HERSCHEL/PLANCK

SVM USER MANUAL

CHAPTER 4 SVM SUBSYSTEM DEFINITION

CHAPTER 4.1 CONTROL AND DATA MANAGEMENT SUBSYSTEM

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1. LIST OF ACRONYMS

Acronyms	Definitions
ASW	Application Software
ACC	ACMS Control Computer
ACMS	Attitude Control and Measurement Subsystem
AFO	Autonomous Fail Operational
AFS	Autonomous Fail Safe
BC	Bus Controller
BOL	Beginning Of Life
BSW	Basic Software
CFK	Carbon Filled Kapton
CDMU	Central Data Management Unit
DOD	Depth Of Discharge
DTC	Direct Telecommand
DTM	Direct Telemetry
EAT	Event Action Table
EOL	End Of Life
FCL	Fold-back Current Limiter
FCV	Flow Control Valve
FHWOH	Wide-Band Optics Horizontal Polarization.
FHWOV	Wide-Band Optics Vertical Polarization
GYR	Gyroscope
HCS	Heater Control Switch.
HIFI	Herschel Heterodyne Instrument for the Far Infrared
HPS	Heater Protection Switch.
LCL	Latching Current Limiter
LSB	Least Significant Bit
MLI	Multi Layer Insulation
MOT	Monitoring Table
MSB	Most Significant Bit
NOP	Non Operative
NRZ	Non Return to Zero
OP	Operative

Acronyms	Definitions
OSR	Optical Solar Reflector
PCDU	Power Control Distribution Unit
PCS	Power Control System
PLM	Payload Module
RCS	Reaction Control System
RF	Radio Frequency
RFDN	Radio Frequency Distribution Network
RT	Remote Terminal
RWL	Reaction Wheel
S/C	Spacecraft or Satellite
SAS	Sun Acquisition Sensor
SCC	Sorption Cooler Compressor
SCE	Sorption Cooler Electronic
SP-L	Shifted Phase-L
SSM	Second Surface Mirrors
STR	Star Tracker
TBC	To Be Confirmed
TBD	To Be Defined
TBW	To Be Written
TC	Telecommand
TCS	Thermal Control Subsystem
TCT	Thermal Control Table
THM	Thermistors
TM	Telemetry
TWTA	Telemetry Wave Tube Amplifier
TWTAs	Telemetry Wave Tube Assembly
XPND	Transponder

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2. DOCUMENTS

2.1. APPLICABLE DOCUMENTS

Acronym	Title	Code

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2.2. ANNEXED APPLICABLE DOCUMENTS

Acronym	Title	Code

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2.3. REFERENCE DOCUMENTS

Acronym	Title	Code
[TCSRS]	SVM Thermal Control Subsystem Specification	H-P-SP-AI-0007
[MLIRS]	SVM TCS Thermal Blankets (MLI) and Hardware Specification	H-P-SP-AI-0017
[HPRS]	Heat Pipes Specification	H-P-SP-AI-0018
[TCSDD]	TCS Design Description	H-P-RP-AI-0039
[FLAW]	Fine Control Law Analysis, Issue 2	H-P-TN-AI-0060
[HTDL]	Heaters and Thermistors description and layout	H-P-TN-AI-0069
[THICD]	SVM Thermal Interface Control Document	H-P-IC-AI-0002
[THAN]	SVM TCS Thermal Analysis	H-P-RP-AI-0040
[PSATHAN]	Planck Solar Array Thermal Analysis	H-P-TN-AI-0017
[STDEF]	Star Tracker Assembly Definition	H-P-TN-AI-0076
[PHPDEF]	Planck Heat Pipes Network Definition and Interface	H-P-TN-AI-0020
[THIFCO]	Thermal Hardware Interfaces and Constraints	H-P-TN-AI-0063
[RCSTHAN]	RCS Lines and Units Thermal Analysis and Heater Sizing	H-P-TN-AI-0080
[RCSHTIN]	RCS Units and Pipelines Heaters and Thermistors Installation	H-P-TN-AI-0104
[SOFDIR]	System Operations and FDIR Requirements	H-P-1-ASPI-SP-0209
[FDIRSPEC]	SVM FDIR Design Specification	H-P-TN-AI-0024
[CDMUASWRS]	CDMU Application Software Requirements Specification	H-P-SP-AI-0031

Acronym	Title	Code
[CDMUASWICD]	CDMU Application Software Interface Control Document	H-P-4-SSF-IC-0001
[CDMUASWUM]	CDMU Application Software User Manual	H-P-4-SSF-MA-0001
[CDMUBSWICD]	CDMU Software Interface Control Document for the Basic Software	H-P-4-SES-NT-0076
[PMOON]	Plank Moon Transit	H-P-1-ASP-TN-0855
[SOHOTH]	SOHO Thermal Analysis – PLANCK Scenario 2	H-P-TN-AI-0070
[SOHOOP]	SOHO Failure Operational Aspects	H-P-TN-AI-0071
[SVMCONFREP]	SVM Configuration Report	H-P-RP-AI-0003
[SVMHKPK]	SVM Housekeeping Packets Definition	H-P-TN-AI-0100
[TMTCBDG]	SVM TM/TC Budget	H-P-TN-AI-0018
[TCSMPBDG]	TCS Mass and Power Budgets	H-P-BD-AI-0004
[MASSBDG]	Mass Budget and Properties Report	H-P-BD-AI-0006
[PWRBDG]	SVM Power Budget	H-P-BD-AI-0008
[HASWTAB]	Herschel CDMU ASW default on board tables	H-P-TN-AI-0151
[PASWTAB]	Planck CDMU ASW default on board tables	H-P-TN-AI-0152
[SVMTCSTO]	SVM TCS Transfer Orbit	H-P-RP-AI-0067
[HIFIIDDB]	Herschel S/C Design Impacts of HIFI IDDB 3.2 Implementation	H-P-TN-AI-0093
[HEPLMRS]	H-EPLM Requirements Specification	H-P-2-ASPI-SP-0250

3. THERMAL CONTROL SUBSYSTEM (TCS)

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3.1. TCS DESCRIPTION

The Herschel/Planck SVM TCS is in charge to maintain all the SVM components, within their flight temperature limits, during all the mission phases and in the different operational modes.

The temperature limits are guaranteed also for the Instrument warm units.

For thermal reasons these equipments, functionally belonging to the PLM, cannot be accommodated inside the PLM itself and are therefore hosted by the SVM. For some of these units it is also requested to limit the temperature fluctuation.

For each satellite, the two modules, PLM and SVM, can be considered independent from a thermal point of view since the conductive heat fluxes between the two modules are limited. This is a very important aspect because while the temperature requirements of the SVM equipments are the typical ones for a scientific satellite, the thermal requirements of the PLM units are much more stringent.

H/P SVM Thermal Control S/S makes use of proven techniques such as:

- Multi Layer Insulation Blankets;
- High and Low emissivity Tapes;
- Paints;
- Heaters and Thermistors (and relevant harness);
- Second Surface Mirrors (rigid and/or flexible);
- Thermal Fillers and Washers;
- Adhesives;
- Aluminium Doublers;
- Heat Pipes.

More precisely:

- Radiators of various sizes located on all the lateral panels in order to radiate into space the heat dissipated by the units;
- MLI blankets to insulate the remaining surface of the lateral panels not used as radiator to minimize the heater power need in cold cases;
- MLI blankets to thermally decouple the PLM from the SVM;
- MLI blankets on the lower floor and RCS panel to minimize the external heat flux in the hot cases and the heater power need in the cold cases;
- MLI blankets with low emissivity coatings (emissivity < 0.1) on internal structure and equipment's having a dedicated temperature stability requirement, in order to minimize the thermal coupling with the rest of SVM and minimize the disturbs;
- MLI blankets with low emissivity coatings (emissivity < 0.1) on tanks having temperature gradient requirement, in order to minimize the thermal coupling with the rest of SVM and minimize the temperature variation (Planck);
- On Herschel , a fin (3 cm height of 5 mil kapton) has been added to avoid the Sun impingement on the ± Y panel during the ± 1° attitude change;
- High emissivity coatings of the other internal structure and equipments, in order to increase thermal radiation exchange inside the SVM and minimise temperature gradients. Note that all aluminium internal surfaces and internal equipment are requested to be black painted for that reason. The carbon fibre structures does not need painting thanks to their natural high emissivity;
- RCS items are thermally isolated from the rest of the platform by means of low emissivity tapes and washers. An exception is represented by the thrusters that are requested to be coupled by means of interposition of thermal filler at the S/C I/F;
- All dissipating units are mounted on the lateral panels using interface filler;
- Aluminium doublers are used to spread heat of some units on the supporting panel;
- Automatically controlled (via CDMU) heater circuits to maintain all items above their minimum temperature limits. In order to comply with very stringent stability requirements, the heater design will be properly tuned and a suitable heater operation control law provided
- Heat Pipe network to thermally control Planck SCC (Sorption Cooler Compressor).

