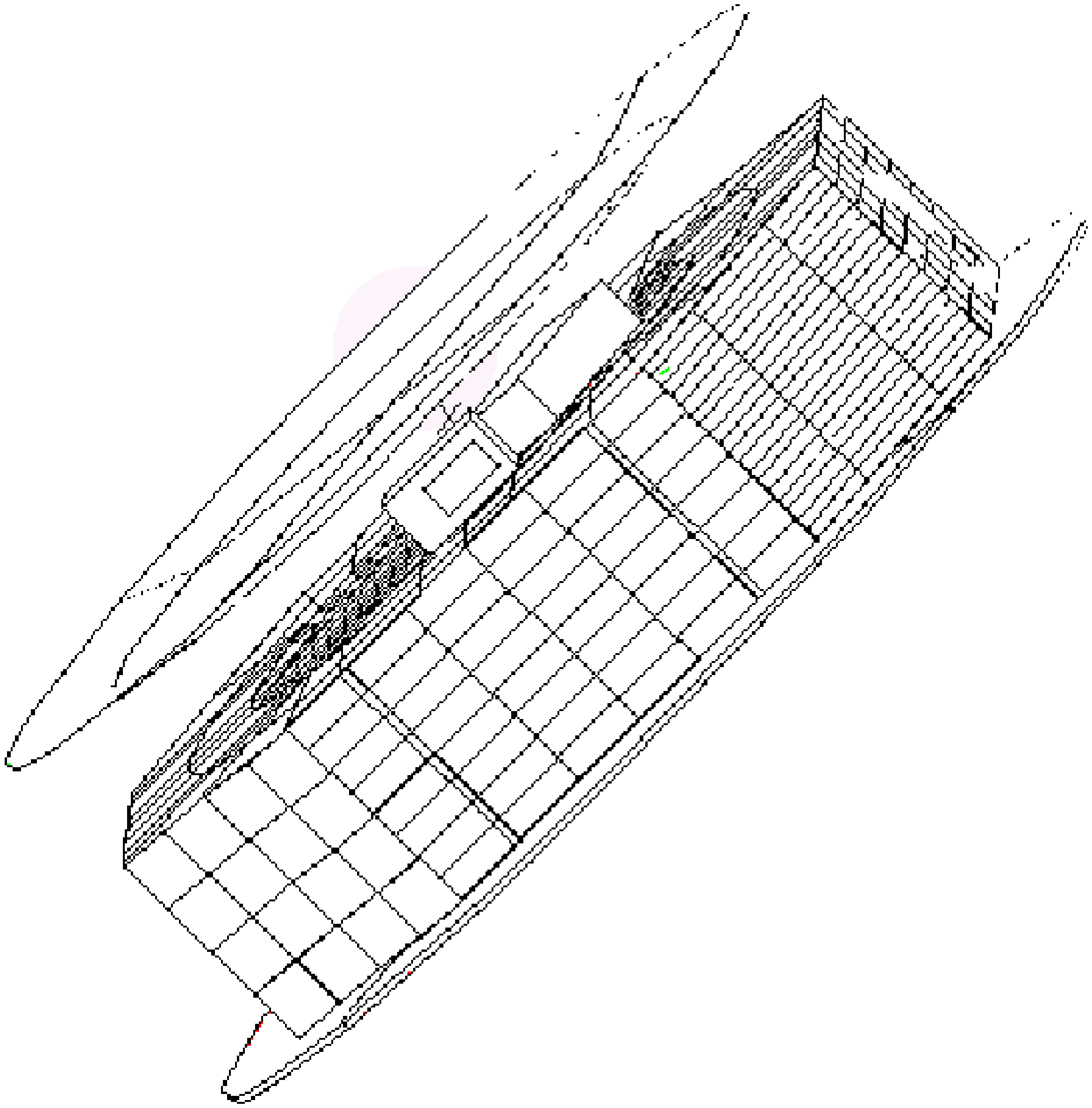


Figure 4.1.1-1 PLANCK – Overall View

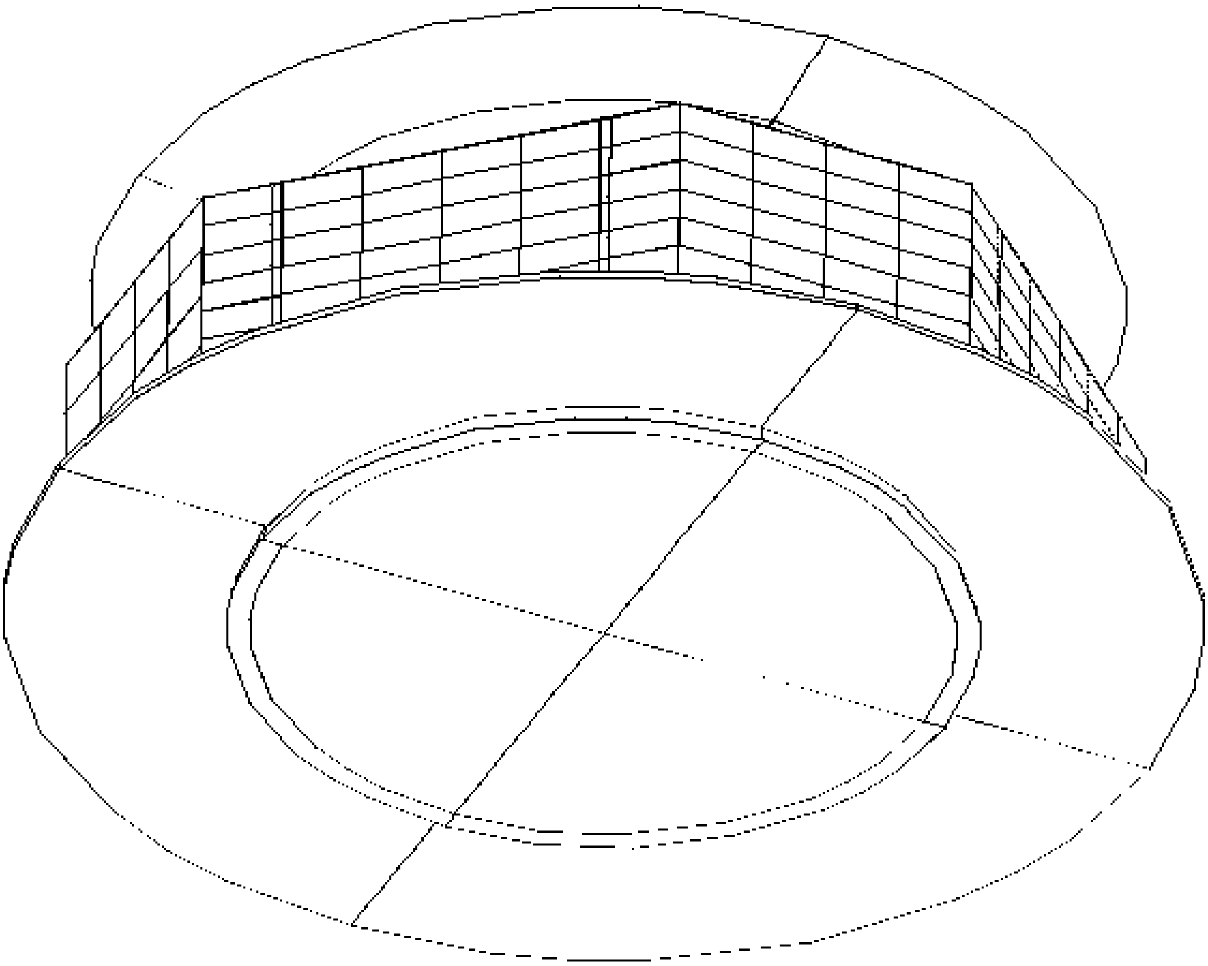


Figure 4.1.1-2 PLANCK – Overall View

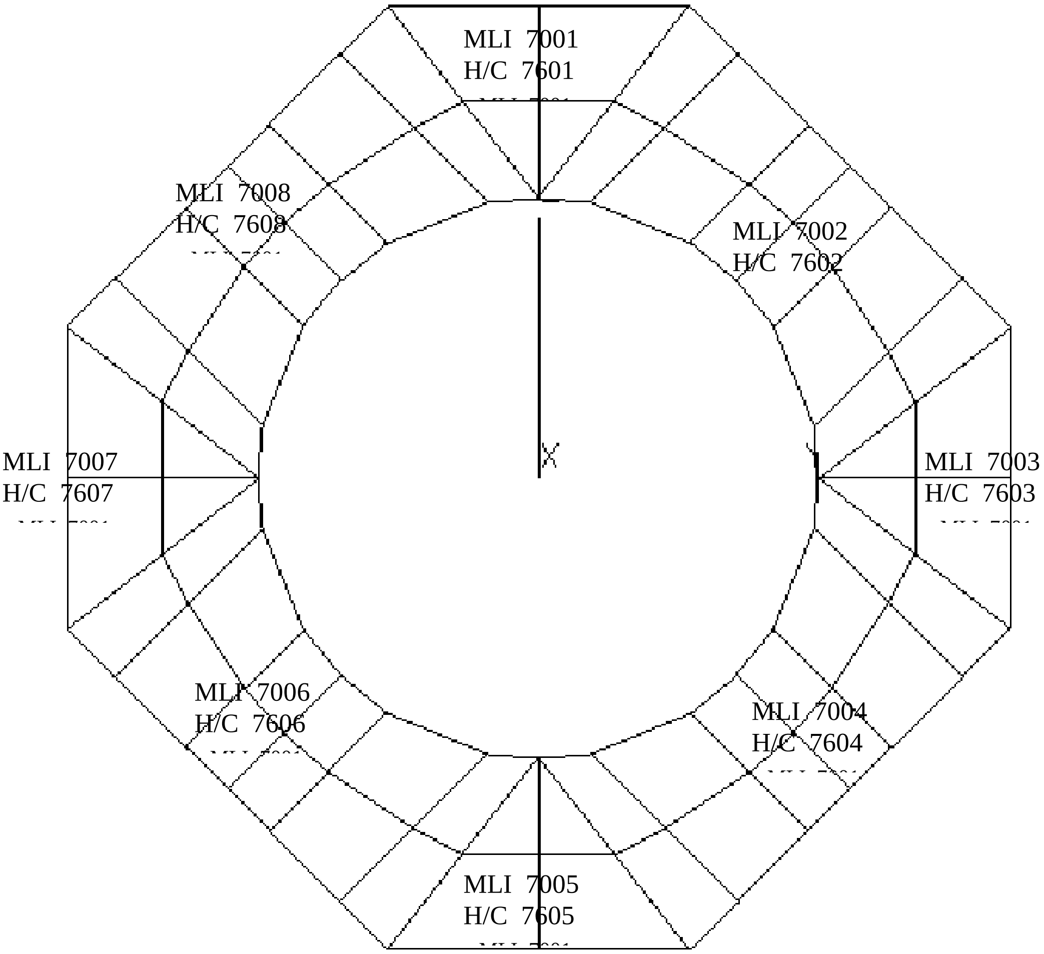
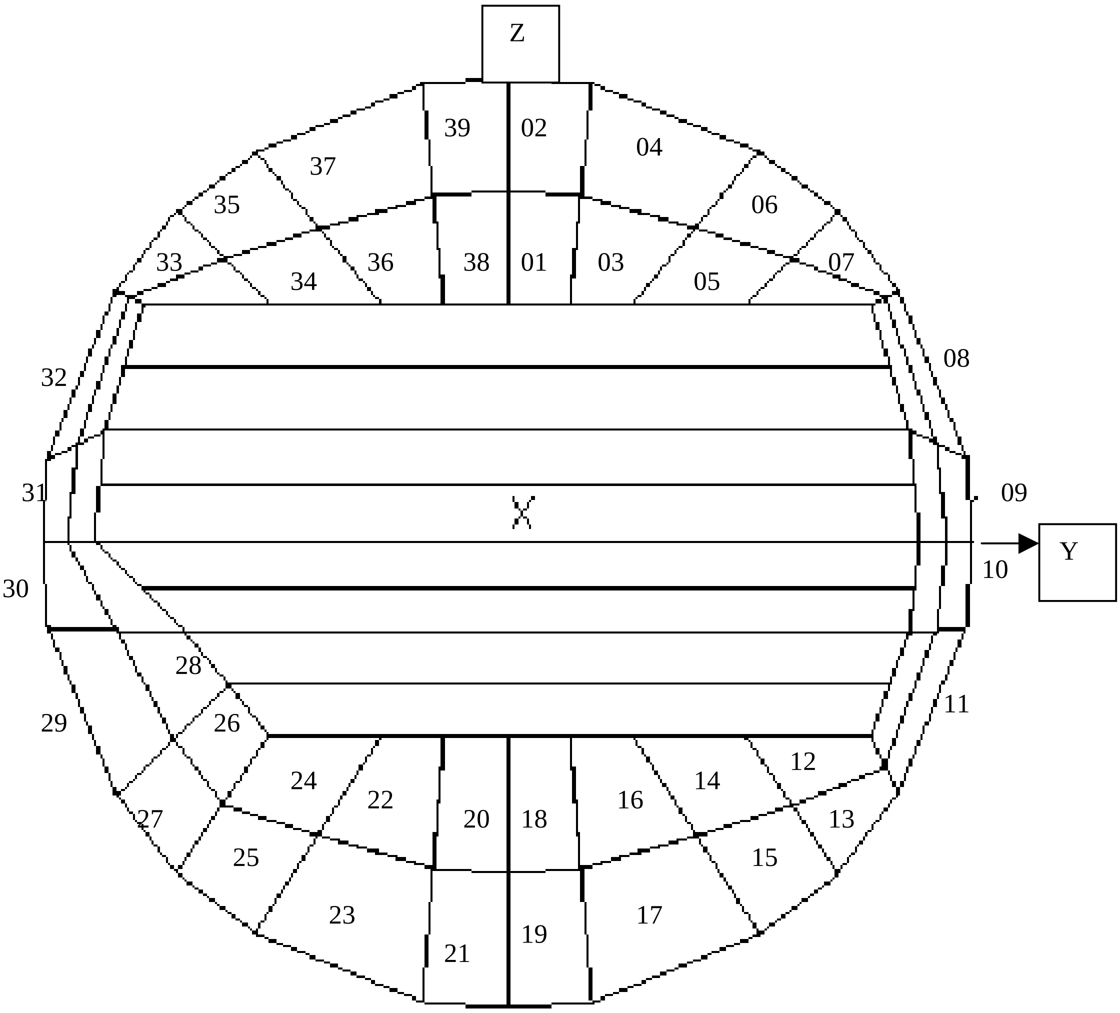


Figure 4.1.1-3 PLANCK – Upper Closure Panel



for MLI external nodes 72XX (add the number declared in figure)
for H/C external nodes 73XX (add the number declared in figure)
for H/C internal nodes 74XX (add the number declared in figure)