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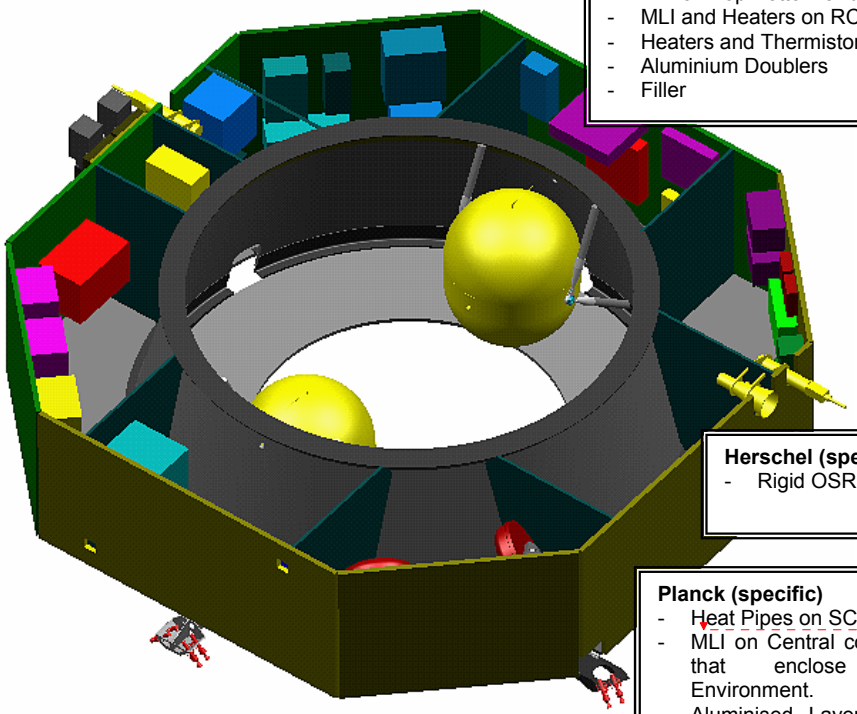
3.2. TCS CONFIGURATION

The SVM Thermal Control of the two satellites is developed trying to keep the maximum commonality between them.

Due to the different units/equipments layouts and to the different solar aspect angles, Herschel and Planck SVM are quite different from a thermal point of view and the two thermal control configurations are quite different as well. Consequently, the commonality approach concerns mainly the kind of design and the choice of material, while the sizing (radiator areas, heater powers etc.) is different for the two satellites.



- Black Paint on Internal Panel (except warm unit panels)
- Flexible SSM on External Radiator Panels
- MLI on Top/Bottom and lateral panels
- MLI and Heaters on RCS Tanks
- Heaters and Thermistors
- Aluminium Doublers
- Filler

Herschel (specific)
- Rigid OSR on Warm Unit panels (only)

Planck (specific)
- Heat Pipes on SCC Panels.
- MLI on Central cone and Shear Web that enclose SCC Panels Environment.
- Aluminised Layer on Rear Side of Upper/Lower Closure Panel (limited to area of SCC Panels Environment only).
- Aluminised Layer on N.3 Helium Tanks.

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Figure 3-1 H/P SVM TCS Main Items

3.2.1. Second Surface Mirrors

All the lateral panels nominally impinged by sun radiation are equipped with rigid *Second Surface Mirrors* (SSM) (high emissivity and low absorptivity) on the outside surface for the amount required to radiate the internal heat to space and limit the solar heat input on the panel. The appropriate SSM radiating area has been defined taking into account the thermo-optical degradation of the SSMs at end of life. The area of each panel not needed as radiator is covered with MLI.

Radiator areas under direct sun impingement are equipped with ITO coated rigid OSR due to their very low value of alpha/epsilon and low degradation.

3.2.2. Multi Layer Insulation

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MLI blankets consist of a certain number of thin polymer sheets. To be as much insulating as possible the internal sheets have a low emissivity coating (< 0.05) and a net separator between them.

The following different types of MLI composition have been defined and are considered as the baseline solution:

Type B (external)

- 1 outer layer of Carbon Filled Kapton/VDA;
- 1 layer Dacron net;
- 8 x (1 layer of Double Aluminized Mylar (0.25 mil) perforated; 1 Dacron net layer);
- 1 bottom layer of Double Aluminized Kapton.

Type C (external hi-efficiency)

- 1 outer layer of Double Aluminized Kapton;
- 1 layer Dacron net;
- 18 x (1 layer of Double Aluminized Mylar (0.25 mil) perforated; 1 Dacron net layer);
- 1 bottom layer of Double Aluminized Kapton.

Type D (internal)

- 1 outer layer of Double Aluminized Kapton;
- 1 layer Dacron net;

- 5 x (1 layer of Double Aluminized Mylar (0.25 mil) perforated; 1 Dacron net layer);
- 1 bottom layer of Double Aluminized Kapton.

Type E (high temperature)

- 1 outer layer of Carbon Filled Kapton/VDA;
- 1 layer Nomex scrim;
- 3 x (1 layer of Double Aluminized Kapton (0.3 mil) perforated; 1 Nomex scrim layer);
- 1 bottom layer of Double Aluminized Kapton

Note that:

- Use of type B MLI is used (Carbon Filled Kapton), both on Herschel and Planck, because CFK is more robust with respect to "Type A" concerning handling and ESD prevention, and for commonality reasons.
- In order to provide an optimum insulation level in critical interface areas, such as top and bottom platforms, type C MLI (with a higher number of internal reflector layers) is used. For mass saving reasons, use of Type C MLI is limited to critical interface areas only (I/F between PLM and SVM and I/F between Solar Arrays and Planck SVM).
- Internal MLI design (type D) accounts for best compromise between mass and insulation performance (lower temperature gradients are to be guaranteed). Its use is foreseen on:
  - Herschel tanks;
  - Herschel HIFI units and relevant panels;
  - Planck SCC panels internal side;
  - Planck tanks.
- Type E is foreseen around Thrusters for high temperature application.

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3.2.3. Thermal Doublers

The structural composition of the radiators is a honeycomb sandwich between two thin aluminium sheets. This structure does not allow a good heat transfer by conduction along the panel. So, thermal doublers in aluminium AL99.5 % (thermal conductivity = 231 W/m/K) are installed under some dissipating units in order to spread the generated heat over larger areas.

The following thermal doublers are foreseen:

- Herschel
  - On -Y panel, 1 doubler under FHWEH, approx. dimensions: 290 x 240 x 2 mm
  - On –Y/-Z panel, 1 doubler under FHWEV, approx. dimensions: 290 x 240 x 2 mm
  - On –Y/-Z panel, 1 doubler under FHHRV/FHFCU, approx. dimensions: 784 x 446 x 2mm
  - On +Y/+Z panel, 1 doubler under TWT1, approx. dimensions: 435 x 144 x 2 mm
  - On +Y/+Z panel, 1 doubler under TWT2, approx. dimensions: 435 x 144 x 2 mm
- Planck: on sub-platform, 1 doubler under BEU, approx. dimensions: 180 x 400 x 2 mm

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3.2.4. Thermal Interface Fillers

Thermal interface fillers are used to increase the thermal coupling of the dissipating units to the honeycomb structure and reduce the uncertainty in the evaluation of their contact conductance.

As a baseline design, use of a graphite solid filler type SIGRAFLEX (thickness 0.35 mm) is foreseen.

In principle all dissipating units are assumed to be equipped with thermal interface filler.

Also the interfaces concerning heat pipe installation on Planck make use of this kind of solid thermal filler.

Heat pipes interfaces include:

- SCC/SCE baseplate to heat pipes junction;
- Heat pipe to heat pipe junction (crossing heat pipes);
- Heat Pipes to honeycomb panels' junction.

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Selection of graphite foil (SIGRAFLEX) as filler at heat pipe mounting interfaces is justified by the need to guarantee the possible complete dismountability of the heat pipes.

No use of liquid filler is currently foreseen.

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3.2.5. Thermal Washers

In order to provide a suitable thermal control of equipment and/or structural supports requiring to be decoupled by the surrounding environment, use of insulating thermal washers is foreseen.

Both for Herschel and Planck, RCS items such as filters, valves and pipelines (not the thrusters) will require to be insulated from the structure. The relevant washers are provided by the RCS supplier.

The same applies for LGA & MGA antennas at S/C I/F level.

The relevant washers are provided by the antennas supplier.

The Planck solar array is requested to be insulated from the structure. The relevant washers are provided by the Solar Array supplier.

3.2.6. Paints and Finishes

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Internal SVM surfaces will generally have high emissivity characteristics, in order to minimise temperature gradients inside the SVM as required by the TCS requirements.

The black paint “Aeroglaze Z306” having high emissivity (about 0.9) will be used on the lateral panels’ internal side.