Figure 4.1.1-4 PLANCK –Subplatform Panel

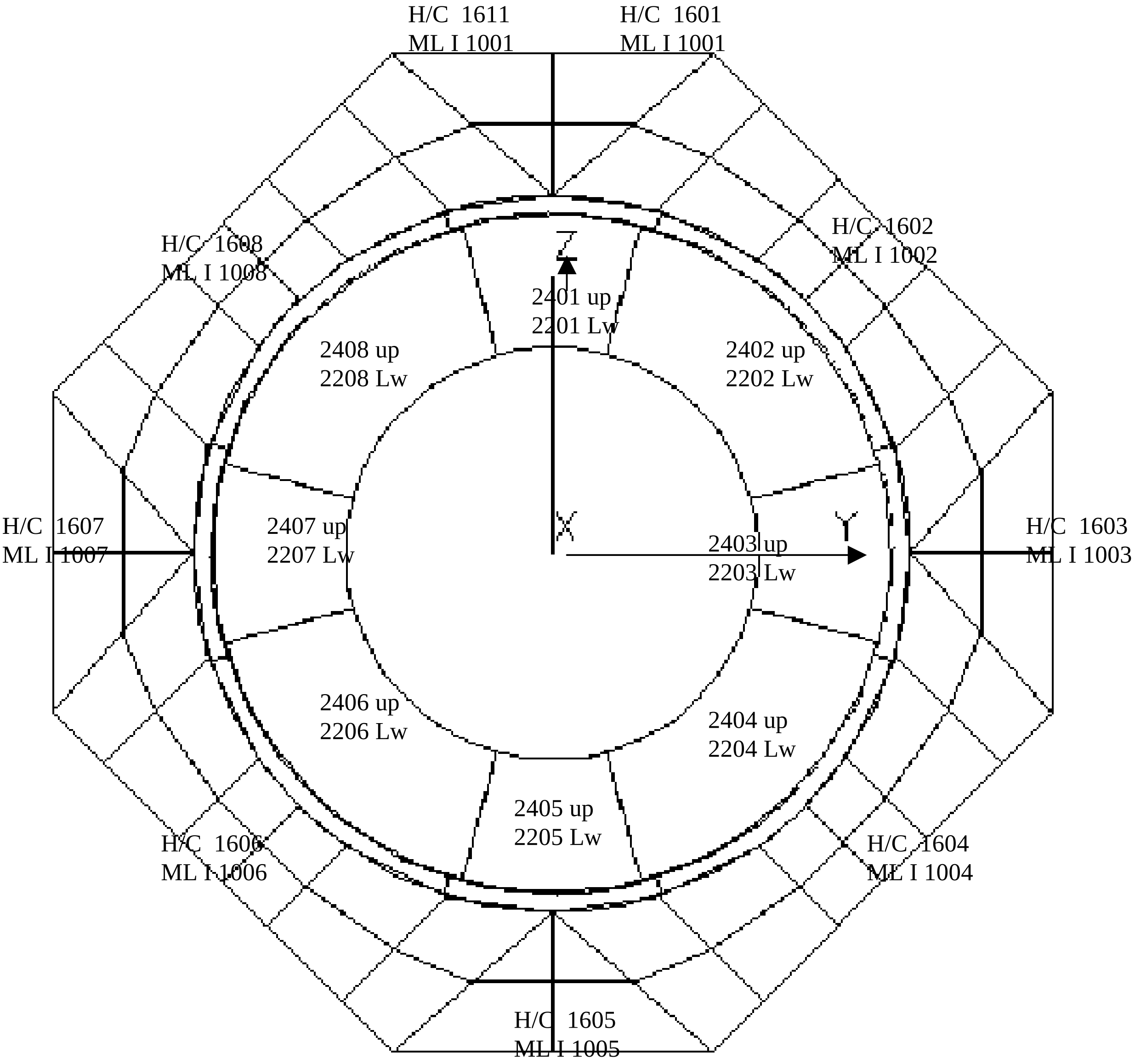


Figure 4.1.1-4 PLANCK – Lower Closure / RCS Panel Internal view

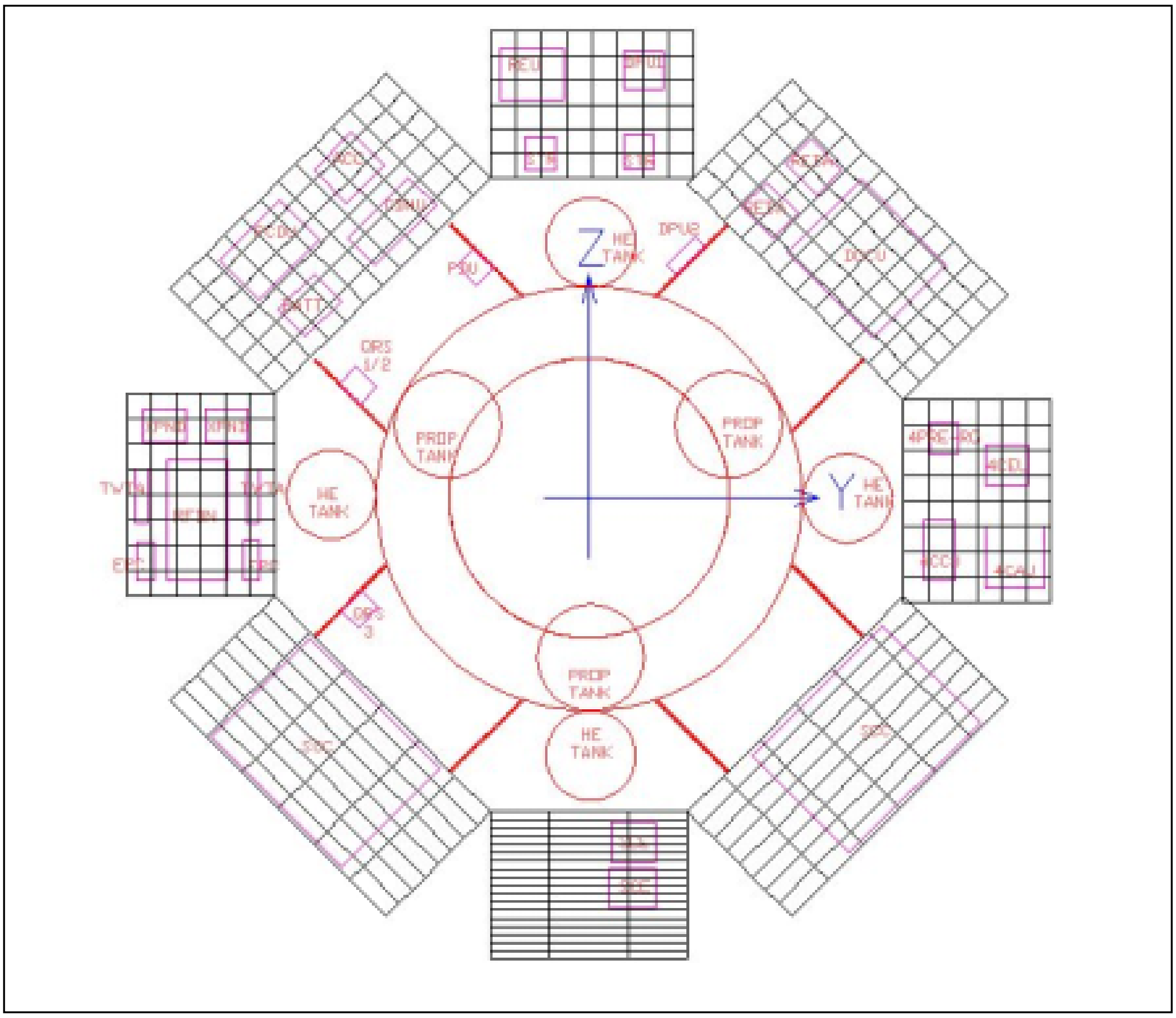


Figure 4.1.1-5 PLANCK – Internal view

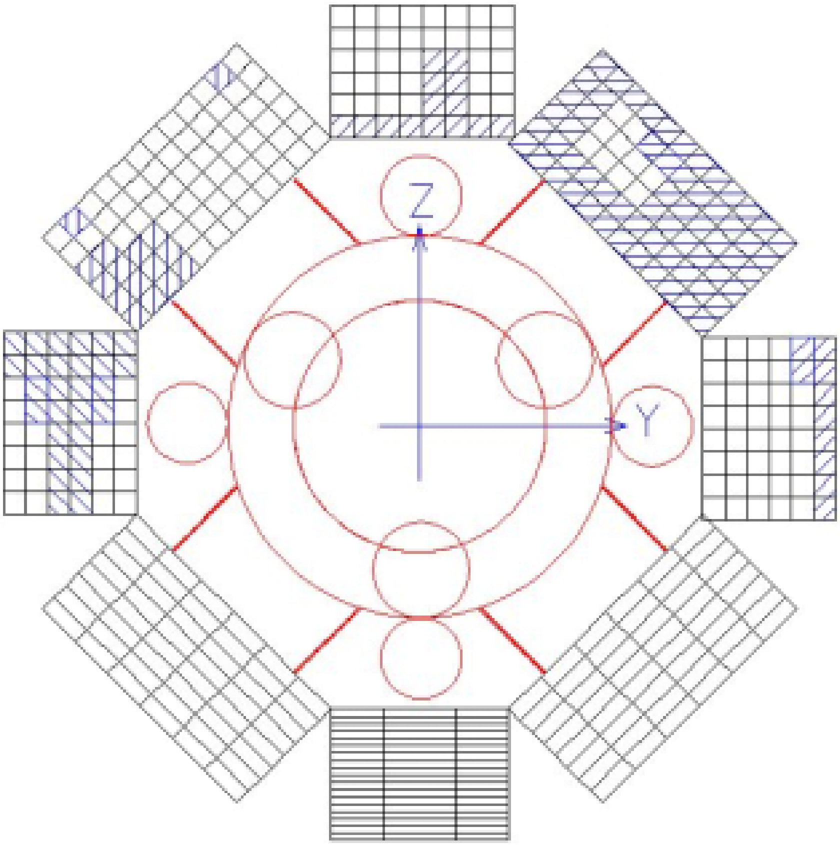
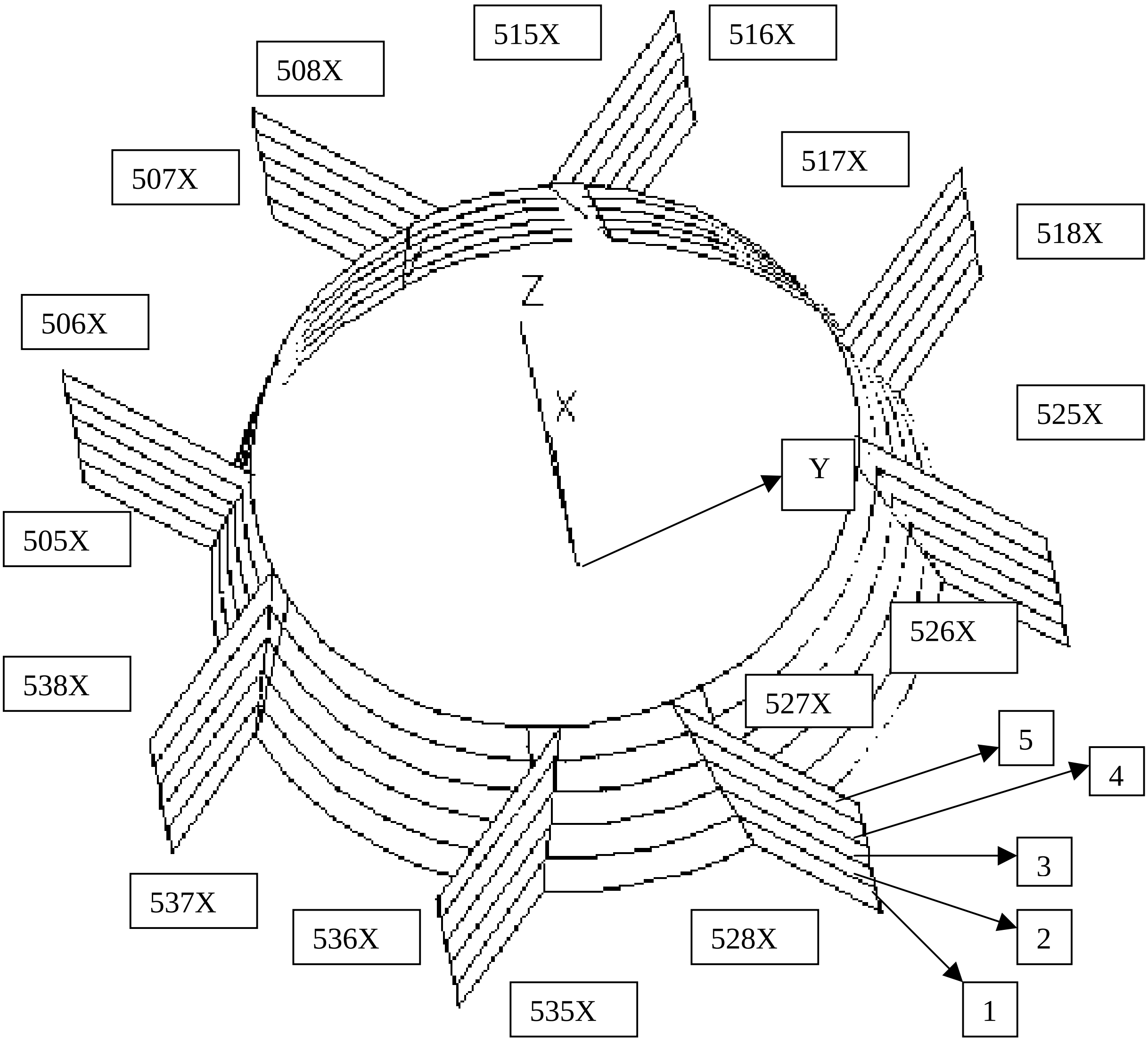


Figure 4.1.1-6 PLANCK – Lateral Panel Internal view with MLI distribution



To obtain all Shear panel nodes is sufficient to change the increasing number X , from 1 to 5 for all ones.

Figure 4.1.1-7 PLANCK – Shear Panel

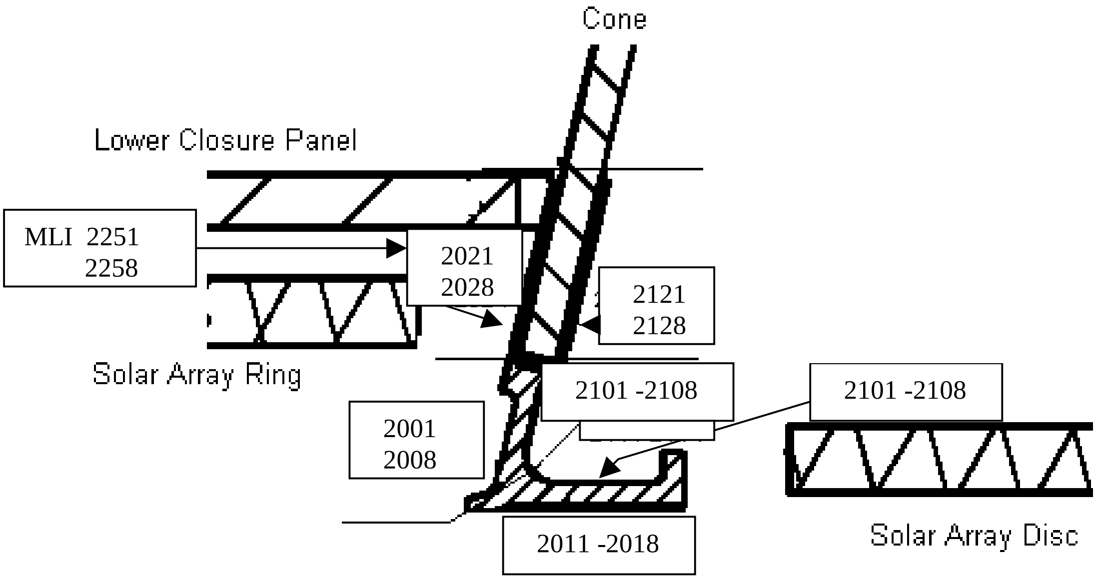


Figure 4.1.1-8 PLANCK – Adapter Ring Nodal division

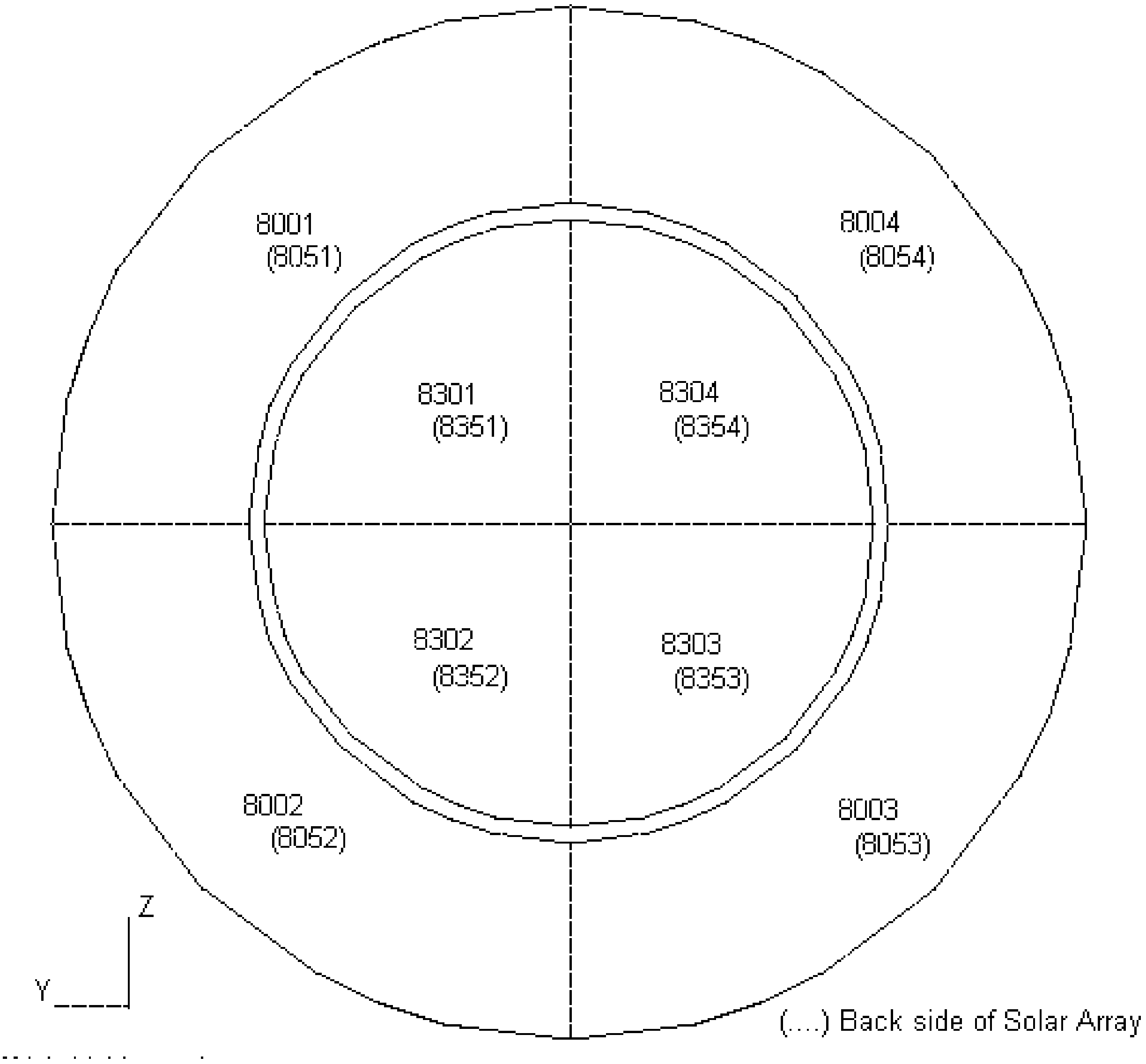


Figure 4.1.1-9 PLANCK – Solar Array External view

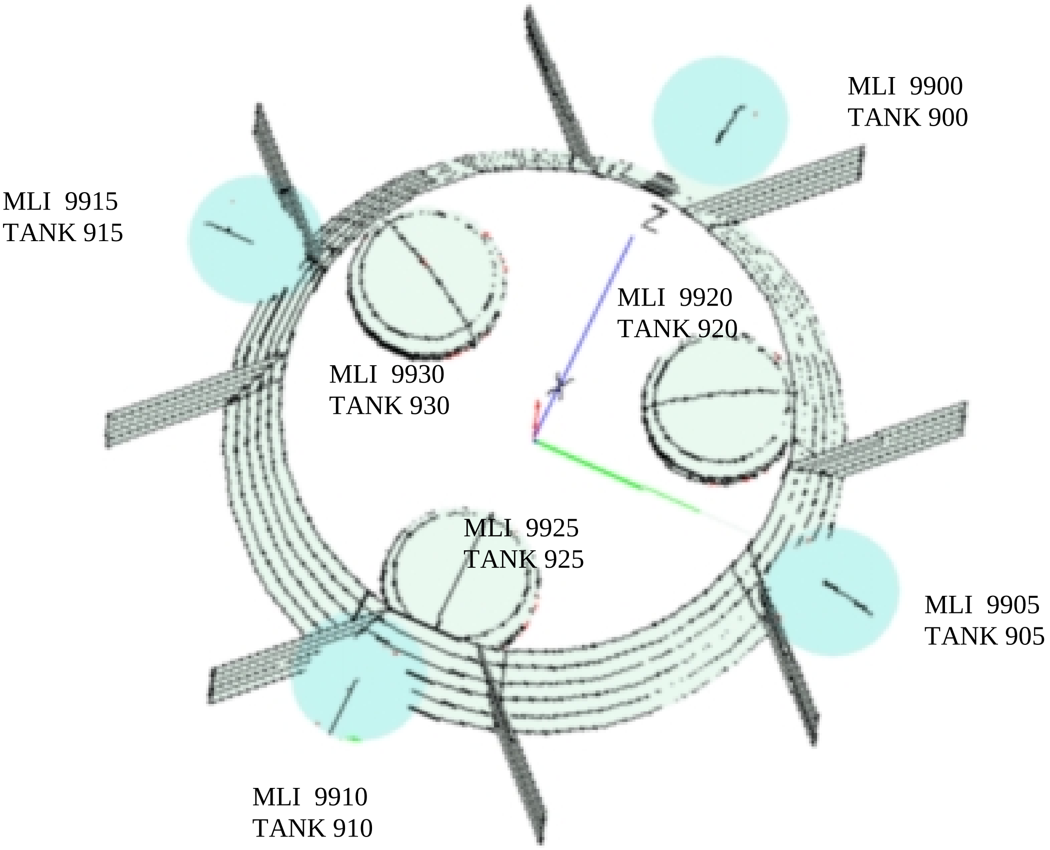
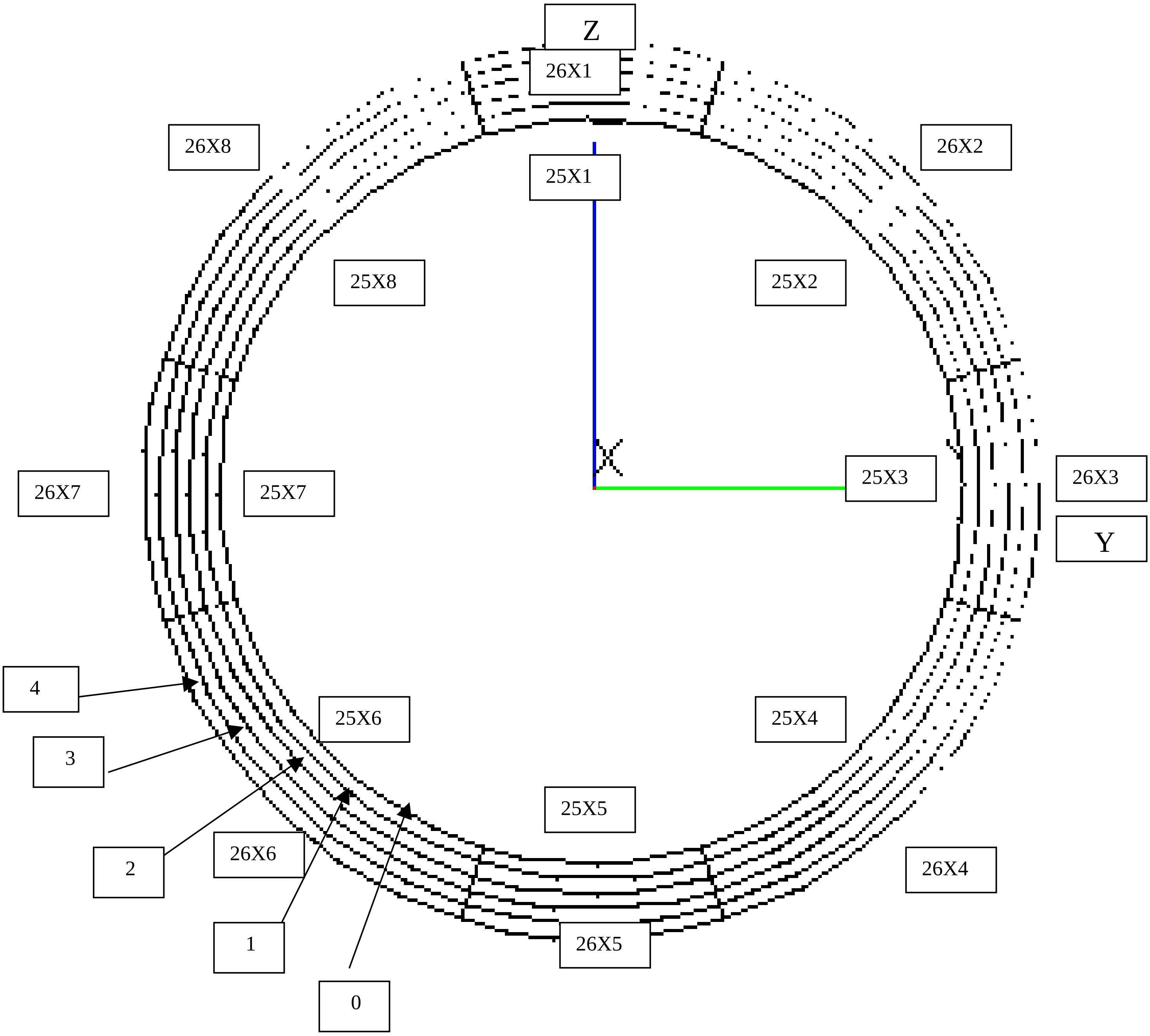


Figure 4.1.1-10 PLANCK – Helium and Propellant Tanks



To obtain all CONE nodes is sufficient to change the increasing number X , from 0 to 4 for all ones.
(nodes 26X1 are relative to external face , instead 25X1 to internal one)

Figure 4.1.1-11 PLANCK – Internal Cone

4.1.2 Radiator Panels Black Paint / MLI Area

The radiative areas obtained from the thermal analysis are shown in Fig. 4.1.1-6 and the amounts of the MLI and OSR areas are reported in Table 4.1.2-1.

Panel	**Total Panel Area** [m²]	**MLI Area** [m²]	**Paint Area** [m²]	**Paint Area / Total panel** %
+Z	0.974	0.308	0.666	68
+Y +Z	1.462	1.259	0.203	14
+Y	0.974	0.229	0.745	76
+Y -Z	1.462	0	1.462	100
-Z	0.974	0	0.974	100
-Y –Z	1.462	0	1.462	100
-Y	0.974	0.582	0.392	40
-Y +Z	1.462	0.325	1.137	78
Total	9.744	2.703	7.041	

Table 4.1.2-1 PLANCK – External Radiative Areas

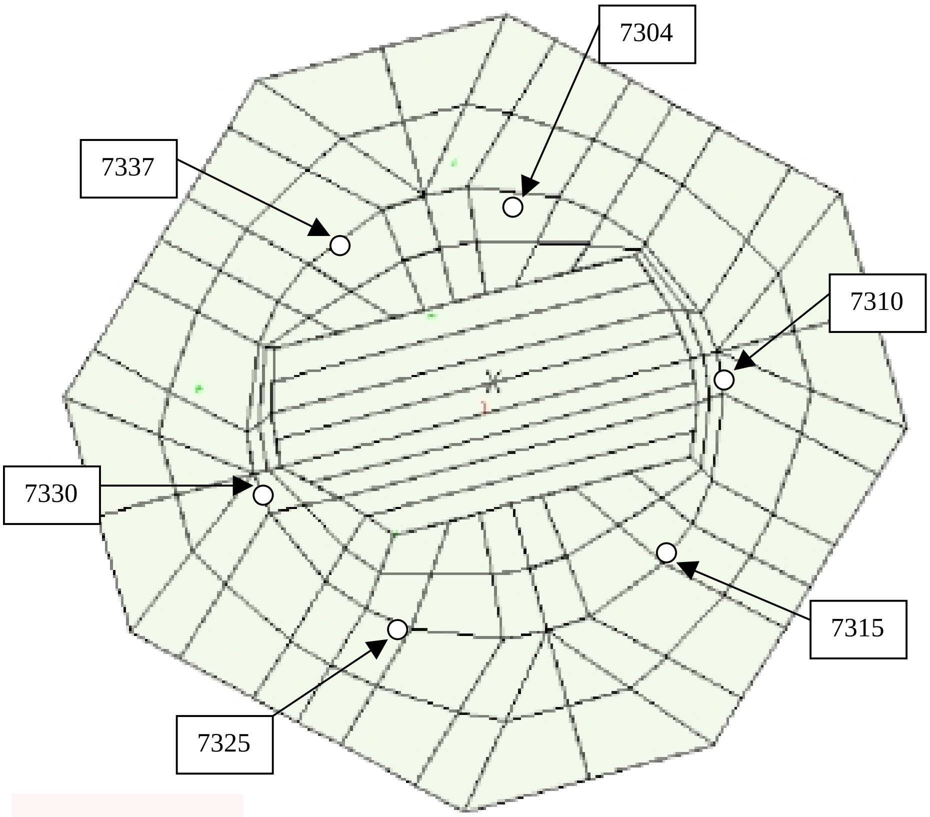
4.1.3 Thermal Mathematical Model (TMM)

The Thermal Mathematical Model (TMM) has been prepared with Esatan software and contains the thermal node description, the thermal conductivity network and the unit and heater dissipation.
It is composed by 1846 nodes:

- 847 relative to external model including node 99999 that define the space with a temperature of –269 °C
- 1019 for internal model describing the Service Module.

The thermal conductivity network has been built with 4529 linear conductors and 19292 radiative conductors derived from Esarad computation.

There are 6 nodes that represent the I/F PLM points. They are connected to the Upper Payload Subplatform, the 6 nodes are listed hereafter:



4.1.3.1 Conductive Couplings

See para 3.1.3.2.

Details of Unit – Panel Contact Conductances (including spreading effect if applicable) are given in Table 4.1.3.1-2

MLI thermal conductivity is depending on the different number of layers (see Table 3.1.2-1).
Application is:

- 20 layers MLI composition is used on the Top of the Satellite facing to PPLM and on the rear of Solar Array
- 10 layers MLI composition is used on all the other external surfaces:
- 7 layers MLI composition is used on the Tanks and on the SCC panels

Structural characteristcs and thermal conductivity (Kz, Kxy) of the panels are reported in Table 4.1.3.1-1 (Remark: the conductivity evaluation has been made as per RD.2-1).

Table 4.1.3.1-1 PLANCK – SVM Honeycomb panels thermal properties

LOCATION	H/C TYPE	SKIN TYPE	SKIN CONDUCTIVITY [W/MK]	THICK. SKIN [MM]	THICK. CORE[MM]	KXY [W/MK]	KZ [W/MK]
Upper and Lower Closure	3/16-5056-.0007	M18/G801	20	0.4	20	1.21	1.19
Subplatform	3/16-5056-.0007	AA7075T6	130	0.3	19.4	4.34	1.18
Lateral	3/16-5056-.0007	AA7075T6	130	0.3	35	2.64	1.17
Equipment Platform	3/16-5056-.0007	M18/G801	20	0.3	20	1.03	1.18
Shear Web	3/16-5056-.001	M18/G969	20	0.76	15	2.43	1.78
Cone	3/16-5056-.001	M40/914	20	0.54	15	1.95	1.74
Reinforced Cone	1/8-5056-.002	M40/914	20	1.08	13.92	4.39	5.32

Table 4.1.3.1-2 PLANCK – Unit-Panel Contact Conductances

UNIT	**PANEL**	**Contact area [cm2]**	**Node/HP area [cm2]**	**Mounting Nodes/ nr. HP**	**Mounting nodes Total Area**	**Ac/An**	**^filler (1=yes) (0=no)**	**GL Ac<1000cm² [W/°C]**	**GL Ac>1000cm² [W/°C]**	**GL (with spreading effect)**
STR	L/P+ Z (lw floor)	289.00	3315.00	1	3315	0.09	1		1.71	
REU	L/P+ Z	1710.00	203.00	16	3248	0.53	1			17.10
DPU	L/P+ Z	780.00	203.00	9	1827	0.43	1		9.23	
DCCU+FV	L/P+Z+Y	3960.00	203.00	36	7308	0.54	1			39.60
REBA1	L/P+Z+Y	492.20	203.00	6	1218	0.40	1		8.35	
REBA2	L/P+Z+Y	492.20	203.00	6	1218	0.40	1		8.35	
4 CCU	L/P+ Y	56.25	203.00	8	1624	0.03	1		0.58	
4 CEU	L/P+ Y	430.00	203.00	4	812	0.53	1	9.17		
4 CAU	L/P+ Y	1230.00	203.00	9	1827	0.67	1			12.30
4 K PRE-REG	L/P+ Y	225.00	203.00	4	812	0.28	1		5.29	
RFDN	L/P -Y	2634.24	203.00	18	3654	0.72	1			26.34
EPC1	L/P -Y	224.10	203.00	6	1218	0.18	1		3.51	
EPC2	L/P -Y	224.10	203.00	3	609	0.37	1		7.02	
TRANSX/B1	L/P -Y	373.38	203.00	4	812	0.46	1	9.04		
TRANSX/B2	L/P -Y	373.38	203.00	4	812	0.46	1	9.04		
TWT1	L/P -Y	306.00	203.00	8	1624	0.19	1		3.71	
TWT2	L/P -Y	306.00	203.00	4	812	0.38	1		7.42	
PCDU	L/P -Y+Z	1235.00	203.00	12	2436	0.51	1			12.35
CDMU	L/P -Y+Z	1012.50	203.00	8	1624	0.62	1			10.13
ACC	L/P -Y+Z	787.50	203.00	6	1218	0.65	1	9.74		
BATT	L/P -Y+Z	704.00	203.00	9	1827	0.39	1		8.25	
PDU	SH -Y+Z R	225.00	2510.00	1	2510	0.09	1		1.71	
QRS1	SH -Y+Z L	297.00	1120.00	1	1120	0.27	1		5.21	
QRS2	SH -Y+Z L	297.00	2510.00	1	2510	0.12	1		2.32	
QRS3	SH -Y-Z L	297.00	2510.00	1	2510	0.12	1		2.32	
DAE	Subplatf	414.00	4320.00	1	4320	0.10	1		1.95	
BEU	Subplatf	2462.40	4320.00	1	4320	0.57	1			24.62
PAU	Subplatf	1060.00	2660.00	1	2660	0.40	1			10.60

4.1.3.2 SVM INTERFACES REQUIREMENTS

The PLACK SVM interface requirements are listed below:

REQUIREMENT	DESCRIPTION	RESULT	STATUS
ITP-080-P	Cryo structure total negative loads onto SVM of 1 W	Boundary in theTMM	C
ITI-010-P	Total neg. loads on the BEU of max 15 W	Boundary in theTMM	C
ITP-140-P	MLI on top SVM max decoupling	Low Emissivity used	C
ITP-150-P	MLI on top SVM Exter. layer temp. < 200 K	215 K	NC
ITP-170-P	Radiative loads between PAU & BEU < 2.3 W	(1)	C
ITP-180-P	MLI on SVM sub-platform Exter. layer temp. < 200 K	222 K	NC
ITP-190-P	MLI onto back side of the Solar Array	Low Emissivity used	C
ITP-200-P	MLI on Solar Array back-side Exter. layer temp. < 300 K	296 K	C
ITP-210-P	PLM truss attach. point temp. < 293 K	313 K	NC
ITP-220-P	I/F truss stability at 1/60 Hz < TBD	(2)	C
ITP-230-P	Radiative panels temp. stability at 1/60 Hz = 0.01 K/Hz^0.5	(3)	C
ITI-030-P	Internal Temp. design range and stability req.	See Analysis Results and discussion	C
ITI-040-P	SCC thermal design	See Analysis Results and discussion	C
ITL-020-P	ARIANE 5 interfaces	N A	N A

(1) = see Table 4.1.5.3-2

(2) = see Table 4.1.5.2-5

(3) = see Table 4.1.5.2-4

4.2 PLANCK - THERMAL ANALYSIS

4.2.1 Thermal Analysis Cases

4.2.1.1 Steady State

In according to AD2.10, the list of the orbital Steady State cases analysed is presented in the following table:

CASE	α Degradation	Sun on Panel	Solar Aspect Angle	Attitude	Solar Constant [W/m²]	Remarks
3	BOL	+Z	10	Rot X = 0 Rot Y = +10	1285	
8	EOL	+Z	0	Rot X = 0 Rot Y = 0	1405	
Survival	BOL	+Z	10	Rot X = 0 Rot Y = +10	1285	

Table 4.2.1.1-1 PLANCK - Orbit Cases description

The spin of the satellite around its X-axis (1round per minute) has a negligible effect on the amount of solar fluxes on the sun-exposed surfaces, so it is not considered in the current analysis.