The central cone, the shear panels and the two floors have the skins in carbon fibre (emissivity about 0.8) and therefore do not need dedicated painting.

The units will be black painted.

Use of electrical conductive black paint (e.g. AEROGLAZE Z307) is foreseen on external radiator panels not directly impinged by solar flux.

On Herschel, FHWOH and FHWOV HIFI units are required to have low emissivity external treatment (Aluminum/Alodine).

Also the relevant panels (internal side) mounting the HIFI units are requested to be with a low emissivity coating (Alodine treatment).

A low emissivity coating, onto the allowable area, (CHOFOIL aluminum tape eps=0.05) on the adapter ring is foreseen.

On Planck, SCC/SCE units and relevant panels/heat pipes are assumed to have low emissivity coating.

SCC panels’ insulation with respect to internal SVM will be further achieved by means of MLI blankets in order to enhance the temperature stability of structural panels and interface truss, otherwise deeply affected by the SCC operation mode.

On SAS –X SSM Silver Teflon Tape is foreseen on the external side of the case unit.

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3.2.7. Heaters

Foil and wire heaters are used on board Herschel and Planck.

Foil heaters are double circuits, double layer, thermofoil and internal redundant heater.

Inherent magnetic compensation is foreseen.

Heaters will be bonded using Y966 PSA tape and AV138 glue-drops.

The only exception is for the Thrusters and Planck Helium Tank heaters that will be installed using adhesive RTV566

Typologies of foil heaters are provided in Table 3-1:

Type	Dimensions [mm]	Nominal Resistance [Ω]	Location
B	100 x 26	155	Panels
C	137 x 55	47	Panels
D	320 x 21	945	Tanks
E	45 x 21	310	FCV 1N Thruster H STR Primary Baffle
F	205 x 28	28	Heat Pipes
G	140 x 40	64	Panels
J	90 x 45	90	Panels and Star Trackers of (Planck)
K	50 x 20	42.5	RCS units
L	145 x 50	276	Star trackers (Herschel)
M	70 x 15	700	Planck Helium Tanks
N	47 x 14	510	FCV 20N Thruster

Table 3-1 Foil Heaters Summary

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Wire heaters are used on RCS pipelines only, with a provision of a heater power density in the range between 0.2 and 0.6 w/m.

Main characteristics are reported in Table 3-2 and wire outlet types are shown in Figure 3-2:

Characteristics	Values
Material	Alloy 875 or Kanthal A1
AWG Wire	AWG 26
Number of wires	2
Resistivity [Ohm/m]	11 [Ohm/m]
Insulation	FEP/polymide

Table 3-2 Wire Heaters Characteristics

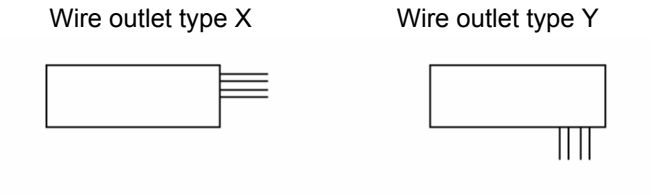

Figure 3-2 Wire Outlet Types

All the flat heaters have a Main circuit and a Redundant circuit. The same electrical connection will be done both for the Main circuit and a Redundant circuit as shown in Figure 3-3:

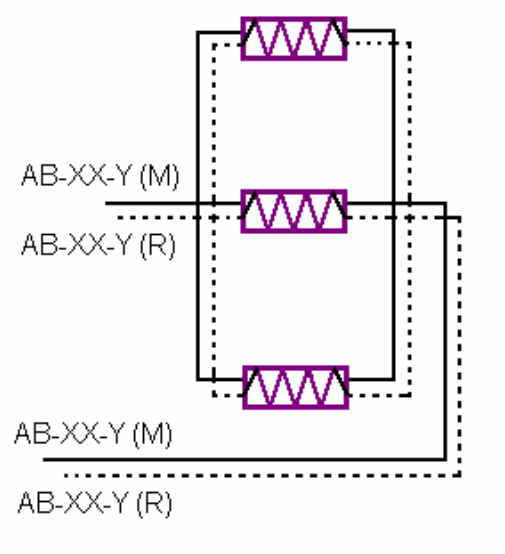

Figure 3-3 Heater Circuit Sketch

Line number	Location	Line name	Reference unit	Total heater	Heater type	Heater Id	Resistance [Ω]	Electrical connection type	Equivalent resistance [Ω]	Heater line commanded by THM	Equivalent power [W] @27 V
1	**+Y+Z**	HTR104NS	XPND1	1	G	H1-01-G (M+R)	64	-	**64**	**49/97/145**	**11.39**
2		HTR105NS	XPND2	1	G	H2-01-G (M+R)	64	-	**64**	**50/98/146**	**11.39**
3	**+Y**	HTR204NS	BATTERY (*)	(*)	(*)	(*)	(*)	(*)	(*)	**51/99/147**	**14.9 (*)**
4	**TANKS**	HTR7071NS	TANK+Y/-Y	2	D	H4-01-D (M+R)	945	Parallel	**472.5**	**-**	**1.54**
					D	H4-02-D (M+R)	945				
5	**+Y-Z**	HTR301S	FPSPU/FPDPU	2	C	H5-01-C (M+R)	47	Parallel	**23.50**	**53/101/149**	**31.02**
					C	H5-02-C (M+R)	47				
6	**+Y-Z**	HTR304NS	FPBOLC	2	B	H6-01-B (M+R)	155	Parallel	**77.50**	**54/102/150**	**9.41**
					B	H6-02-B (M+R)	155				
7	**+Y+Z**	HTR110NS	CRS1	1	P	H7-01-P (M+R)	30	-	**30**	**55/103/151**	**24.3**
8	**+Y-Z**	HTR305S	FPDECMEC	3	G	H8-01-G (M+R)	64	Parallel	**26.52**	**56/104/152**	**27.48**
					G	H8-02-G (M+R)	64				
					B	H8-03-B (M+R)	155				
9	**RCS**	HTR1523NS	PIPES		WIRE			Series	See [RCSHTIN]	**57/105/153**	See [RCSHTIN]
10	**-Z**	HTR401S	CCU/HSDCU/HSFCU	5	C	H10-01-C (M+R)	47	Parallel	**16.38**	**58/106/154**	**44.51**
					J	H10-02-J (M+R)	90				
					J	H10-03-J (M+R)	90				
					J	H10-04-J (M+R)	90				
					B	H10-05-B (M+R)	155				
11	**RCS**	HTR1562NS	PIPES		WIRE			Series	See [RCSHTIN]	**59/107/155**	See [RCSHTIN]
12	**-Y-Z**	HTR501NS	FHWOV	2	G	H12-01-G (M+R)	64	Parallel	**32**	**60/108/156**	**22.78**
					G	H12-02-G (M+R)	64				
13		HTR502S	FHHRV	4	J	H13-01-J (M+R)	90	Parallel	**18.70**	**61/109/157**	**38.98**
					J	H13-02-J (M+R)	90				
					G	H13-03-G (M+R)	64				
					G	H13-04-G (M+R)	64				
14	**STR 1 Primary Baffle**	HTR80052NS	STR 1 Primary Baffle	3	E	H14-01-E (M+R)	310	Parallel	**103.33**	**62/110/158**	**7.05**
					E	H14-02-E (M+R)	310				
					E	H14-03-E (M+R)	310				
15	**-Y-Z**	HTR506S	FHWEV/FHICU	4	G	H15-01-G (M+R)	64	Parallel	**20.43**	**63/111/159**	**35.7**
					J	H15-02-J (M+R)	90				
					J	H15-03-J (M+R)	90				
					J	H15-04-J (M+R)	90				

(*) Internal battery heaters managed by the TCS

Table 3-3 Herschel TCS Heater Lines Description (cont.)