The Solar Constant has been defined by ALCATEL with the following value:

Cold Cases (BOL3,Survival) :	1285 W/m², which correspond a temperature of the Sun of 5772 K
Hot Cases (EOL8) :	1405 W/m², which correspond a temperature of the Sun of 5792 K

The following part of the satellite have been set to a boundary temperature (see A.D. 2.10):

- PLM Groove Shield BOL case : -193.15 °C
  EOL case : -113.15 °C
- Space node : -269 °C

4.2.1.2 Transient Cases

To verify the thermal stability requirement for the SCC Radiative Panels and the SVM/PLM I/F points a transient analysis has been performed taking into account the variation of SCC Power dissipation on each bed.
The analysed cases are the followings :

- Cold Transient (Case 1):
  Starting from S/S case BOL1 (Sun on -X , SAA= 0°).
  Ending to S/S case BOL3 (Sun on -X , SAA=+10°).
  Duration of change of attitude: 1200s
  Overall duration of transient case: 345600s (96 hours)

- Hot Transient (Case 2):
  Starting from S/S case EOL3 (Sun on -X , SAA=+10°).
  Ending to S/S case EOL8 (Sun on -X , SAA= 0°).
  Duration of change of attitude: 1200s
  Overall duration of transient case: 345600s (96 hours)

The working SCC has a dissipation profile of 667s, while the single bed has a whole cycle in 4002 s (6 time 667s).
Each SCC is composed of six thermal nodes for the Inner bed and six for the Outer shell, for each thermal node is considered the thermal capacity, the linear conductor and the power dissipation for each phase and has been utilised a simplified BOL and EOL thermal mathematical model reported in Table 4.2.1.2-1/2
In Table 4.2.1.2-3 are reported the value relative to Gas gap conductance for a period time of 1334 sec up to 2000 one .

Highly Simplified BOL Thermal Model of 20 K Sorption Cooler Compressor Assembly

(To be used by Alcatel to simulate compressor interface with radiator)

(Pradeep Bhandari, Mauro Prina, 11-15-2001) (Phone: 818-354-7597) **Modified Model**

Parameter	**Location**	**Units**	**Phase 1 Heatup 0-667 s**	**Phase 2 Desorb 667-1334 s**	**Phase 3 Cool 1334-2000 s**	**Phase 4 Absorb 2001-2667 s**	**Phase 5 Absorb 2668-3333 s**	**Phase 6 Absorb 3335-4000 s**	**Phase Cycle Time**
Therm. Mass	**Inner Bed**	MC_p (J/K)	800	3600	900	670	690	710	
	Outer Shell	MC_p (J/K)	720	720	720	720	720	720	
Conductance	*(Inner Bed to Outer Shell)*	W/K	0.02	0.03	***	6.53	6.53	6.53	
Heat Input	**Inner Bed**	W	201	150	0	36	36	36	
	Outer shell	W	0	0	7	7	7	7	

**** see attached table**

(Gas-Gap Conductance Worksheet)

BOL
Model

Notes:

1) The above values are for beginning of life (excluding margin)
2) The total cycle time is 667*6 = 4000 seconds.
3) There are 6 identical beds which are of phase, by one phase width of 667 sec., with respect to each other.

Table 4.2.1.2-1 PLANCK - Simplified BOL SCC model

Highly Simplified EOL Thermal Model of 20 K Sorption Cooler Compressor Assembly

(To be used by Alcatel to simulate compressor interface with radiator)

(Pradeep Bhandari, Mauro Prina, 11-15-2001) (Phone: 818-354-7597) Modified Model

			Phase 1	Phase 2	Phase 3	Phase 4	Phase 5	Phase 6	
Parameter	**Location**	**Units**	**Heatup**	**Desorb**	**Cool**	**Absorb**	**Absorb**	**Absorb**	**Phase**
			0-667 s	**667-1334 s**	**1334-2000 s**	**2001-2667 s**	**2668-3333 s**	**3335-4000 s**	**Cycle Time**
Therm. Mass	**Inner Bed**	MC_p (J/K)	800	3600	***930***	670	690	710	
	Outer Shell	MC_p (J/K)	720	720	720	720	720	720	
Conductance	*(Inner Bed to Outer Shell)*	W/K	0.02	0.03	***	6.53	6.53	6.53	
Heat Input	**Inner Bed**	W	216	183	0	36	36	36	***EOL Model***
	Outer shell	W	46	46	7	7	7	7	
	Total	W							519 Watts (EOL + Margin)

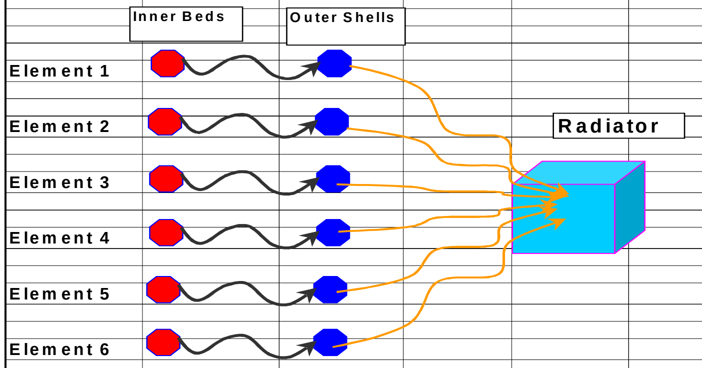
**** see attached table**

Use Table in "Gas-Gap Conductance" Workheet for values during Cool phase

Changed thermal capacitance from last model to get better heat balance

Notes:

1) The above values are for end of life (including margin)
2) The total cycle time is 667*6 = 4000 seconds.
3) There are 6 identical beds which are of phase, by one phase width of 667 sec., with respect to each other.
4) At any time one bed is heating up, one desorbing, one cooling, and three absorbing.
5) Outer shell is thermally and structurally connected to the radiator.
6) Additonal thermal masses for items outside of the compressor elements need to be accounted for to ensure that the radiator thermal oscillations are not excessive.



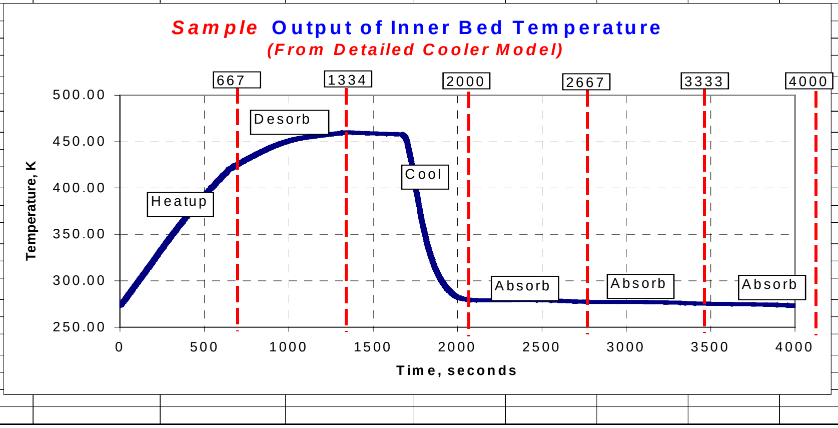


Table 4.2.1.2-2 PLANCK - Simplified EOL SCC model

Time	Gas gap Conductance	Time	Gas gap Conductance	Time	Gas gap Conductance	Time	Gas gap Conductance
[s]	[W/K]	[s]	[W/K]	[s]	[W/K]	[s]	[W/K]
0	0.0313	341	2.3479	394	6.2940	447	6.5519
286	0.0314	342	2.6215	395	6.3069	448	6.5525
289	0.0316	343	2.8875	396	6.3187	449	6.5530
291	0.0318	344	3.1393	397	6.3307	450	6.5534
292	0.0319	345	3.3734	398	6.3420	451	6.5536
293	0.0321	346	3.5880	399	6.3526	452	6.5537
294	0.0325	347	3.7832	400	6.3634	453	6.5539
295	0.0329	348	3.9600	401	6.3728	454	6.5541
296	0.0331	349	4.2804	402	6.3824	455	6.5542
297	0.0337	350	4.4133	403	6.3914	667	6.5543
298	0.0344	351	4.5360	404	6.4003		
299	0.0352	352	4.6454	405	6.4086		
300	0.0359	353	4.7481	406	6.4171		
301	0.0368	354	4.8422	407	6.4247		
302	0.0383	355	4.9295	408	6.4321		
303	0.0397	356	5.0096	409	6.4391		
304	0.0414	357	5.0853	410	6.4456		
305	0.0434	358	5.1568	411	6.4516		
306	0.0459	359	5.2245	412	6.4578		
307	0.0487	360	5.2856	413	6.4636		
308	0.0519	361	5.3454	414	6.4689		
309	0.0558	362	5.4002	415	6.4738		
310	0.0602	363	5.4532	416	6.4793		
311	0.0653	364	5.5034	417	6.4837		
312	0.0709	365	5.5503	418	6.4887		
313	0.0775	366	5.5956	419	6.4932		
314	0.0849	367	5.6379	420	6.4971		
315	0.0934	368	5.6789	421	6.5009		
316	0.1029	369	5.7178	422	6.5049		
317	0.1137	370	5.7541	423	6.5083		
318	0.1258	371	5.7893	424	6.5119		
319	0.1393	372	5.8235	425	6.5151		
320	0.1546	373	5.8553	426	6.5183		
321	0.1716	374	5.8862	427	6.5214		
322	0.1908	375	5.9163	428	6.5242		
323	0.2123	376	5.9436	429	6.5264		
324	0.2366	377	5.9708	430	6.5291		
325	0.2641	378	5.9967	431	6.5315		
326	0.2956	379	6.0219	432	6.5335		
327	0.3317	380	6.0453	433	6.5356		
328	0.3735	381	6.0680	434	6.5373		
329	0.4224	382	6.0902	435	6.5393		
330	0.4799	383	6.1119	436	6.5409		
331	0.5482	384	6.1314	437	6.5423		
332	0.6297	385	6.1514	438	6.5436		
333	0.7276	386	6.1705	439	6.5450		
334	0.8556	387	6.1886	440	6.5463		
335	0.9855	388	6.2058	441	6.5473		
336	1.1518	389	6.2216	442	6.5480		
337	1.3457	390	6.2375	443	6.5488		
338	1.5667	391	6.2526	444	6.5497		
339	1.8118	392	6.2673	445	6.5505		
340	2.0749	393	6.2808	446	6.5512		

Table 4.2.1.2-2 PLANCK - Gas gap conductance

4.2.1.3 Survival case

In case of failure on board of the satellite (i.e. computers board) is necessary to switch off all the units in mode "Not Operative" and operate only wih the subsystem ACMS and PCS in mode "Operative".
From this instant the TCS must guarantee the survival mode of the satellite with the utilization of substitution heaters.
Two cases have been performed :

- BOL3 (Sun on -X , SAA=+10°).
  Overall duration of transient case: 259200s (72 hours)

- EOL8 (Sun on -X , SAA= 0°).
  Overall duration of transient case: 259200s (72 hours)

4.2.1.4 Propellant Tank

A trade-off analysis has been performed in order to investigate the thermal decoupling and stability requirement in transient mode for propellant Tanks and the results were presented in the TCS PM#1.

4.2.2 Power Dissipation

The power dissipations are shown in Table 4.2.2-1.
The values presented in the table have been considered the state of Scientific Observation as a cold case (BOL3 and Survival).
The Telecom Phase instead has been considered as a hot case (EOL8).

NODE	LABEL	Scientific Observ. BOL [W]	Telecom Phase EOL [W]	Survival [W]
11	STR1	0	0	0
12	STR2	13	13	0
13	DPU1	32	32	0
14	DPU2 (on shear)	0	0	0
15	REU	92	92	0
101	DCCU + FV	19	19	0
102	REBA1	0	0	0
103	REBA2	41.5	41.5	0
201	4 CCU	60	60	0
202	4 CAU	15	15	0
203	4 PRE-REG	20	20	0
204	4 CEU	41	41	0
311	SCC1 - Outer Shell1	71	86.67	0
312	SCC1 - Outer Shell2	71	86.67	0
313	SCC1 - Outer Shell3	71	86.67	0
314	SCC1 - Outer Shell4	71	86.67	0
315	SCC1 - Outer Shell5	71	86.67	0
316	SCC1 - Outer Shell6	71	86.67	0
401	SCE1	110	110	0
402	SCE2	0	0	0
511	SCC2 - Outer Shell1	0	0	0
512	SCC2 - Outer Shell2	0	0	0
513	SCC2 - Outer Shell3	0	0	0
514	SCC2 - Outer Shell4	0	0	0
515	SCC2 - Outer Shell5	0	0	0
516	SCC2 - Outer Shell6	0	0	0
521	BEU	43.7	58.7	-15
522	PAU	15	15	0
525	DAE Power unit	20	20	0
551	QRS3 (on shear)	0	0	0
601	TRANSX/B1	7	13	13
602	TRANSX/B2	7	7	7
603	TWTA1	0	38	38
604	TWTA2	0	0	0
605	RFDN	0	8	8
606	EPC1	9	9	9
607	EPC2	0	0	0
701	CDMU	36	36	36
702	ACC	24	24	24
703	BATT	0	0	6

NODE	LABEL	Scientific Observ. BOL [W]	Telecom Phase EOL [W]	Survival [W]
704	PCDU	153	127	126
705	QRS1 (on shear)	8	8	8
706	QRS2 (on shear)	0	8	8
707	PDU (on shear)	10	10	10
900	He TANK +Z			
905	He TANK +Y			
910	He TANK -Z			
915	He TANK -Y			
920	P TANK +Y+Z			
925	P TANK -Z			
930	P TANK -Y+Z			

Table 4.2.2-1 PLANCK - Unit Power Dissipation

4.2.3 Heater Sizing and Breakdown

An optimized heater definition approach was followed in order to define the minimum heater power needed by the TCS. It included the following major steps:

h) selection of the minimum applicable temperature limits
i) addition of +3°C to the minimum limits (i.e. to achieve the minimum heater control threshold)
j) addition of the defined uncertainty (+9°C/ +11°C as applicable) to obtain a new set of temperatures
k) computation of the needed heater power to maintain units at the those temperature levels in steady state conditions
l) definition of the upper threshold at +5°C above the minimum threshold
m) transient analysis with automatic heater control routines within the defined thresholds
n) verification of the results and local adjustement of heater power as necessary to achieve a proper variation of the equipment temperatures between thersholds (with a heater duty cycle < 100%)

The Heater circuit breakdown with the heater power impressed on the TMM nodes is shown in Table 4.2.3-1

Table 4.2.3-1 PLANCK – Heater Circuits Breakdown and Temperature Thresholds

HEATER LINE IDENTIFICATION			PURPOSE	Heater Node	Heater node power [W]	Threshold [°C] (com. on unit)	PURPOSE	Heater Node	Heater node power [W]	Threshold [°C] (com. on unit)
	Main	Red.								
HTR -	MA1	RA1	Nominal	6604	9.5	comp. array				
				6605	9.5					
				6612	9.5					
				6613	9.5					
				6607	3.0					
				6615	3.0					
				6609	2.0					
				6617	2.0					
HTR -	MA2	RA2					Survival	6609	2.0	-12/-7 (TWT1)
								6617	2.0	
								6604	9.5	
								6605	9.5	
								6612	9.5	
								6613	9.5	
								6607	3.0	
								6615	3.0	
HTR -	MA3	RA3	Nominal	6647	3.0	comp. array				
				6648	3.0					
				6644	19.0					
				6645	19.0					
				6633	2.0					
				6641	2.0					
HTR -	MA4	RA4					Survival	6647	3.0	-12/-7 (EPC2)
								6648	3.0	
								6644	19.0	
								6645	19.0	
								6633	2.0	
								6641	2.0	
HTR -	MB1	RB1					Survival	6720	5.0	5/10 (Batt.)
								6722	5.0	
								6703	5.0	
								6729	5.0	
								6740	5.0	
								6764	5.0	
HTR -	MC1	RC1	Nominal	801	30.0	-7/-2 (HP801)				
				802	30.0					
HTR -	MC2	RC2	Nominal	803	30.0	-7/-2 (HP803)				
				804	30.0					
HTR -	MC3	RC3	Nominal	805	30.0	-7/-2 (HP806)				
				806	30.0					
HTR -	MC4	RC4	Nominal	807	30.0	-7/-2 (HP808)				
				808	30.0					
HTR	MC5	RC5					Survival	801	75.0	-17/-12 (SCE1)

-										
HTR -	MC6	RC6					Survival	802	75.0	-17/-12 (SCE1)
HTR -	MC7	RC7					Survival	803	75.0	-17/-12 (SCE1)
HTR -	MC8	RC8					Survival	804	75.0	-17/-12 (SCE1)
HTR -	MC9	RC9					Survival	805	75.0	-17/-12 (SCE2)
HTR -	MC10	RC10					Survival	806	75.0	-17/-12 (SCE2)
HTR -	MC11	RC11					Survival	807	75.0	-17/-12 (SCE2)
HTR -	MC12	RC12					Survival	808	75.0	-17/-12 (SCE2)
HTR -	MD1	RD1					Survival	6026	15.0	-17/-12 (DPU)
								6027	15.0	
								6028	15.0	
								6029	5.0	
								6032	5.0	
								6037	5.0	
								6040	5.0	
HTR -	MK1	RK1					Survival	522	10.0	-17/-12 (PAU)
HTR -	ME1	RE1					Survival	6108	10.0	-27/-22 (REBA2)
								6132	5.0	
								6156	5.0	
HTR -	MF1	RF1					Survival	6203	10.0	-17/-12 (CCU)
								6218	10.0	
								6227	10.0	
								6233	15.0	
								6243	15.0	
HTR -	MF2	RF2					Survival	6214	10.0	-17/-12 (Pre-reg)
								6215	10.0	
								6230	15.0	
								6237	15.0	
HTR -	MH1	RH1	Nominal	900	2.0	13/18 (Tank-1)	Survival	900	2.0	13/18 (Tank-1)
HTR -	MH2	RH2	Nominal	905	2.0	13/18 (Tank-2)	Survival	905	2.0	13/18 (Tank-2)
HTR -	MH3	RH3	Nominal	910	2.0	13/18 (Tank-3)	Survival	910	2.0	13/18 (Tank-3)
HTR -	MH4	RH4	Nominal	915	2.0	13/18 (Tank-4)	Survival	915	2.0	13/18 (Tank-4)
HTR -	MH5	RH5					Survival	920	2.0	13/18 (Prop-1)
HTR -	MH6	RH6					Survival	925	2.0	13/18 (Prop-2)
HTR -	MH7	RH7					Survival	930	2.0	13/18 (Prop-3)
HTR -	MH8	RH8	Nominal	8508	2.0	13/18 (RCT1 m)	Survival	8508	2.0	13/18 (RCT1 m)
				8608	2.0			8608	2.0	
HTR -	MH9	RH9	Nominal	8708	2.0	13/18 (RCT2 m)	Survival	8708	2.0	13/18 (RCT2 m)
				8808	2.0			8808	2.0	
HTR -	MH10	RH10	Nominal	1133	2.0	13/18 (RCT1 m)	Survival	1133	2.0	13/18 (RCT1 m)
				1134	2.0			1134	2.0	
HTR -	MH11	RH11	Nominal	1233	2.0	13/18 (RCT2 m)	Survival	1233	2.0	13/18 (RCT2 m)
				1234	2.0			1234	2.0	

HTR-	MH12	RH12	Nominal	1333	2.0	13/18 (RCT3 m)	Survival	1333	2.0	13/18 (RCT3 m)
				1334	2.0			1334	2.0	
HTR-	MH13	RH13	Nominal	1433	2.0	13/18 (RCT4m)	Survival	1433	2.0	13/18 (RCT4m)
				1434	2.0			1434	2.0	
HTR-	MH14	RH14	Nominal	1533	2.0	13/18 (RCT5m)	Survival	1533	2.0	13/18 (RCT5m)
				1534	2.0			1534	2.0	
HTR-	MH15	RH15	Nominal	1733	2.0	13/18 (RCT6 m)	Survival	1733	2.0	13/18 (RCT6 m)
				1734	2.0			1734	2.0	
HTR-	MH16	RH16	Nominal	TBD		13/18 (TBD)	Survival	TBD		13/18 (TBD)
HTR-	MH17	RH17	Nominal	TBD		13/18 (TBD)	Survival	TBD		13/18 (TBD)
HTR-	MH18	RH18	Nominal	TBD		13/18 (TBD)	Survival	TBD		13/18 (TBD)
HTR-	MI1	RI1	Nominal	11	10.0	-17/-12 (STR1)	Survival	11	10.0	-17/-12 (STR1)
HTR-	MI2	RI2	Nominal	12	10.0	-17/-12 (STR2)	Survival	12	10.0	-17/-12 (STR2)
HTR-	MI3	RI3	Nominal	3921	5.0	-67/-62 (SAS+Y)	Survival	3921	5.0	-67/-62 (SAS+Y)
HTR-	MI4	RI4	Nominal	3970	5.0	-67/-62 (SAS-X)	Survival	3970	5.0	-67/-62 (SAS-X)

4.2.4 Emergency Mode Cases and Results

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4.2.5 Analysis Results

4.2.5.1 Steady state results

The temperature results hereafter presented, refer to the Steady State analysed cases reported in paragraph 4.2.1.1
In Table 4.2.5.1-1 a overall summary result of the thermal unit is represented.
The values are inclusive of uncertainty as reported in RD (xx).

NODE	LABEL	Temp. Oper. [°C]		Temp. Non Oper. [°C]		BOL3 [°C] T - UFP	EOL8 [°C] T + UFP	SURV [°C] T - UFP
11	STR1	-10	30	-20	40	3.22	23.49	-18.40
12	STR2	-10	30	-20	40	7.23	29.12	-13.04
13	DPU1	-10	40	-20	50	-0.44	19.71	-13.35
14	DPU2 (on shear)	-10	30	-20	50	5.57	26.72	-18.43
15	REU	-20	30	-30	40	4.62	25.80	-23.21
101	DCCU + FV	-10	40	-20	50	9.82	31.36	-11.01
102	REBA1	-20	50	-30	70	3.09	24.36	-17.65
103	REBA2	-20	50	-30	70	20.44	41.09	-23.00
201	4 CCU	-10	40	-20	50	18.25	39.86	-13.17
202	4 CAU	-10	40	-20	50	-5.07	15.85	-13.28
203	4 PRE-REG	-10	40	-20	50	5.95	26.68	-13.14
204	4 CEU	-10	40	-20	50	13.00	33.61	-13.19
401	SCE1	-10	40	-20	50	-3.30	9.33	-17
402	SCE2	-10	40	-20	50	-16.59	4.27	-17
521	BEU	-20	40	-30	50	11.27	38.16	-27.73
522	PAU	-20	40	-20	50	12.24	36.65	-19.05
525	DAE Power Unit	-20	45	-20	55	20.98	42.87	-4.44
551	QRS3 (on shear)	-15	45	-25	65	4.72	28.84	-6.67
601	TRANSX/B1	-10	50	-20	60	10.49	36.71	13.07
602	TRANSX/B2	-10	50	-20	60	4.35	28.42	-1.52
603	TWTA1	-15	50	-25	60	4.91	27.35	9.77
604	TWTA2	-15	50	-25	60	-16.09	7.54	-22.30
605	RFDN	-40	70	-50	80	-6.18	21.75	-8.47
606	EPC1	-15	45	-25	55	-7.88	16.86	-0.98
607	EPC2	-15	45	-25	55	-11.71	7.37	-22.97
701	CDMU	-10	45	-20	55	1.27	21.48	-2.47
702	ACC	-10	45	-20	55	-1.67	17.69	-3.13
703	BATT1	0	35	-10	45	4.63	24.57	6.89
704	PCDU	-10	45	-20	55	25.63	40.11	13.14
705	QRS1	-15	45	-25	55	14.61	35.82	5.86
706	QRS2	-15	45	-25	55	10.02	34.42	4.27
707	PDU	-15	45	-25	55	11.84	31.91	-4.18
900	He TANK +Z	10	40	10	40	17.00	29.00	13.00
905	He TANK +Y	10	40	10	40	17.00	29.00	13.00
910	He TANK -Z	10	40	10	40	17.00	32.22	13.00
915	He TANK -Y	10	40	10	40	17.00	29.00	13.00
920	P TANK +Y+Z	10	40	10	40	14.34	36.68	13.00
925	P TANK -Z	10	40	10	40	13.88	37.24	13.00
930	P TANK -Y+Z	10	40	10	40	13.80	36.16	13.00

Table 4.2.5.1-1 PLANCK - Unit Temperatures Results

4.2.5.2 Transient Temperature results

A summary results of the transient analysis is reported in the following pages.
In Table 4.2.5.2-1 are reported minimum temperature results in cold case (BOL3) and in Table 4.2.5.2-2 the maximum one for the hot case (EOL8) :

NODE	LABEL	TIME [^C]	TMIN [^C]	MIN LIMIT [^C]
11	STR1	265800	12.3	-20
12	STR2	265800	17	-10
13	DPU1	266400	8.9	-10
14	DPU2	264600	15	-20
15	REU	267000	14.5	-20
101	DCCU	264600	19.3	-10
102	REBA1	278400	12.5	-30
103	REBA2	265800	29.8	-20
201	4 CCU	277200	28.3	-10
202	4 CAU	276600	4.5	-10
203	4 PRE-RE	277800	15.4	-10
204	CEU	264000	22.4	-10
401	SCE1	332400	-0.7	-10
402	SCE2	332400	-4.4	-20
521	BEU	177600	21	-20
522	PAU	261600	22	-20
525	DAE POWER BOX	178200	30.7	-20
551	QRS3	259800	15.1	-15
601	XPND_1	264600	21.7	-10
602	XPND_2	259800	15.1	-20
603	TWTA_1	259200	10.8	-15
604	TWTA_2	259800	-6.3	-25
605	RFDN	259200	5.9	-40
606	EPC1	259200	3.4	-15
607	EPC2	259200	-6.6	-25
701	CDMU	264000	10.9	-10
702	ACC	264000	7.9	-10
703	BATT	264000	14.5	0
704	PCDU	264000	35.2	-10
705	QRS1	261000	24.7	-15
706	QRS2	260400	20	-15
707	PDU	277800	21.4	-15
900	Helium Tank	345600	13.9	10
905	Helium Tank	345600	14.9	10
910	Helium Tank	277800	19.2	10
915	Helium Tank	345600	14.6	10
920	Prop. Tank	177000	24	10
925	Prop. Tank	177000	23.8	10
930	Prop. Tank	177000	23.7	10
8001	External S.A.	262800	108.1	-160

NODE	LABEL	TIME [^C]	TMIN [^C]	MIN LIMIT [^C]
8002	External S.A.	202200	107.1	-160
8003	External S.A.	259200	106.4	-160
8004	External S.A.	263400	107.8	-160
8051	Back External S.A.	262800	107.8	-160
8052	Back External S.A.	202200	106.7	-160
8053	Back External S.A.	259200	106.1	-160
8054	Back External S.A.	263400	107.5	-160
8301	Central S.A.	261600	114.2	-160
8302	Central S.A.	261000	113.8	-160
8303	Central S.A.	260400	113.8	-160
8304	Central S.A.	260400	113.9	-160
8351	Back Central S.A.	261600	113.9	-160
8352	Back Central S.A.	261000	113.5	-160
8353	Back Central S.A.	260400	113.5	-160
8354	Back Central S.A.	260400	113.6	-160

Table 4.2.5.2-1 PLANCK - Cold Transient Analysis Results

NODE	LABEL	TIME [^C]	TMAX+UFP [^C]	MAX LIMIT [^C]
11	STR1	335400	23.9	40
12	STR2	335400	28.5	30
13	DPU1	335400	19.6	40
14	DPU2	335400	26.6	50
15	REU	335400	25.7	30
101	DCCU	335400	31.3	40
102	REBA1	335400	24.3	70
103	REBA2	335400	41	50
201	4 CCU	335400	39.9	40
202	4 CAU	335400	15.8	40
203	4 PRE-RE	335400	26.6	40
204	CEU	335400	33.6	40
401	SCE1	288000	7.9	40
402	SCE2	288000	2.8	50
521	BEU	334800	38	40
522	PAU	334800	36.5	40
525	DAE POWER BOX	334800	42.7	45
551	QRS3	332400	28.4	45
601	XPND_1	344400	29.5	50
602	XPND_2	334800	27.6	60
603	TWTA_1	340800	25.4	50
604	TWTA_2	334800	6.9	60
605	RFDN	334200	21	70
606	EPC1	334200	13.4	45
607	EPC2	334800	6.8	55
701	CDMU	334800	21.2	45
702	ACC	334800	17.5	45
703	BATT	334800	24.2	35
704	PCDU	334800	39.8	45
705	QRS1	334800	35.3	45
706	QRS2	334800	33.9	45
707	PDU	335400	31.7	45
900	Helium Tank	172800	25.4	45
905	Helium Tank	172800	26.8	45
910	Helium Tank	336600	32.1	45
915	Helium Tank	172800	27.1	45
920	Prop. Tank	336600	36.5	45
925	Prop. Tank	336000	37.1	45
930	Prop. Tank	335400	35.9	45
8001	External S.A.	329400	126.9	120
8002	External S.A.	328200	126.8	120
8003	External S.A.	328200	126.6	120
8004	External S.A.	340200	126.5	120
8051	Back External S.A.	334800	126.5	120
8052	Back External S.A.	328200	126.5	120
8053	Back External S.A.	328200	126.2	120

NODE	LABEL	TIME [^C]	TMAX+UFP [^C]	MAX LIMIT [^C]
8054	Back External S.A.	253800	126.1	120
8301	Central S.A.	326400	130.1	120
8302	Central S.A.	331800	129.9	120
8303	Central S.A.	329400	129.7	120
8304	Central S.A.	331800	129.7	120
8351	Back Central S.A.	333000	129.8	120
8352	Back Central S.A.	331800	129.6	120
8353	Back Central S.A.	329400	129.3	120
8354	Back Central S.A.	329400	129.3	120

Table 4.2.5.2-2 PLANCK - Hot Transient Analysis Results

For SCC zone are reported the following graphics presented in Figure 4.2.5.2-1&3 for the temperature variation of the working SCC in Cold/Hot configuration .
In Figure 4.2.5.2-2&4 are depicted the I/F point temperature , instead in Figure 4.2.5.2-5&6 is represent a zoom of the temperature variation of the working SCC where the limit to reach are declared below in Table 4.2.5.2-3:

SCC	Sorption Cooler Compressor	+/-3 K	(3K,1K,0.5K)**

Note (**) : +/- 3K for First adjacent element
+/- 1K for the Next adjacent element
+/- 0.5 for Next most element