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Line number	Location	Line name	Reference unit	Total heater	Heater type	Heater Id	Resistance [Ω]	Electrical connection type	Equivalent resistance [Ω]	Heater line commanded by THM	Equivalent power [W] @27 V
16	**-Y**	HTR601NS	FHWOH	4	J	H16-01-J (M+R)	90	Parallel	**22.5**	**64/112/160**	**32.40**
					J	H16-02-J (M+R)	90				
					J	H16-03-J (M+R)	90				
					J	H16-04-J (M+R)	90				
17		HTR602S	FHWEH	4	J	H17-01-J (M+R)	90	Parallel	**22.5**	**65/113/161**	**32.40**
					J	H17-02-J (M+R)	90				
					J	H17-03-J (M+R)	90				
					J	H17-04-J (M+R)	90				
18		HTR603S	FHHRH	4	J	H18-01-J (M+R)	90	Parallel	**18.7**	**66/114/162**	**38.98**
					J	H18-02-J (M+R)	90				
					G	H18-03-G (M+R)	64				
					G	H18-04-G (M+R)	64				
19		HTR604S	FHLCU/FHIFH	3	J	H19-01-J (M+R)	90	Parallel	**34.88**	**67/115/163**	**20.90**
					J	H19-02-J (M+R)	90				
					B	H19-03-B (M+R)	155				
20		HTR605S	FHLSU	4	J	H20-01-J (M+R)	90	Parallel	**25.14**	**68/116/164**	**29.00**
					J	H20-02-J (M+R)	90				
					B	H20-03-B (M+R)	155				
					J	H20-04-J (M+R)	90				
21	**-Y+Z**	HTR702NS	RWL2	1	G	H21-01-G (M+R)	64	-	**64**	**69/117/165**	**11.39**
22		HTR704NS	RWL4	1	G	H22-01-G (M+R)	64	-	**64**	**70/118/166**	**11.39**
23		HTR701NS	RWL1	1	G	H23-01-G (M+R)	64	-	**64**	**71/119/167**	**11.39**
24		HTR703NS	RWL3	1	G	H24-01-G (M+R)	64	-	**64**	**72/120/168**	**11.39**
25	**TANKS**	HTR70NS	TANK+Y	7	D	H25-01-D (M+R)	945	Parallel	**135**	**73/121/169**	**5.4**
					D	H25-02-D (M+R)	945				
					D	H25-03-D (M+R)	945				
					D	H25-04-D (M+R)	945				
					D	H25-05-D (M+R)	945				
					D	H25-06-D (M+R)	945				
					D	H25-07-D (M+R)	945				

Table 3-3 Herschel TCS Heater Lines Description (cont.)

Line number	Location	Line name	Reference unit	Total heater	Heater type	Heater Id	Resistance [Ω]	Electrical connection type	Equivalent resistance [Ω]	Heater line commanded by THM	Equivalent power [W] @27 V
26	**TANKS**	HTR71NS	TANK-Y	7	D	H26-01-D (M+R)	945	PARALLEL	**135**	**74/122/170**	**5.4**
					D	H26-02-D (M+R)	945				
					D	H26-03-D (M+R)	945				
					D	H26-04-D (M+R)	945				
					D	H26-05-D (M+R)	945				
					D	H26-06-D (M+R)	945				
					D	H26-07-D (M+R)	945				
27	**STAR TRACKER**	HTR20000NS	STAR TRACKER	8	L	H27-01-L (M+R)	276	PARALLEL	**34.50**	**75/123/171**	**21.13**
					L	H27-02-L (M+R)	276				
					L	H27-03-L (M+R)	276				
					L	H27-04-L (M+R)	276				
					L	H27-05-L (M+R)	276				
					L	H27-06-L (M+R)	276				
					L	H27-07-L (M+R)	276				
					L	H27-08-L (M+R)	276				
28	**-Y-Z**	HTR507NS	FHIFV	1	G	H28-01-G (M+R)	64	-	**64**	**76/124/172**	**11.4**
29	**20 N TH**	HTR8133NS	FCV A1A	1	N	H29-01-E (M+R)	510	-	**510**	**77/125/173**	**1.43**
30		HTR8233NS	FCV C2A	1	N	H30-01-E (M+R)	510	-	**510**	**78/126/174**	**1.43**
31		HTR8333NS	FCV C1A	1	N	H31-01-E (M+R)	510	-	**510**	**79/127/175**	**1.43**
32		HTR8433NS	FCV A2A	1	N	H32-01-E (M+R)	510	-	**510**	**80/128/176**	**1.43**
33		HTR8533NS	FCV C4A	1	N	H33-01-E (M+R)	510	-	**510**	**81/129/177**	**1.43**
34		HTR8633NS	FCV C3A	1	N	H34-01-E (M+R)	510	-	**510**	**82/130/178**	**1.43**
35	**RCS**	HTR1544NS	PIPES		WIRE			Series	See [RCSHTIN]	**83/131/179**	See [RCSHTIN]
36	**STR 2 Primary Baffle**	HTR81052NS	STR 2 Primary Baffle	3	E	H36-01-E (M+R)	310	PARALLEL	**103.33**	**84/132/180**	**7.05**
					E	H36-02-E (M+R)	310				
					E	H36-03-E (M+R)	310				
37	**RCS**	HTR1554NS	PIPES		WIRE			Series	See [RCSHTIN]	**85/133/181**	See [RCSHTIN]

Table 3-3 Herschel TCS Heater Lines Description (cont.)

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Line number	Location	Line name	Reference unit	Total heater	Heater type	Heater Id	Resistance [Ω]	Electrical connection type	Equivalent resistance [Ω]	Heater line commanded by THM	Equivalent power [W] @27 V
38	**Gyro**	HTR100NS	GYRO	8	H1	H38-01-H1 (M+R)	74	PARALLEL	**16.12**	**86/134/182**	**45.22**
					H1	H38-02-H1 (M+R)	74				
					H2	H38-03-H2 (M+R)	150				
					H2	H38-04-H2 (M+R)	150				
					H3	H38-05-H3 (M+R)	240				
					H3	H38-06-H3 (M+R)	240				
					H4	H38-07-H4 (M+R)	150				
					H4	H38-08-H4 (M+R)	150				
39	**20 N TH**	HTR8134NS	FCV A1B	1	N	H39-01-E (M+R)	510	-	**510**	**87/135/183**	**1.43**
40		HTR8234NS	FCV C2B	1	N	H40-01-E (M+R)	510	-	**510**	**88/136/184**	**1.43**
41		HTR8334NS	FCV C1B	1	N	H41-01-E (M+R)	510	-	**510**	**89/137/185**	**1.43**
42		HTR8434NS	FCV A2B	1	N	H42-01-E (M+R)	510	-	**510**	**90/138/186**	**1.43**
43		HTR8534NS	FCV C4B	1	N	H43-01-E (M+R)	510	-	**510**	**91/139/187**	**1.43**
44		HTR8634NS	FCV C3B	1	N	H44-01-E (M+R)	510	-	**510**	**92/140/188**	**1.43**
45	**RCS**	HTR1513NS	PIPES		WIRE			Series	See [RCSHTIN]	**93/141/189**	See [RCSHTIN]
46	**RCS**	HTR1506NS	PIPES		WIRE			Series	See [RCSHTIN]	**94/142/190**	See [RCSHTIN]
47	**RCS**	HTR1535NS	PIPES		WIRE			Series	See [RCSHTIN]	**95/143/191**	See [RCSHTIN]
48	**RCS**	HTR1550NS	PT	1	K	H48-01-K (M+R)	42.5	Series / PARALLEL	**148.8**	**96/144/192**	**4.9**
			LV1	1	K	H48-02-K (M+R)	42.5				
			LV2	1	K	H48-03-K (M+R)	42.5				
			LF	2	K	H48-04-K (M+R)	42.5				
					K	H48-05-K (M+R)	42.5				
49	**+Y+Z**	HTR111NS	CRS2	1	P	H49-01-P (M+R)	30	-	**30**	**12/20/36**	**24.3**

Table 3-3 Herschel TCS Heater Lines Description

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Line number	Location	Line name	Reference unit	Total Heater	Heater Type	Heater Id	Resistance [Ω]	Electrical connection type	Equivalent resistance [Ω]	Heater line commanded by THM	Equivalent power [W] @27 V
1	**+Z**	HTR5427S	Star Tracker 1	1	B	P1-01-B (M+R)	155	-	**155**	**49/97/145**	**4.7**
2		HTR5527S	Star Tracker 2	1	B	P2-01-B (M+R)	155	-	**155**	**50/98/146**	**4.7**
3		HTR13S	DPU 1	2	G	P3-01-G (M+R)	64	PARALLEL	**32**	**51/99/147**	**22.8**
					G	P3-02-G (M+R)	64				
4		HTR14S	DPU 2	2	G	P4-01-G (M+R)	64	PARALLEL	**32**	**52/100/148**	**22.8**
					G	P4-02-G (M+R)	64				
5	**+Y**	HTR205S	REU	4	C	P5-01-C (M+R)	47	PARALLEL	**11.75**	**53/101/149**	**62.0**
					C	P5-02-C (M+R)	47				
					C	P5-03-C (M+R)	47				
					C	P5-04-C (M+R)	47				
6		HTR220S	CCU & CEU (4KCDE)	6	B	P6-01-B (M+R)	155	PARALLEL	**13.88**	**54/102/150**	**52.5**
					B	P6-02-B (M+R)	155				
					C	P6-03-C (M+R)	47				
					J	P6-04-J (M+R)	90				
					J	P6-05-J (M+R)	90				
					G	P6-06-G (M+R)	64				
35		HTR202S	CAU	4	J	P35-01-J (M+R)	90	PARALLEL	**18.7**	**83/131/179**	**39.0**
					J	P35-02-J (M+R)	90				
					G	P35-03-G (M+R)	64				
					G	P35-04-G (M+R)	64				
7	**SCC/SCE PANELS**	HTRHP7NS	Heat Pipe	3	F	P7-01-F (M+R)	28.04	PARALLEL	**9.35**	**55/103/151**	**78**
					F	P7-02-F (M+R)	28.04				
					F	P7-03-F (M+R)	28.04				
8		HTRHP8NS	Heat Pipe	3	F	P8-01-F (M+R)	28.04	PARALLEL	**9.35**		**78**
					F	P8-02-F (M+R)	28.04				
					F	P8-03-F (M+R)	28.04				
9		HTRHP9S	Heat Pipe	5	F	P9-01-F (M+R)	28.04	PARALLEL / Series	**8.01**		**91**
					F	P9-02-F (M+R)	28.04				
					F	P9-03-F (M+R)	28.04				
					F	P9-04-F (M+R)	28.04				
					F	P9-05-F (M+R)	28.04				

Table 3-4 Planck TCS Heater Lines Description (cont.)