Table 4.2.5.2-3 PLANCK - SCC requirement

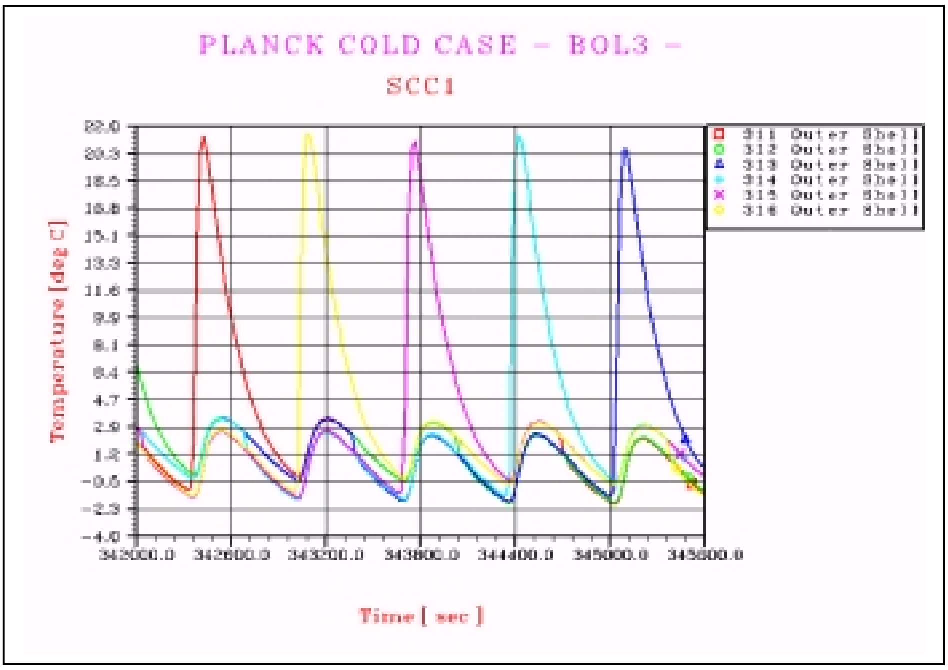


Figure 4.2.5.2-1 PLANCK – SCC Outer Shell’s Temperature

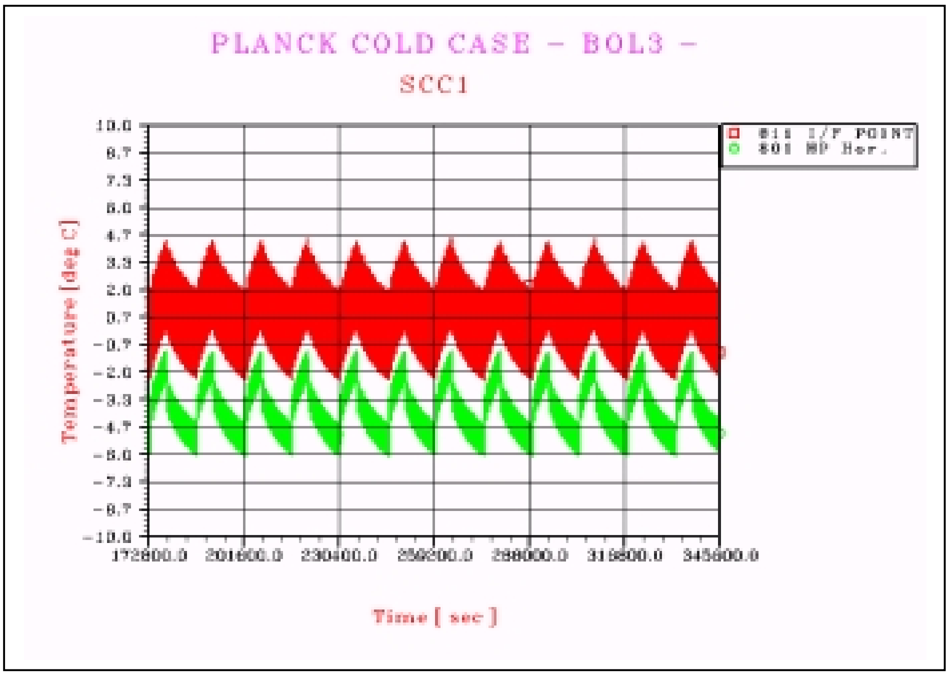


Figure 4.2.5.2-2 PLANCK – SCC I/F POINT Temperature

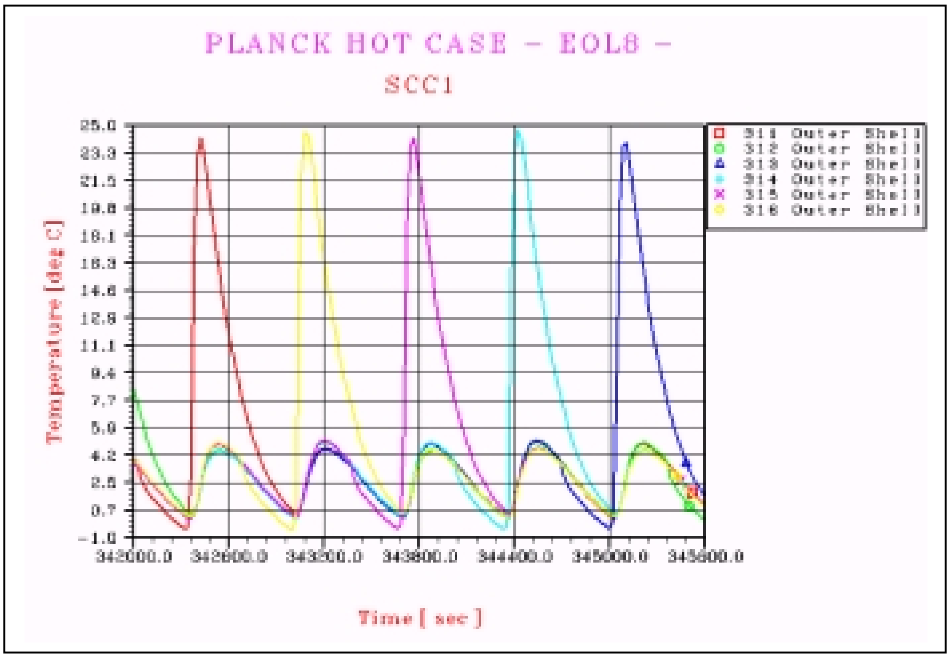


Figure 4.2.5.2-3 PLANCK – SCC Outer Shell-H.P. I/F Temperature

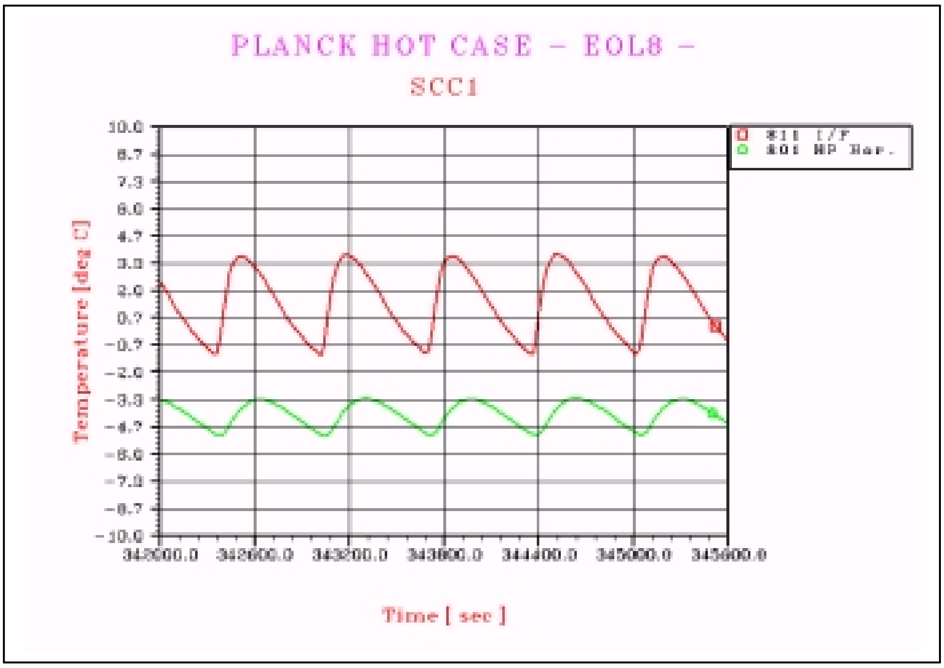


Figure 4.2.5.2-4 PLANCK – SCC I/F POINT Temperature

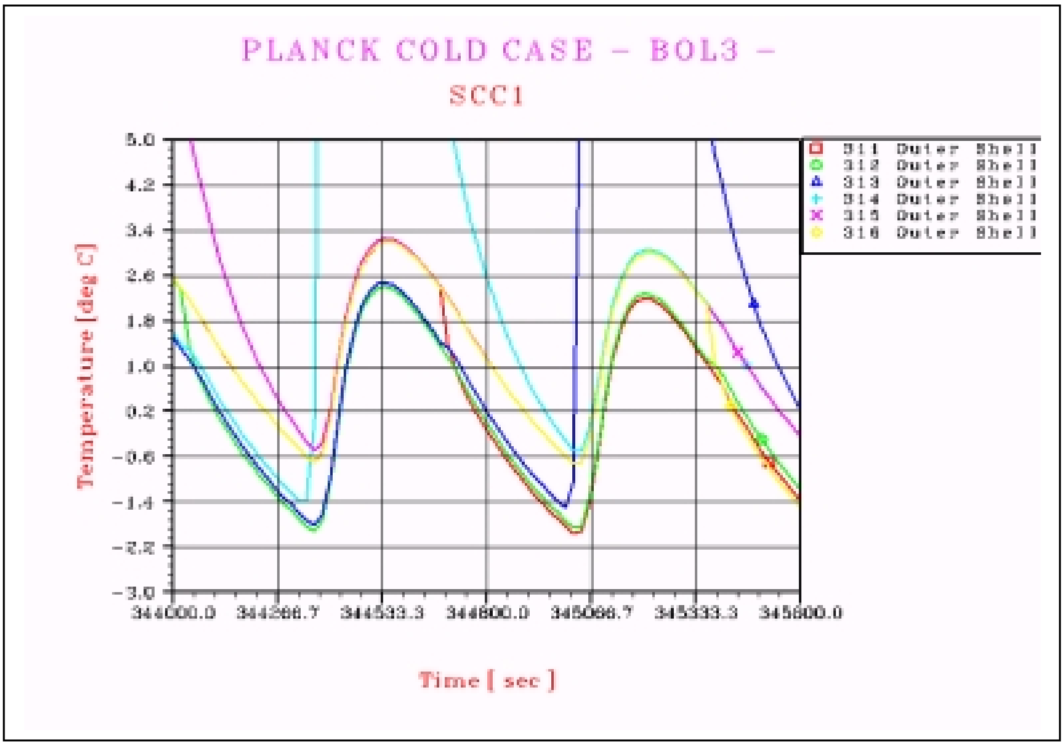


Figure 4.2.5.2-5 PLANCK – SCC Outer Shell's Temperature

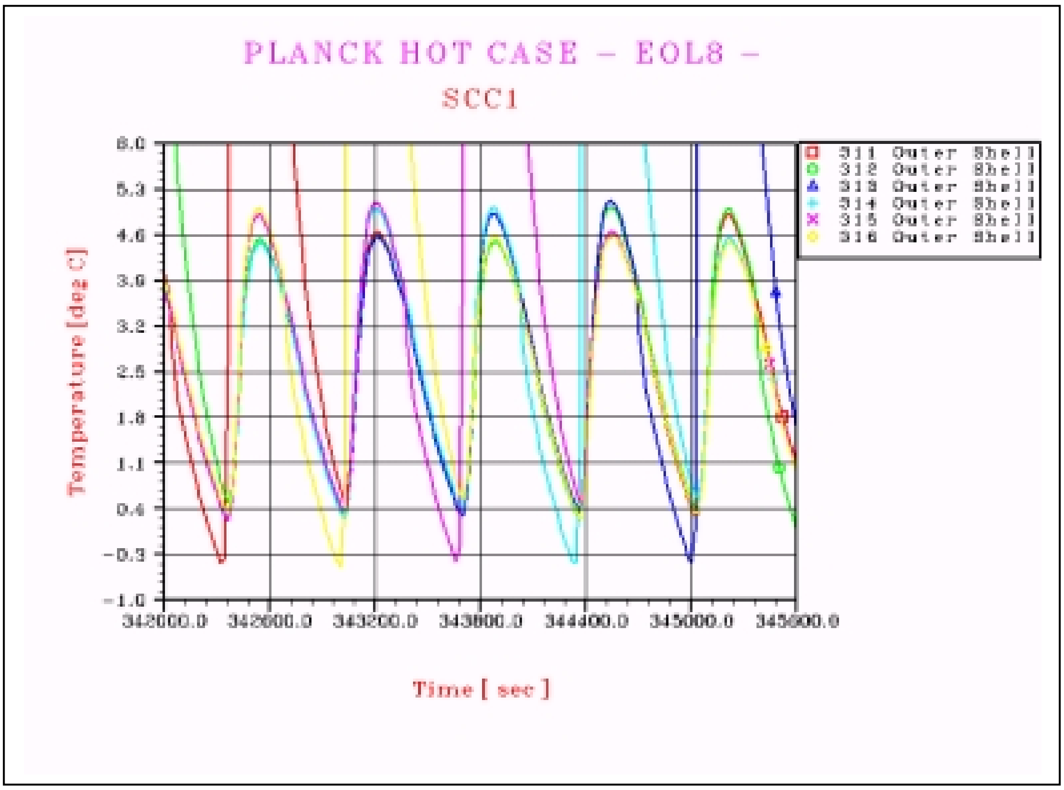


Figure 4.2.5.2-6 PLANCK – SCC Outer Shell's Temperature

For SCC panels and SVM/PLM interface points, the average value of all panel nodes temperature has been considered in the evaluation of the temperature variation with their respective limit requirements reporetd in Table 4.2.5.2-4, Table 4.2.5.2-5 for both cases :
The spectral density has been calculated with one measurement every 20 sec , 7200 sec before the end of transient duration .

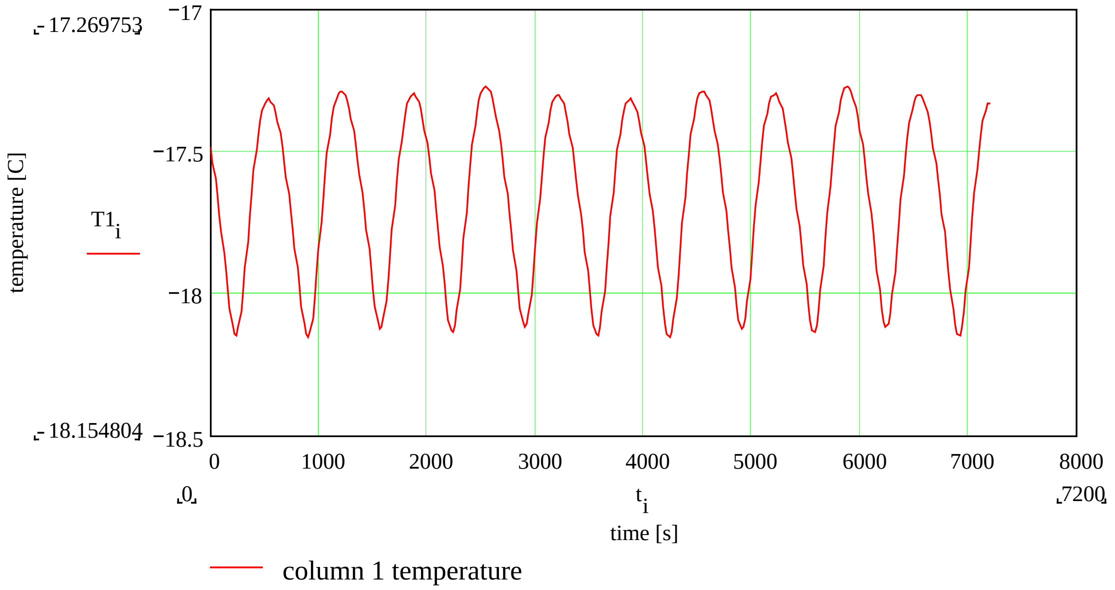
node	description	Requirement 1/60 Hz	COLD CASE Results K/Hz$^{1/2}$	HOT CASE Results K/Hz$^{1/2}$
3001-16	L/P +Z	0.01 (TBC)	4.85e-4	7.8 e-4
3101-24	L/P +Z,+Y	0.01 (TBC)	8.97e-4	1.2 e-3
3201-16	L/P +Y	0.01 (TBC)	2.21 e-3	1.11 e-3
3301-24	L/P -Z,+Y	0.01 (TBC)	0.277	0.26
3401-16	L/P -Z	0.01 (TBC)	0.247	0.23
3501-24	L/P -Z,-Y	0.01 (TBC)	0.158	0.06
3601-16	L/P -Y	0.01 (TBC)	0.048	0.04
3701-24	L/P +Z,-Y	0.01 (TBC)	3.09 e-3	2.6 e-3