Line number	Location	Line name	Reference unit	Total Heater	Heater Type	Heater Id	Resistance [Ω]	Electrical connection type	Equivalent resistance [Ω]	Heater line commanded by THM	Equivalent power [W] @27 V
10	**SCC/SCE PANELS**	HTRHP10S	Heat Pipe	5	F	P10-01-F (M+R)	28.04	PARALLEL / Series	**8.01**		**91**
					F	P10-02-F (M+R)	28.04				
					F	P10-03-F (M+R)	28.04				
					F	P10-04-F (M+R)	28.04				
					F	P10-05-F (M+R)	28.04				
11		HTRHP11S	Heat Pipe	5	F	P11-01-F (M+R)	28.04	PARALLEL / Series	**8.01**	**55/103/151**	**91**
					F	P11-02-F (M+R)	28.04				
					F	P11-03-F (M+R)	28.04				
					F	P11-04-F (M+R)	28.04				
					F	P11-05-F (M+R)	28.04				
12		HTRHP12S	Heat Pipe	5	F	P12-01-F (M+R)	28.04	PARALLEL / Series	**8.01**		**91**
					F	P12-02-F (M+R)	28.04				
					F	P12-03-F (M+R)	28.04				
					F	P12-04-F (M+R)	28.04				
					F	P12-05-F (M+R)	28.04				
13		HTRHP13S	Heat Pipe	5	F	P13-01-F (M+R)	28.04	PARALLEL / Series	**8.01**		**91**
					F	P13-02-F (M+R)	28.04				
					F	P13-03-F (M+R)	28.04				
					F	P13-04-F (M+R)	28.04				
					F	P13-05-F (M+R)	28.04				
14	**He tank -Z**	TR910NS	He tank -Z	2	M	P14-01-M (M+R)	700	PARALLEL	**350**	**62/110/158**	**2.08**
					M	P14-02-M (M+R)	700				
	He tank +Y		He tank +Y	1	M	P14-03-M (M+R)	700		**700**		**1.04**
	He tank +Z		He tank +Z	1	M	P14-04-M (M+R)	700		**700**		**1.04**
15	**Sub platform**	HTR522S	PAU	1	J	P15-01-J (M+R)	90	-	**90**	**63/111/159**	**8.1**
16	**SH. PAN. +Z+Y**	HTR203S	CRU	2	J	P16-01-J (M+R)	90	PARALLEL	**56.9**	**64/112/160**	**12.8**
					B	P16-02-B (M+R)	155				
17	**S. P. -Z+Y**	HTR705NS	CRS1	1	P	P17-01-P (M+R)	30	-	**30**	**65/113/161**	**24.3**
18	**S. P. -Z+Y**	HTR706NS	CRS2	1	P	P18-01-P (M+R)	30	-	**30**	**66/114/162**	**24.3**
19	**S. P. -Z+Y**	HTR551NS	CRS3	1	P	P19-01-P (M+R)	30	-	**30**	**67/115/163**	**24.3**
20	**PROP. TANKS**	HTR9250NS	TANK +Z-Y/+Z-Y/-Z	3	D	P20-01-D (M+R)	945	PARALLEL	**315**	**-**	**2.31**
					D	P20-02-D (M+R)	945				
					D	P20-03-D (M+R)	945				

Table 3-4 Planck TCS Heater Lines Description (cont.)

Line number	Location	Line name	Reference unit	Total Heater	Heater Type	Heater Id	Resistance [Ω]	Electrical connection type	Equivalent resistance [Ω]	Heater line commanded by THM	Equivalent power [W] @27 V
21	**PROP. TANKS**	HTR920NS	TANK +Z+Y	7	D	P21-01-D (M+R)	945	PARALLEL	**135**	**69/117/165**	**5.4**
					D	P21-02-D (M+R)	945				
					D	P21-03-D (M+R)	945				
					D	P21-04-D (M+R)	945				
					D	P21-05-D (M+R)	945				
					D	P21-06-D (M+R)	945				
					D	P21-07-D (M+R)	945				
22	**PROP. TANKS**	HTR925NS	TANK +Z-Y	7	D	P22-01-D (M+R)	945	PARALLEL	**135**	**70/118/166**	**5.4**
					D	P22-02-D (M+R)	945				
					D	P22-03-D (M+R)	945				
					D	P22-04-D (M+R)	945				
					D	P22-05-D (M+R)	945				
					D	P22-06-D (M+R)	945				
					D	P22-07-D (M+R)	945				
23	**PROP. TANKS**	HTR930NS	TANK –Z	7	D	P23-01-D (M+R)	945	PARALLEL	**135**	**71/119/167**	**5.4**
					D	P23-02-D (M+R)	945				
					D	P23-03-D (M+R)	945				
					D	P23-04-D (M+R)	945				
					D	P23-05-D (M+R)	945				
					D	P23-06-D (M+R)	945				
					D	P23-07-D (M+R)	945				
24	**1N THRUSTER**	HTR8508NS	1N FCV A1A on -Y +Z (+Z side)	1	E	P24-01-E (M+R)	310	-	**310**	**72/120/168**	**2.35**
25		HTR8708NS	1N FCV B1A on -Y +Z (-Z side)	1	E	P25-01-E (M+R)	310	-	**310**	**73/121/169**	**2.35**
26	**20N THRUSTER**	HTR1133NS	FCV D1A	1	N	P26-01-E (M+R)	510	-	**10**	**74/122/170**	**1.43**
27		HTR1233NS	FCV D2A	1	N	P27-01-E (M+R)	510	-	**510**	**75/123/171**	**1.43**
28		HTR1333NS	FCV F1A	1	N	P28-01-E (M+R)	510	-	**510**	**76/124/172**	**1.43**
29		HTR1433NS	FCV F2A	1	N	P29-01-E (M+R)	510	-	**510**	**77/125/173**	**1.43**
30		HTR1533NS	FCV U1A	1	N	P30-01-E (M+R)	510	-	**510**	**78/126/174**	**1.43**
31		HTR1733NS	FCV U2A	1	N	P31-01-E (M+R)	510	-	**510**	**79/127/175**	**1.43**

Table 3-4 Planck TCS Heater Lines Description (cont.)

Line number	Location	Line name	Reference unit	Total Heater	Heater Type	Heater Id	Resistance [Ω]	Electrical connection type	Equivalent resistance [Ω]	Heater line commanded by THM	Equivalent power [W] @27 V
32	**RCS**	HTR1850NS	PT	1	K	P32-01-K (M+R)	42.5	Series / PARALLEL	**148.8**	**80/128/176**	**4.9**
			LV1	1	K	P32-02-K (M+R)	42.5				
			LV2	1	K	P32-03-K (M+R)	42.5				
			LF	2	K	P32-04-K (M+R)	42.5				
					K	P32-05-K (M+R)	42.5				
33		HTR1809NS	PIPES		WIRE			Series	See [RCSHTIN]	**81/129/177**	See [RCSHTIN]
34		HTR1805NS	PIPES		WIRE			Series	See [RCSHTIN]	**82/130/178**	See [RCSHTIN]
36	**+Z+Y**	HTR103S	REBA 1&2 DCCU	3	G	P36-01-G (M+R)	64	PARALLEL	**21.3**	**84/132/180**	**34.2**
					G	P36-02-G (M+R)	64				
					G	P36-03-G (M+R)	64				
37	**+Z-Y**	HTR703S	BATTERY (*)	(*)	(*)	(*)	(*)	(*)	(*)	**85/133/181**	**14.9** (*)
38	**1N THRUSTER**	HTR8608NS	1N FCV A1B on –Y+Z (+Z side)	1	E	P38-01-E (M+R)	310	-	**310**	**86/134/182**	**2.35**
39		HTR8808NS	1N FCV B1B on –Y+Z (-Z side)	1	E	P39-01-E (M+R)	310	-	**310**	**87/135/183**	**2.35**
40	**20N THRUSTER**	HTR1134NS	FCV D1B	1	N	P40-01-E (M+R)	510	-	**510**	**88/136/184**	**1.43**
41		HTR1234NS	FCV D2B	1	N	P41-01-E (M+R)	510	-	**510**	**89/137/185**	**1.43**
42		HTR1334NS	FCV F1B	1	N	P42-01-E (M+R)	510	-	**510**	**90/138/186**	**1.43**
43		HTR1434NS	FCV F2B	1	N	P43-01-E (M+R)	510	-	**510**	**91/139/187**	**1.43**
44		HTR1534NS	FCV U1B	1	N	P44-01-E (M+R)	510	-	**510**	**92/140/188**	**1.43**
45		HTR1734NS	FCV U2B	1	N	P45-01-E (M+R)	510	-	**510**	**93/141/189**	**1.43**
46	**RCS**	HTR1815NS	PIPES		WIRE			Series	See [RCSHTIN]	**94/142/190**	See [RCSHTIN]
47	**RCS**	HTR1867NS	PIPES		WIRE			Series	See [RCSHTIN]	**95/143/191**	See [RCSHTIN]
48	**RCS**	HTR1884NS	PIPES		WIRE			Series	See [RCSHTIN]	**96/144/192**	See [RCSHTIN]

(*) Internal battery heaters managed by the TCS

Table 3-4 Planck TCS Heater Lines Description

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3.2.8. Thermistors

Thermistors are used for heater control and unit temperature monitoring.

The main characteristics of the thermistors/acquisition chain are given in Table 3-5:

Characteristics	Values
Typology	Betatherm G15K4D393
Resistance in [ohm] at 25°C	15 Kohms
Receiver Accuracy	< ±3 °C in the range –40 °C to +80 °C < ±1 °C in the range –10 °C to +40 °C
Analogue to Digital resolution	12 BIT
BIT amplitude	0.05 °C
Measurement temperature range	-40 to +80°C
Stability	< ±0.1 °C in the range –10 °C to +40 °C short term (i.e. no ageing, stable temperature)

Table 3-5 Thermistors Characteristics

Thermistors used for heater control are three per circuit, according to the “majority voting rule”.

Note that thermistors are installed on the unit baseplate at the Temperature Reference Point (TRP).

Heater line	Heaters location	Heater line status used/spare/ not available	Unit ON threshold [°C]	Unit OFF or threshold [°C]	MODULE = SIOH1			MODULE = SIOH2			MODULE = SIOH3			Group
					Th. location		M/C	Th. location		M/C	Th. location		M/C	
TCS Line 01	close to XPND1	used	-9/-6	-9/-6	XPND1	THM-49	M+C	XPND1	THM-97	M+C	XPND1	THM-145	M+C	ET0
TCS Line 02	close to XPND2	used	-9/-6	-9/-6	XPND2	THM-50	M+C	XPND2	THM-98	M+C	XPND2	THM-146	M+C	ET0
TCS Line 03	inside BATTERY	used	1/4	1/4	BATTERY	THM-51	M+C	BATTERY	THM-99	M+C	BATTERY	THM-147	M+C	ET0
TCS Line 04	TANKS	used	N/A	N/A	FPDPU	THM-52	M	FPDPU	THM-100	M		THM-148	spare	ET0
TCS Line 05	close to FPSPU, FPDPU	used	-14/-11	-14/-11	FPSPU	THM-53	M+C	FPSPU	THM-101	M+C	FPSPU	THM-149	M+C	ET0
TCS Line 06	close to FPBOLC	used	-14/-11	-14/-11	FPBOLC	THM-54	M+C	FPBOLC	THM-102	M+C	FPBOLC	THM-150	M+C	ET0
TCS Line 07	CRS 1	used	49/49.5	49/49.5	CRS 1	THM-55	M+C	CRS 1	THM-103	M+C	CRS 1	THM-151	M+C	ET0
TCS Line 08	close to FPDECMEC	used	-14/-11	-14/-11	FPDECMEC	THM-56	M+C	FPDECMEC	THM-104	M+C	FPDECMEC	THM-152	M+C	ET0
TCS Line 09	RCS PIPES	used	23/24	23/24	RCS piping	THM-57	M+C	RCS piping	THM-105	M+C	RCS piping	THM-153	M+C	ET0
TCS Line 10	close to CCU, HSDCU, HSFCU	used	-9/-6	-9/-6	CCU	THM-58	M+C	CCU	THM-106	M+C	CCU	THM-154	M+C	ET0
TCS Line 11	RCS PIPES	used	23/24	23/24	RCS piping	THM-59	M+C	RCS piping	THM-107	M+C	RCS piping	THM-155	M+C	ET0
TCS Line 12	close to FHWOV	used	C.L. set at 4.5	-2.5/+0.5	FHWOV	THM-60	M+C	FHWOV	THM-108	M+C	FHWOV	THM-156	M+C	ET0
TCS Line 13	close to FHHRV	used	-9/-6	-9/-6	FHHRV	THM-61	M+C	FHHRV	THM-109	M+C	FHHRV	THM-157	M+C	ET0
TCS Line 14	STR1 Primary Baffle	used	14/14.5	14/14.5	STR1 Prim. Baff.	THM-62	M+C	STR1 Prim. Baff.	THM-110	M+C	STR1 Prim. Baff.	THM-158	M+C	ET0
TCS Line 15	close to FHWEV, FHICU	used	1/4	1/4	FHWEV	THM-63	M+C	FHWEV	THM-111	M+C	FHWEV	THM-159	M+C	ET0
TCS Line 16	close to FHWOH	used	C.L. set at 3.5	-3.5/-0.5	FHWOH	THM-64	M+C	FHWOH	THM-112	M+C	FHWOH	THM-160	M+C	ET0
TCS Line 17	close to FHWEH	used	1/4	1/4	FHWEH	THM-65	M+C	FHWEH	THM-113	M+C	FHWEH	THM-161	M+C	ET1
TCS Line 18	close to FHHRH	used	-9/-6	-9/-6	FHHRH	THM-66	M+C	FHHRH	THM-114	M+C	FHHRH	THM-162	M+C	ET1
TCS Line 19	close to FHLCU, FHIFH	used	-9/-6	-9/-6	FHLCU	THM-67	M+C	FHLCU	THM-115	M+C	FHLCU	THM-163	M+C	ET1
TCS Line 20	close to FHLSU	used	11/14	11/14	FHLSU	THM-68	M+C	FHLSU	THM-116	M+C	FHLSU	THM-164	M+C	ET1
TCS Line 21	on RWL2	used	1/4	1/4	RWL2 cover	THM-69	M+C	RWL2 cover	THM-117	M+C	RWL2 cover	THM-165	M+C	ET1
TCS Line 22	on RWL4	used	1/4	1/4	RWL4 cover	THM-70	M+C	RWL4 cover	THM-118	M+C	RWL4 cover	THM-166	M+C	ET1
TCS Line 23	on RWL1	used	1/4	1/4	RWL1 cover	THM-71	M+C	RWL1 cover	THM-119	M+C	RWL1 cover	THM-167	M+C	ET1
TCS Line 24	on RWL3	used	1/4	1/4	RWL3 cover	THM-72	M+C	RWL3 cover	THM-120	M+C	RWL3 cover	THM-168	M+C	ET1
TCS Line 25	on TANK +Y	used	11/14	11/14	TANK +Y	THM-73	M+C	TANK +Y	THM-121	M+C	TANK +Y	THM-169	M+C	ET1
TCS Line 26	on TANK -Y	used	11/14	11/14	TANK -Y	THM-74	M+C	TANK -Y	THM-122	M+C	TANK -Y	THM-170	M+C	ET1
TCS Line 27	close to STR's	used	C.L. set at 0.0	-7/-4	STR center plate	THM-75	M+C	STR center plate	THM-123	M+C	STR center plate	THM-171	M+C	ET1
TCS Line 28	close to FHIFV	used	-9/-6	-9/-6	FHIFV	THM-76	M+C	FHIFV	THM-124	M+C	FHIFV	THM-172	M+C	ET1
TCS Line 29	on FCV A1A	used	11/17	11/17	FCV A1A	THM-77	M+C	FCV A1A	THM-125	M+C	FCV A1A	THM-173	M+C	ET1
TCS Line 30	on FCV C2A	used	11/17	11/17	FCV C2A	THM-78	M+C	FCV C2A	THM-126	M+C	FCV C2A	THM-174	M+C	ET1

Table 3-6 Herschel Thermistors List (cont.)