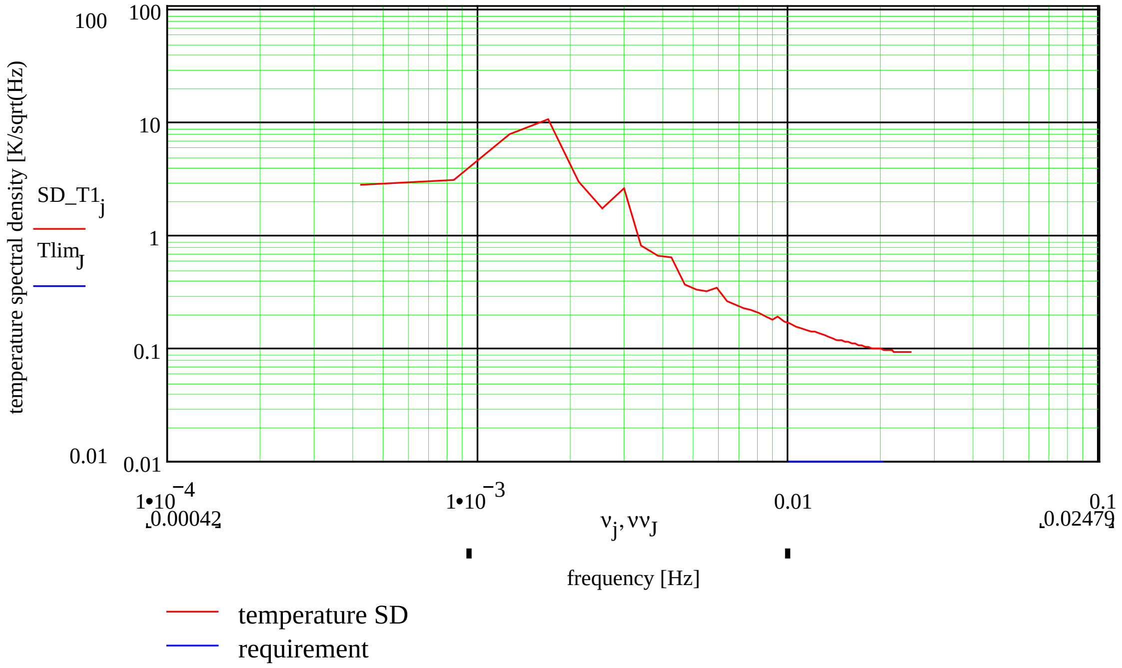
Table 4.2.5.2-4 PLANCK - SCC ASD results

nodes	description	Requirement 1/60 Hz	COLD CASE Results K/Hz$^{1/2}$	HOT CASE Results K/Hz$^{1/2}$
7304	I/F SVM	T.B.D.	2.66 e-3	3.14 e-3
7310	I/F SVM	T.B.D.	8.37 e-3	5.54 e-3
7315	I/F SVM	T.B.D.	.0101	5.44 e-3
7325	I/F SVM	T.B.D.	5.087e-3	6.81 e-3
7330	I/F SVM	T.B.D.	0.0125	0.02 e-3
7337	I/F SVM	T.B.D.	3.167 e-3	3.9 e-3

Table 4.2.5.2-5 PLANCK - I/F SVM/PLM ASD results

Typical spectral density calculation:





The software used is MathCad and the Fourier transform is computed as follow:

$$S_j = \frac{1}{\sqrt{N+1}} {}_{k=0}^{N} s_K e^{\frac{2\pi ijk}{(N+1)}}$$

(Note: the normalization

$$\frac{1}{\sqrt{N+1}}$$

is that utilized by MathCad for the computation of the discrete Fourier trasform.)

The PSD$_{sj}$ is computed as follow:

$$PSD_{sj} = 2\frac{\left|S_j\right|^2}{N+1} t_{\max} = 2N\Delta t \frac{\left|S_j\right|^2}{N+1}$$

and consequently the ASD$_{sj}$ is:

$$ASD_{sj} = \sqrt{PSD_{s,j}} = \sqrt{2N\Delta t} \frac{\left|S_j\right|}{\sqrt{N+1}}$$

4.2.5.3 SUBPLATFORM UNITS

This paragraph is dedicated at the subplatform zone where are located the followings units :

BEU and PAU: on + X side SUBPLATFORM
DAE mounted on - X side (internal zone).

Thermal filler is interposed between unit baseplate and floor, the obtained linear conductor result to be :

PAU	10.60	[W/ K]
DAE	1.95	[W/ K]
BEU	12.29	[W/ K]

Only for BEU unit has been considered a thermal doubler of 9mm interposed between, baseplate unit - doubler up face and doubler lower face - subplatform floor.

DAE : external thermal properties ,black paint , epsilon = .9

BEU/PAU: These units are externally covered with a MLI 10 layer and one side of each unit Vs space is black paint painted in order to reject the his power dissipation see Figure 4.2.5.3-1 PLANCK - BEU, PAU , DAE

BEU - PAU

Mli = .728 m^2 - .492 m^2

Black paint = .112 m^2 - .030 m^2

Mli composition : 10 LAYER

Boundary condition : Groove Shield 80 K / 160 K (COLD/HOT case).

A summary of the temperature requirement has been reported in Table 4.2.5.3-1 PLANCK - Transient Analysis Results:

		Requirement	**Goal**	Results
NODE		Delta Temp.	Delta Temp.	Temp. Variation / 3600 s
		/ 3600 s	/ 3600 s	Dtmax
		[K]	[K]	[K]
	COLD CASE			
521	BEU	+/-3 K/hour	+/-0.2 K/hour	0.40 K/hour
522	PAU	+/-3 K/hour	+/-1.1 K/hour	0.82 K/hour
	HOT CASE			
521	BEU	+/-3 K/hour	+/-0.2 K/hour	0.32 K/hour
522	PAU	+/-3 K/hour	+/-1.1 K/hour	0.84 K/hour

Table 4.2.5.3-1 PLANCK - Transient Analysis Results

In Table 4.2.5.3-2 has been calculated the flux incident on V-groove shield due to radiative flux :

NODE	UNIT	Requirement Flux	**Calculated Flux**	
521	BEU	2.3 W	1.49 W	COLD CASE
522	PAU	2.3 W	0.36 W	COLD CASE
521	BEU	2.3 W	1.54 W	HOT CASE
522	PAU	2.3 W	0.36W	HOT CASE

Table 4.2.5.3-2 PLANCK - Flux requirement

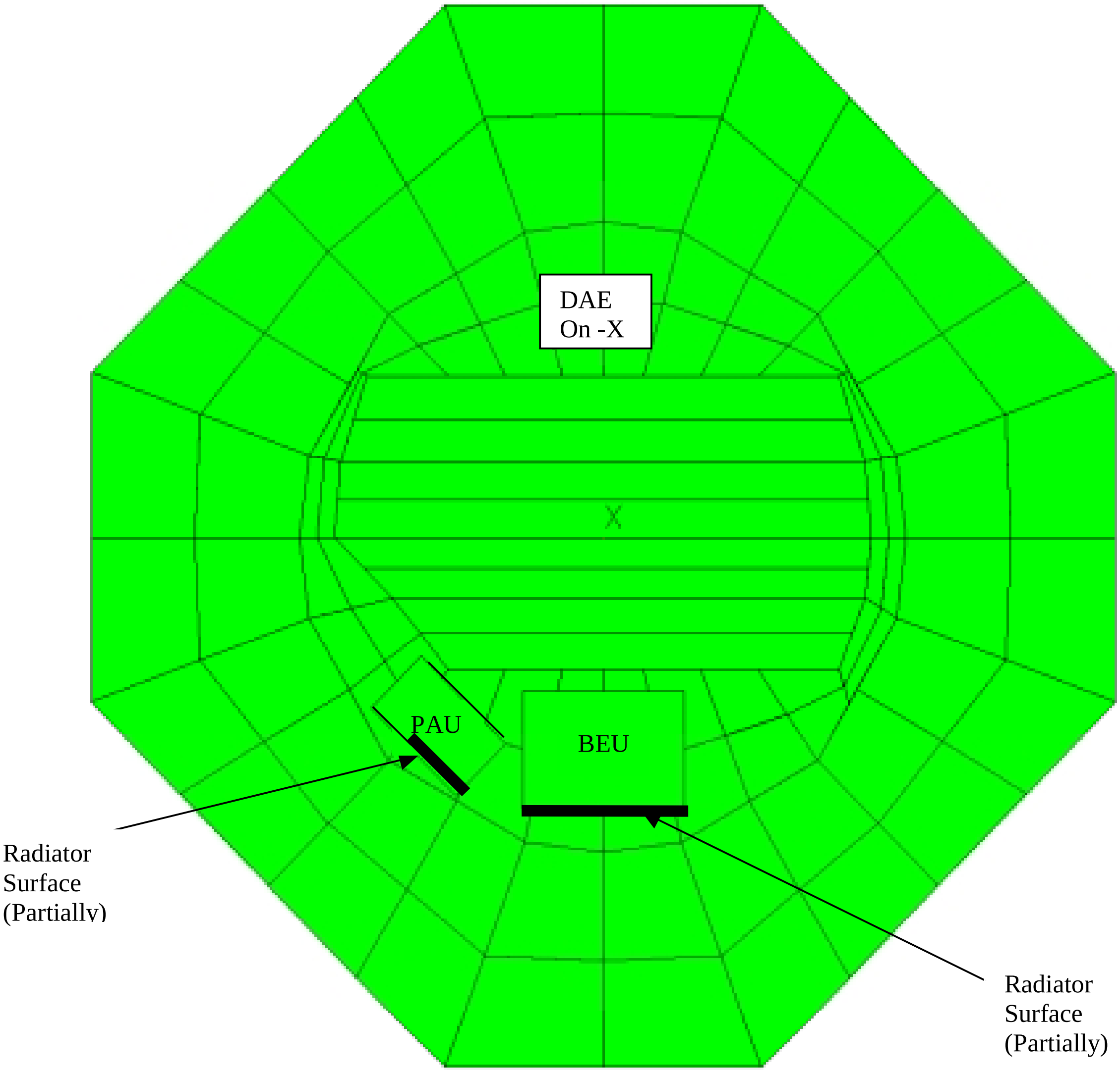


Figure 4.25.3-1 PLANCK – BEU, PAU & DAE design concept

4.2.5.4 Survival Transient results

A summary of the temperature results are reported in table 4.2.5.4-1:

NODE	LABEL	TIME [^C]	TMIN [^C]	MIN LIMIT [^C]
11	STR1	186600	-15.1	-20
12	STR2	183000	-16.3	-20
13	DPU1	169800	-17	-20
14	DPU2	190800	-13.7	-20
15	REU	181800	-26.8	-30
101	DCCU	130200	-11.8	-20
102	REBA1	129600	-18.7	-30
103	REBA2	129600	-24.4	-30
201	4 CCU	154200	-17	-20
202	4 CAU	153600	-7.5	-20
203	4 PRE-RE	152400	-17	-20
204	CEU	152400	-18.5	-20
401	SCE1	252600	-17	-20
402	SCE2	210000	-17	-20
521	BEU	155400	-30	-30
522	PAU	137400	-17.4	-20
525	DAE POWER BOX	129600	-5.6	-20
551	QRS3	143400	-10.7	-25
601	XPND_1	142800	2.7	-10
602	XPND_2	192600	-1.7	-20
603	TWTA_1	229200	-12	-15
604	TWTA_2	130800	-23	-25
605	RFDN	229200	-20.4	-40
606	EPC1	229200	-15.3	-15
607	EPC2	130800	-23.8	-25
701	CDMU	178200	-4	-10
702	ACC	178200	-8.5	-10
703	BATT	178200	2.1	0
704	PCDU	181200	10.8	-10
705	QRS1	180000	2.8	-15
706	QRS2	180000	1.7	-15
707	PDU	187200	-4.6	-15
900	Helium Tank	227400	13	10
905	Helium Tank	150000	13	10
910	Helium Tank	216600	13	10
915	Helium Tank	214200	13	10
920	Prop. Tank	137400	13	10
925	Prop. Tank	137400	13	10
930	Prop. Tank	129600	13	10
8001	External S.A.	159000	98.9	-160
8002	External S.A.	226800	97.9	-160
8003	External S.A.	149400	97.3	-160

NODE	LABEL	TIME [^C]	TMIN [^C]	MIN LIMIT [^C]
8004	External S.A.	179400	98.7	-160
8051	Back External S.A.	159000	98.5	-160
8052	Back External S.A.	226800	97.5	-160
8053	Back External S.A.	244200	96.9	-160
8054	Back External S.A.	179400	98.3	-160
8301	Central S.A.	135600	105	-160
8302	Central S.A.	135600	104.6	-160
8303	Central S.A.	136800	104.6	-160
8304	Central S.A.	186600	104.7	-160
8351	Back Central S.A.	135600	104.6	-160
8352	Back Central S.A.	135600	104.2	-160
8353	Back Central S.A.	136800	104.2	-160
8354	Back Central S.A.	186600	104.4	-160

Table 4.2.5.4-1 PLANCK - Survival Temperature results

In the next page are reported in Figure 4.2.5.4-1/2 the temperature limits reached by SCE units, controlled with a thermostat set at T ON -17/ T OFF -12 deg , in both conditions (BOL3 and EOL8)