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Heater line	Heaters location	Heater line status used/spare/ not available	Unit ON threshold [°C]	Unit OFF or threshold [°C]	MODULE = SIOH1			MODULE = SIOH2			MODULE = SIOH3			Group
					Th. location		M/C	Th. location		M/C	Th. location		M/C	
TCS Line 31	on FCV C1A	used	11/17	11/17	FCV C1A	THM-79	M+C	FCV C1A	THM-127	M+C	FCV C1A	THM-175	M+C	ET1
TCS Line 32	on FCV A2A	used	11/17	11/17	FCV A2A	THM-80	M+C	FCV A2A	THM-128	M+C	FCV A2A	THM-176	M+C	ET1
TCS Line 33	on FCV C4A	used	11/17	11/17	FCV C4A	THM-81	M+C	FCV C4A	THM-129	M+C	FCV C4A	THM-177	M+C	ET2
TCS Line 34	on FCV C3A	used	11/17	11/17	FCV C3A	THM-82	M+C	FCV C3A	THM-130	M+C	FCV C3A	THM-178	M+C	ET2
TCS Line 35	on RCS PIPES	used	23/24	23/24	RCS piping	THM-83	M+C	RCS piping	THM-131	M+C	RCS piping	THM-179	M+C	ET2
TCS Line 36	STR2 Primary Baffle	used	14/14.5	14/14.5	STR2 Prim. Baff.	THM-84	M+C	STR2 Prim. Baff.	THM-132	M+C	STR2 Prim. Baff.	THM-180	M+C	ET2
TCS Line 37	on RCS PIPES	used	23/24	23/24	RCS piping	THM-85	M+C	RCS piping	THM-133	M+C	RCS piping	THM-181	M+C	ET2
TCS Line 38	close to GYRO	used	62.5/63.0	62.5/63.0	GYRO	THM-86	M+C	GYRO	THM-134	M+C	GYRO	THM-182	M+C	ET2
TCS Line 39	on FCV A1B	used	11/17	11/17	FCV A1B	THM-87	M+C	FCV A1B	THM-135	M+C	FCV A1B	THM-183	M+C	ET2
TCS Line 40	on FCV C2B	used	11/17	11/17	FCV C2B	THM-88	M+C	FCV C2B	THM-136	M+C	FCV C2B	THM-184	M+C	ET2
TCS Line 41	on FCV C1B	used	11/17	11/17	FCV C1B	THM-89	M+C	FCV C1B	THM-137	M+C	FCV C1B	THM-185	M+C	ET2
TCS Line 42	on FCV A2B	used	11/17	11/17	FCV A2B	THM-90	M+C	FCV A2B	THM-138	M+C	FCV A2B	THM-186	M+C	ET2
TCS Line 43	on FCV C4B	used	11/17	11/17	FCV C4B	THM-91	M+C	FCV C4B	THM-139	M+C	FCV C4B	THM-187	M+C	ET2
TCS Line 44	on FCV C3B	used	11/17	11/17	FCV C3B	THM-92	M+C	FCV C3B	THM-140	M+C	FCV C3B	THM-188	M+C	ET2
TCS Line 45	on RCS PIPES	used	23/24	23/24	RCS piping	THM-93	M+C	RCS piping	THM-141	M+C	RCS piping	THM-189	M+C	ET2
TCS Line 46	on RCS PIPES	used	23/24	23/24	RCS piping	THM-94	M+C	RCS piping	THM-142	M+C	RCS piping	THM-190	M+C	ET2
TCS Line 47	on RCS PIPES	used	23/24	23/24	RCS piping	THM-95	M+C	RCS piping	THM-143	M+C	RCS piping	THM-191	M+C	ET2
TCS Line 48	on unit: PT, LF, LV1, LV2	used	23/24	23/24	PT unit	THM-96	M+C	PT unit	THM-144	M+C	PT unit	THM-192	M+C	ET2
TCS Line 49	CRS 2	used	49/49.5	49/49.5	CRS 2	THM-12	M+C	CRS 2	THM-20	M+C	CRS 2	THM-36	M+C	ET0

Table 3-6 Herschel Thermistors List

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Heater line	*Heaters location*	Heater line status Used/spare Not-available	Unit ON Threshold [°C]	Unit OFF Threshold [°C]	MODULE = SIOH1			MODULE = SIOH2			MODULE = SIOH3			Group
					Th. Location		*M/C*	*Th. Location*		*M/C*	*Th. Location*		*M/C*	
TCS Line 01	close to STR 1	used	-19/-16	-19/-16	Star Tracker 1	THM-49	M+C	Star Tracker 1	THM-97	M+C	Star Tracker 1	THM-145	M+C	ET0
TCS Line 02	close to STR 2	used	-19/-16	-19/-16	Star Tracker 2	THM-50	M+C	Star Tracker 2	THM-98	M+C	Star Tracker 2	THM-146	M+C	ET0
TCS Line 03	close to DPU1	used	-9/-6	-9/-6	DPU1	THM-51	M+C	DPU1	THM-99	M+C	DPU1	THM-147	M+C	ET0
TCS Line 04	close to DPU2	used	-9/-6	-9/-6	DPU2	THM-52	M+C	DPU2	THM-100	M+C	DPU2	THM-148	M+C	ET0
TCS Line 05	close to REU	used	-9/-6	-9/-6	REU	THM-53	M+C	REU	THM-101	M+C	REU	THM-149	M+C	ET0
TCS Line 06	close to CCU, CEU	used	-9/-6	-9/-6	CCU	THM-54	M+C	CCU	THM-102	M+C	CCU	THM-150	M+C	ET0
TCS Line 07	on Heat Pipes	used	-10/-9	-10/-9	heat pipe	THM-55	M+C	heat pipe	THM-103	M+C	heat pipe	THM-151	M+C	ET0
TCS Line 08	on Heat Pipes	used	-11/-10	-11/-10	DAE	THM-56	M	DAE	THM-104	M	BEU	THM-152	M	ET0
TCS Line 09	on Heat Pipes	used	-12/-11	-12/-11	BEU	THM-57	M	He3 tank +Z	THM-105	M	He3 tank +Z	THM-153	M	ET0
TCS Line 10	on Heat Pipes	used	-13/-12	-13/-12	DCCU	THM-58	M	DCCU	THM-106	M		THM-154	spare	ET0
TCS Line 11	on Heat Pipes	used	-14/-13	-14/-13	He4 tank 3 -Y	THM-59	M	He4 tank 3 -Y	THM-107	M		THM-155	spare	ET0
TCS Line 12	on Heat Pipes	used	-15/-14	-15/-14	CEU (4KCDE)	THM-60	M	CEU (4KCDE)	THM-108	M	He4 tank 1 +Y	THM-156	M	ET0
TCS Line 13	on Heat Pipes	used	-16/-15	-16/-15	He4 tank 1 +Y	THM-61	M		THM-109	spare		THM-157	spare	ET0
TCS Line 14	HELIUM tanks	used	-9/-6	-9/-6	He4 tank 2 -Z	THM-62	M+C	He4 tank 2 -Z	THM-110	M+C	He4 tank 2 -Z	THM-158	M+C	ET0
TCS Line 15	PAU	used	-9/-6	-9/-6	PAU	THM-63	M+C	PAU	THM-111	M+C	PAU	THM-159	M+C	ET0
TCS Line 16	CRU (4K Reg)	used	-9/-6	-9/-6	CRU(4K Reg)	THM-64	M+C	CRU(4K Reg)	THM-112	M+C	CRU(4K Reg)	THM-160	M+C	ET0
TCS Line 17	CRS 1	used	48/48.5	48/48.5	CRS 1	THM-65	M+C	CRS 1	THM-113	M+C	CRS 1	THM-161	M+C	ET1
TCS Line 18	CRS 2	used	48/48.5	48/48.5	CRS 2	THM-66	M+C	CRS 2	THM-114	M+C	CRS 2	THM-162	M+C	ET1
TCS Line 19	CRS 3	used	35/35.5	35/35.5	CRS 3	THM-67	M+C	CRS 3	THM-115	M+C	CRS 3	THM-163	M+C	ET1
TCS Line 20	Propellant TANKS	used	N/A	N/A		THM-68	spare		THM-116	spare		THM-164	spare	ET1
TCS Line 21	on TANK +Z+Y	used	11/14	11/14	TANK +Z+Y	THM-69	M+C	TANK +Z+Y	THM-117	M+C	TANK +Z+Y	THM-165	M+C	ET1
TCS Line 22	on TANK +Z-Y	used	11/14	11/14	TANK +Z-Y	THM-70	M+C	TANK +Z-Y	THM-118	M+C	TANK +Z-Y	THM-166	M+C	ET1
TCS Line 23	on TANK -Z	used	11/14	11/14	TANK -Z	THM-71	M+C	TANK -Z	THM-119	M+C	TANK -Z	THM-167	M+C	ET1
TCS Line 24	on FCV A1A	used	14/21	14/21	1 N FCV A1A	THM-72	M+C	1 N FCV A1A	THM-120	M+C	1 N FCV A1A	THM-168	M+C	ET1
TCS Line 25	on FCV B1A	used	14/21	14/21	1 N FCV B1A	THM-73	M+C	1 N FCV B1A	THM-121	M+C	1 N FCV B1A	THM-169	M+C	ET1
TCS Line 26	on FCV D1A	used	14/21	14/21	20N FCV D1A	THM-74	M+C	20N FCV D1A	THM-122	M+C	20N FCV D1A	THM-170	M+C	ET1
TCS Line 27	on FCV D2A	used	14/21	14/21	20N FCV D2A	THM-75	M+C	20N FCV D2A	THM-123	M+C	20N FCV D2A	THM-171	M+C	ET1
TCS Line 28	on FCV F1A	used	14/21	14/21	20N FCV F1A	THM-76	M+C	20N FCV F1A	THM-124	M+C	20N FCV F1A	THM-172	M+C	ET1
TCS Line 29	on FCV F2A	used	14/21	14/21	20N FCV F2A	THM-77	M+C	20N FCV F2A	THM-125	M+C	20N FCV F2A	THM-173	M+C	ET1
TCS Line 30	on FCV U1A	used	14/21	14/21	20N FCV U1A	THM-78	M+C	20N FCV U1A	THM-126	M+C	20N FCV U1A	THM-174	M+C	ET1
TCS Line 31	on FCV U2A	used	14/21	14/21	20N FCV U2A	THM-79	M+C	20N FCV U2A	THM-127	M+C	20N FCV U2A	THM-175	M+C	ET1
TCS Line 32	on RCS units	used	32/33	32/33	PT unit	THM-80	M+C	PT unit	THM-128	M+C	PT unit	THM-176	M+C	ET1