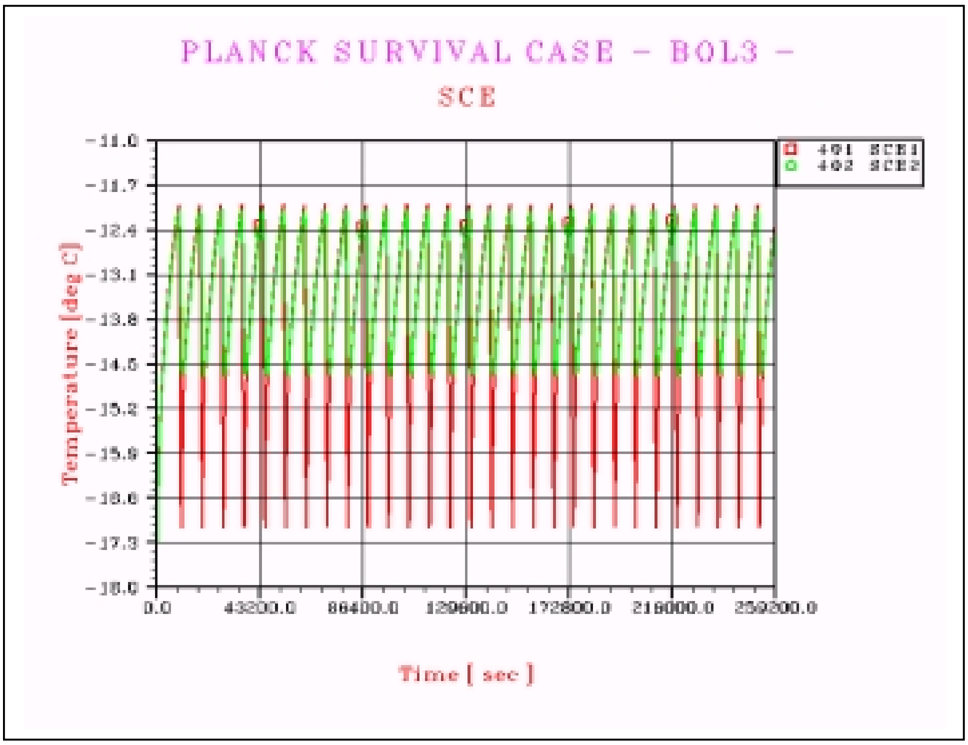


Figure 4.2.5.4-1 PLANCK - SCE

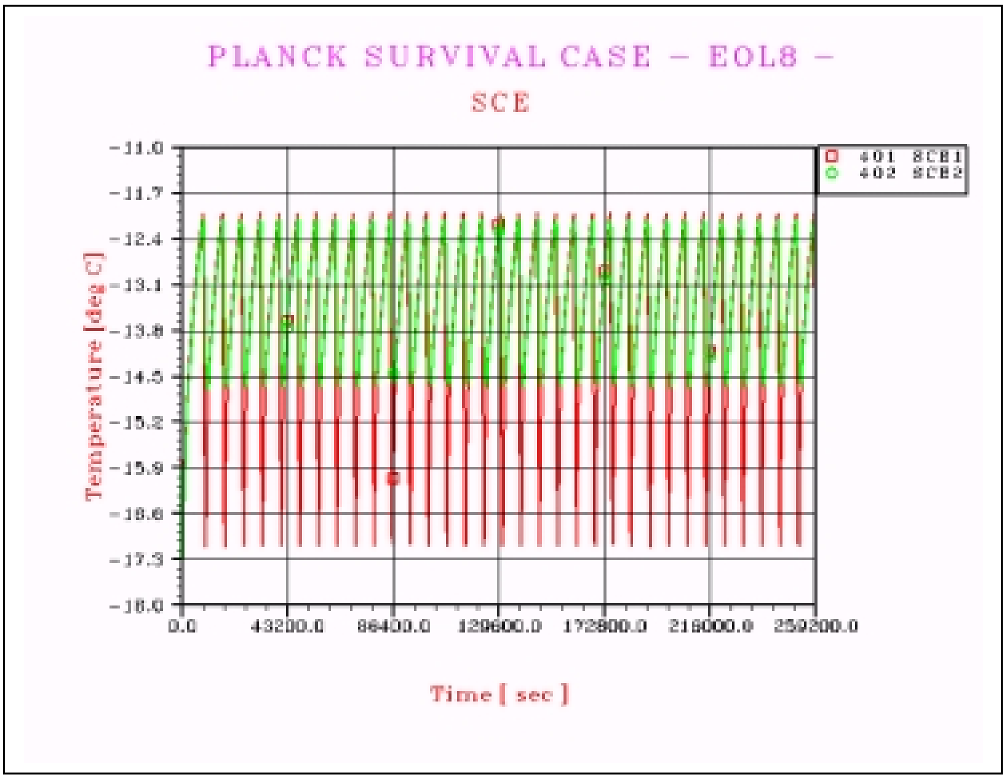


Figure 4.2.5.4-2 PLANCK - SCE

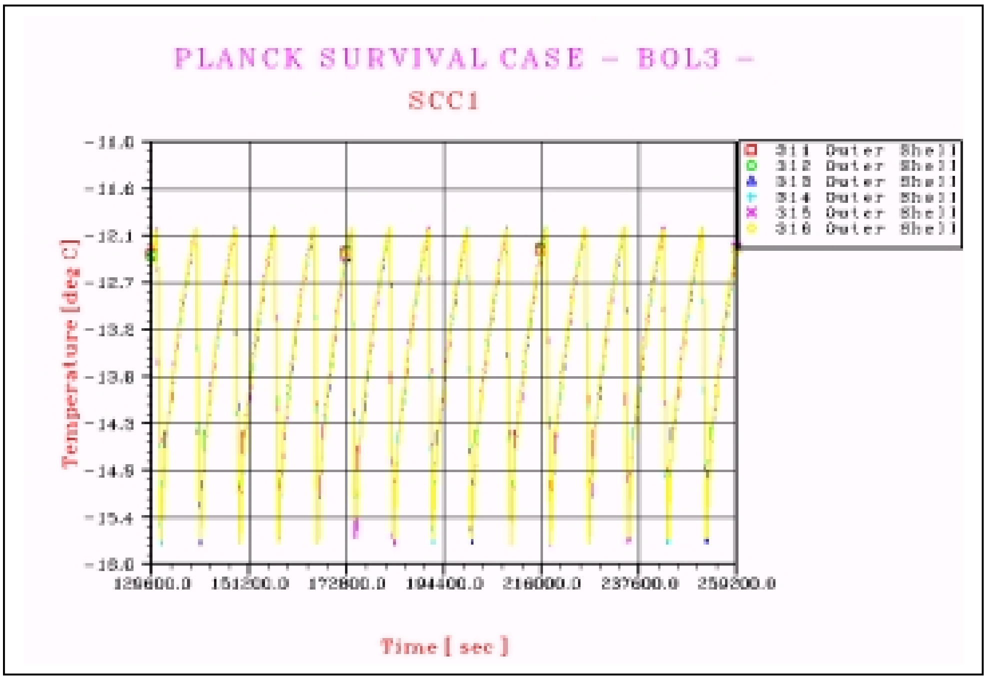


Figure 4.2.5.4-3 PLANCK - SCC Outer Shell's Temperatures

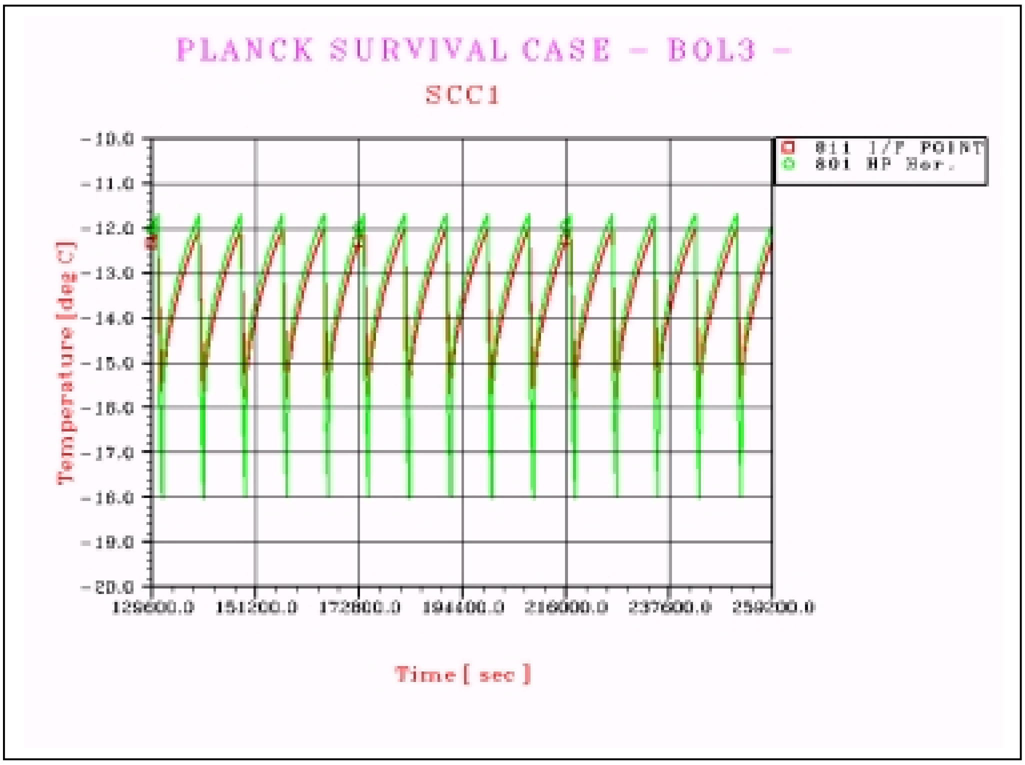


Figure 4.2.5.4-4 PLANCK - SCC I/F POINT Temperatures

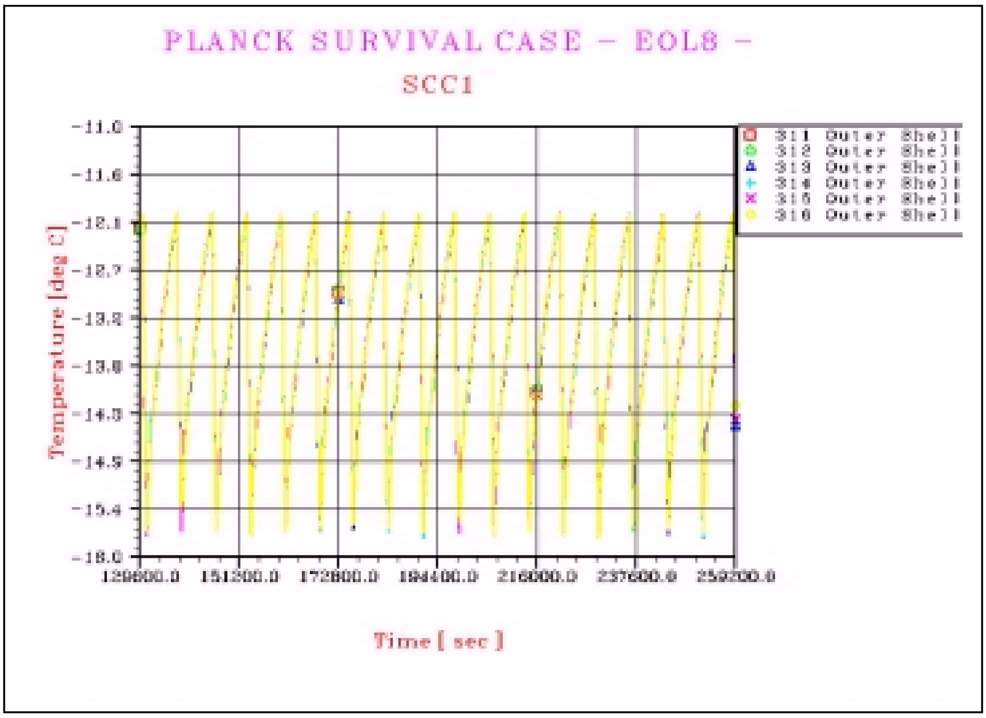


Figure 4.2.5.4-5 PLANCK - SCC Outer Shell's Temperatures

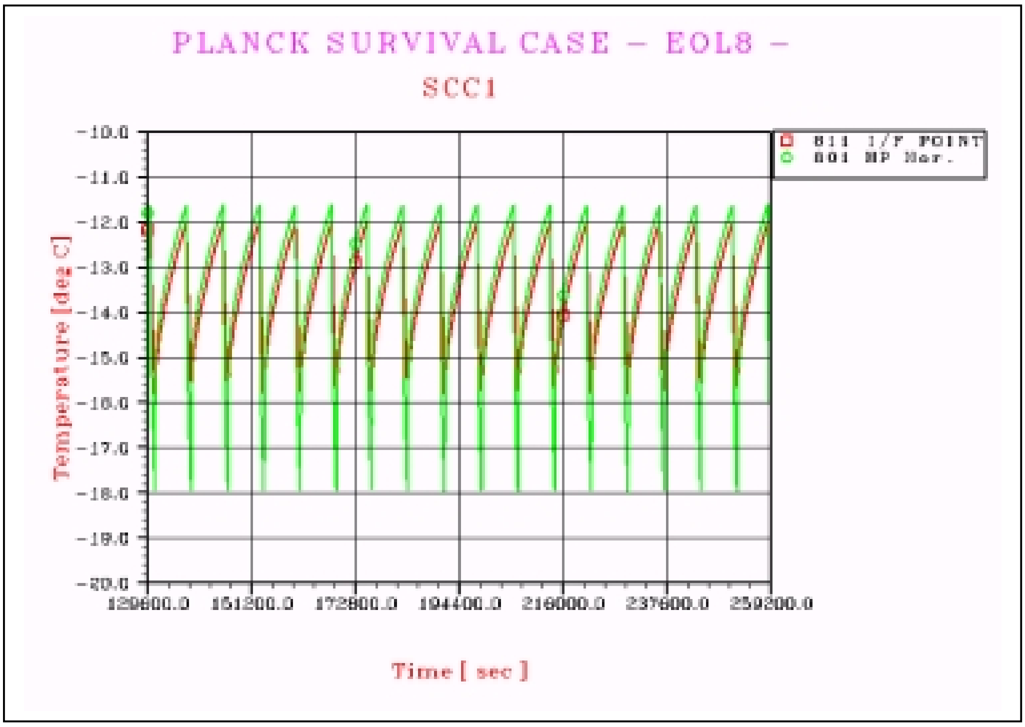


Figure 4.2.5.4-6 PLANCK - SCC I/F POINT Temperatures

4.2.5.5 Tank Temperature results

A trade-off concerning the temperature stability of the propellant tanks has been made and provided during the TCS PM#1.

4.2.6 Heater Power Summary

The Table 4.2.6-1 shows the Average heater power need during BOL/EOL condition and in Table 4.2.6-2 during a Survival mode in BOL and EOL phase.

ID. HEAT.	**HEATER LOCATION**	**BOL3**	**EOL8**
HTR-MA1	HTR TWTA1-EPC1-TRANSX1	46.75	42
HTR-MB1	HTR BATTERY/CDMU/ACC	0	0
HTR-MC1	HTR HP801/HP802	20.85	0
HTR-MC2	HTR HP803/HP804	0.9	0
HTR-MC3	HTR HP805/HP806	60	0
HTR-MC4	HTR HP807/HP808	60	0
HTR-MH1	Helium Tank1	0	0
HTR-MH2	Helium Tank2	0	0
HTR-MH3	Helium Tank3	0	0
HTR-MH4	Helium Tank4	0	0
HTR-MH10	Thrusters 20 N	0	0
HTR-MH11	Thrusters 20 N	0	0
HTR-MH12	Thrusters 20 N	0	0
HTR-MH13	Thrusters 20 N	0	0
HTR-MH14	Thrusters 20 N	1.2	0.94
HTR-MH15	Thrusters 20 N	1.35	1
HTR-MH8	Thrusters 1 N	0	0
HTR-MH9	Thrusters 1 N	0	0
HTR-MI1	HTR STR1	0	0
HTR-MI2	HTR STR2	0	0
HTR-MH16/17/18	LINEE	16.5	16.5
HTR-MI3/4	SAS	0	0
	Total Heater need [W] :	207.55	60.44

Table 4.2.6-1 PLANCK – Nominal Heater Power need

ID. HEAT.	HEATER LOCATION	SURV_BOL3	SURV_EOL8
HTR-MA2	HTR TWTA1-EPC1-TRANSX1	4.3	2.84
HTR-MA4	HTR TWTA2-EPC2-TRANSX2	0	0
HTR-MD1	HTR DPU/REU	51.7	49.2
HTR-ME1	HTR REBA1/REBA2/DCCU	0	0
HTR-MF1	HTR CCU/CAU	60	58.5
HTR-MF2	HTR PRE-REG/CEU	29.3	26.8
HTR-MB1	HTR BATTERY/CDMU/ACC	28	17.1
HTR-MC5	HTR HP801	67	65.6
HTR-MC6	HTR HP802	67	65.6
HTR-MC7	HTR HP803	67	65.6
HTR-MC8	HTR HP804	67	65.6
HTR-MC9	HTR HP805	75	75
HTR-MC10	HTR HP806	75	75
HTR-MC11	HTR HP807	75	75
HTR-MC12	HTR HP808	75	75
HTR-MH1	Helium Tank1	1.3	1.2
HTR-MH2	Helium Tank2	1.1	1.02
HTR-MH3	Helium Tank3	0.65	0.6
HTR-MH4	Helium Tank4	0.73	0.7
HTR-MH5	Prop. Tank1	2	2
HTR-MH6	Prop. Tank2	2	2
HTR-MH7	Prop. Tank3	2	2
HTR-MH10	Thrusters 20N	0	0
HTR-MH11	Thrusters 20N	0	0
HTR-MH12	Thrusters 20N	0	0
HTR-MH13	Thrusters 20N	0	0
HTR-MH14	Thrusters 20N	2.98	2.83
HTR-MH15	Thrusters 20N	2.69	2.57
HTR-MH8	Thrusters 1N	4	4
HTR-MH9	Thrusters 1N	2.46	2.34
HTR-MI1	HTR STR1	0	0
HTR-MI2	HTR STR2	0	0
HTR-MH16/17/18	LINEE	33	33
HTR-MI3/4	SAS	0	0
HTR-MK1	PAU	0	0
	Total Heater need [W] :	796.21	771.1

Table 4.2.6-2 PLANCK – Survival Heater Power need

4.2.7 PLANCK – CONCLUSION

Sizing cases Analyses

All units are within the required temperature range. The goal requirement is not met for:

☐ **BEU/DAE:**	T= 38.0 °C	vs 28 °C as goal
☐ **PAU:**	T= 36.5 °C	vs 30 °C as goal
☐ **DAE POWER UNIT:**	T= 42.7 °C	vs 28 °C as goal

The analysis results show that **Solar Array** temperature is 130 °C.
S.A. temperature requirement to be verified when the supplier will be selected.

Transient analyses

All units are within specification.

Remark:

For the SCC, the temperature requirement in Hot cases is + 7°C. As shown in figure Figure 4.2.5.4-3÷6 (PLANCK – SCC Outer Shell-H.P. I/F Temperature), the temperature profile is going from –1°C to +3.5°C (without 7 °C of uncertainty).

The results of Radiative Panels Amplitude Spectral Density are given in table 4.2.5.2-4. The requirement (TBC) of 0.01 $K/Hz^{1/2}$ is met for all the panels except fot the SCC/SCE ones. Concerning the ASD at the interface truss no requirement is specified but in any case the results of the calculation are given in Table 4.2.5.2-5.

TANK

Trade-off analyses, showing the different impact due to the connection between Tank and Structure, have been presented during a TCS PM1.
The baseline solution foresees the use of rear support bracket made in Titanium and the Upper/Lower support brackets made in CFRP + Aluminium.
The stability of the gradient between each tank is equal to 0.4 K (stability requirement is 0.1K). Additional trade-offs are on going; possible relaxation of the requirement is under investigation at System level.

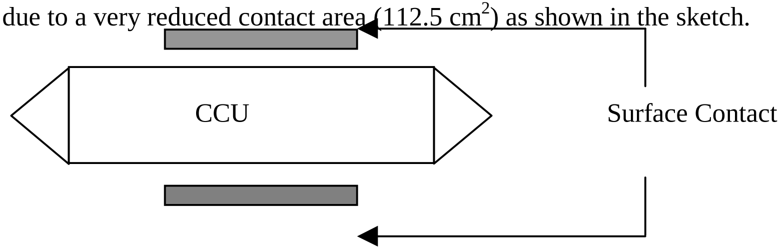
SCC Temperature stability absorbing compressor/adjacent element

This requirement is not completely understood, further clarifications are needed.

Specific open point

- A consistent decrease in term of heaters power, during the survival mode, will be possible changing the Not-operative temperature limit for the SCE (-20°C).
  Actually this unit is mouting on the same Heat Pipes bench used for the SCC that have a not operative limit equal to –50°C.

- Thermal dissipation of the 4CCU has increased; this unit is mounted on the +Y panel with a very low linear conductor due to a very reduced contact area (112.5 cm^2) as shown in the sketch.



Its power dissipation value is now 60 Watt.

To reject the heat flux in hot case, an over-sizing of the external radiator has been realized. During the cold case is necessary a large amount of heater power to maintain the item mounted on this panel within the temperature requirement.

As written in MoM- Planck configuration (H-P-MI-AI-0096), Alenia request to improve the baseplate contact area between the 4CCU and the panel (a possible proposal solution as shown hereafter) in order to optimize the thermal design and consequently reduce the heater power dissipation