Table 3-7 Planck Thermistors List (cont.)

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Heater line	*Heaters location*	Heater line status Used/spare Not-available	Unit ON Threshold [°C]	Unit OFF Threshold [°C]	MODULE = SIOH1			MODULE = SIOH2			MODULE = SIOH3			Group
					Th. Location		*M/C*	*Th. Location*		*M/C*	*Th. Location*		*M/C*	
TCS Line 33	on RCS PIPES	used	23/24	23/24	RCS piping	THM-81	M+C	RCS piping	THM-129	M+C	RCS piping	THM-177	M+C	ET2
TCS Line 34	on RCS PIPES	used	27/28	27/28	RCS piping	THM-82	M+C	RCS piping	THM-130	M+C	RCS piping	THM-178	M+C	ET2
TCS Line 35	close to CAU	used	-9/-6	-9/-6	CAU	THM-83	M+C	CAU	THM-131	M+C	CAU	THM-179	M+C	ET2
TCS Line 36	close to REBA1, REBA2	used	-19/-16	-19/-16	REBA 2	THM-84	M+C	REBA 2	THM-132	M+C	REBA 2	THM-180	M+C	ET2
TCS Line 37	inside BATTERY	used	1/4	1/4	BATTERY	THM-85	M+C	BATTERY	THM-133	M+C	BATTERY	THM-181	M+C	ET2
TCS Line 38	on FCV A1B	used	14/21	14/21	1 N FCV A1B	THM-86	M+C	1 N FCV A1B	THM-134	M+C	1 N FCV A1B	THM-182	M+C	ET2
TCS Line 39	on FCV B1B	used	14/21	14/21	1 N FCV B1B	THM-87	M+C	1 N FCV B1B	THM-135	M+C	1 N FCV B1B	THM-183	M+C	ET2
TCS Line 40	on FCV D1B	used	14/21	14/21	20N FCV D1B	THM-88	M+C	20N FCV D1B	THM-136	M+C	20N FCV D1B	THM-184	M+C	ET2
TCS Line 41	on FCV D2B	used	14/21	14/21	20N FCV D2B	THM-89	M+C	20N FCV D2B	THM-137	M+C	20N FCV D2B	THM-185	M+C	ET2
TCS Line 42	on FCV F1B	used	14/21	14/21	20N FCV F1B	THM-90	M+C	20N FCV F1B	THM-138	M+C	20N FCV F1B	THM-186	M+C	ET2
TCS Line 43	on FCV F2B	used	14/21	14/21	20N FCV F2B	THM-91	M+C	20N FCV F2B	THM-139	M+C	20N FCV F2B	THM-187	M+C	ET2
TCS Line 44	on FCV U1B	used	14/21	14/21	20N FCV U1B	THM-92	M+C	20N FCV U1B	THM-140	M+C	20N FCV U1B	THM-188	M+C	ET2
TCS Line 45	on FCV U2B	used	14/21	14/21	20N FCV U2B	THM-93	M+C	20N FCV U2B	THM-141	M+C	20N FCV U2B	THM-189	M+C	ET2
TCS Line 46	on RCS PIPES	used	19/20	19/20	RCS piping	THM-94	M+C	RCS piping	THM-142	M+C	RCS piping	THM-190	M+C	ET2
TCS Line 47	on RCS PIPES	used	21/22	21/22	RCS piping	THM-95	M+C	RCS piping	THM-143	M+C	RCS piping	THM-191	M+C	ET2
TCS Line 48	on RCS PIPES	used	20/21	20/21	RCS piping	THM-96	M+C	RCS piping	THM-144	M+C	RCS piping	THM-192	M+C	ET2

Table 3-7 Planck Thermistors List

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3.3. TCS FUNCTIONS

The TCS implements an active thermal control, based on thermistors and heaters controlled by a software algorithm.

On both satellites there are 108 heaters and 192 thermistors.

Each control loop is composed by 3 thermistors and 2 heater lines (1 prime and 1 redundant). There are two different classes of control loops:

- Control loop of class A (without thermal stability requirements and checked with a frequency of 60 seconds)

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- Control loop of class B (with thermal stability requirements and checked with a frequency of 10 seconds)

Herschel is equipped with control loops of both classes while Planck is equipped only with control loops of class A.

The commanding towards the heater lines is performed by properly managing, via 1553 S/C bus, the relevant Heater Control Switches (HCS) and Heater Protection Switches (HPS), which physically belongs to the PCDU. The PCDU has 54 prime and 54 redundant HCS, divided into 9 groups of 6 HCSs, one group per HPS.

The nominal operation heaters will be used to maintain the operative temperature during the nominal phases. They will be commanded by the CDMU and operate in ON/OFF mode for Class A control loops regulation or following a Proportional & Integrative (PI) regulation for the Class B control loops.

The thermal regulation will follow the reading of 3 Thermistors per temperature measurement point, for failure tolerance reason (majority voting).

To increase the temperature reading stability, the 3 thermistors values are compared among them and the average of the good ones are used in the algorithm of the temperature control. With this approach it is also possible to detect the failure of one sensor. The temperature monitoring algorithm is described in Section 3.8.1.2.

The functional design of one nominal Heater Control of the Thermal regulation is shown in Figure 3-5.

For each Thermal controlled point, 3 temperature values are acquired by the CDMU.

The CDMU ASW, after a preliminary control on the sensors integrity, operates the Heaters sending to the PCDU HCS the OPEN or CLOSE Command to perform the Class A or Class B Thermal regulation.

The active TCS system has been designed by means of 9 nominal Heaters groups and 9 redundant Heaters groups. Each Heaters group is made up of 1 HPS, 6 HCS and a thermistor.

Each HCS controls one heater line and is based on a Mosfet in the return line. The maximum current of each line is 3.75 A except for one line per group for which it is 4.1 A.

Each group of 6 HCS is protected by an HPS in the positive line that limits output currents and then switches OFF the HPS in the event of an over-current. The capacity of each HPS, and thus of each group, is 10 A.

Heater lines are protected against risk of Mosfet drain-gate short circuit failure via an internal protection that switches OFF heater protection switch and heater control switches.

If it concerns an HCS Mosfet, the failure is detected via a thermistor placed near all the HCS of the group. The temperature threshold for the thermistor is set at 110 °C typically.

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3.4. TCS PERFORMANCE

The TCS shall ensure the temperature stability of the spacecraft during all operative phases, to meet the mission requirements from launch until end of mission with minimum use of heater power.

The Herschel and Planck SVM Thermal control shall ensure that any equipment/unit remains within its operating and non-operating ranges.

The standard heater operation is the ON-OFF logic inside a threshold operated via thermistor.

Many heater circuit lines are requested to operate both in Nominal configuration (unit ON) and in Survival (unit OFF) configuration.

This means that there is the possibility that the same heater circuit line works with different temperature threshold settings

For this reason it is requested that the Application Software is able to manage different temperature thresholds for different S/C operating modes.

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Heater lines characteristics are given in Table 3-3 and Table 3-4 while heater lines thresholds are given in Table 3-6 and Table 3-7.

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FDIR thresholds together with OPerative and Not OPerative temperatures are provided in Table 3-11 and Table 3-12.

For the Herschel HIFI and Star Tracker temperature stability requirements, heaters are operated by means of a fine control law (PID regulation).

The detailed Class B Algorithm using the PWM (Pulse Width Modulation) with a frequency of 1 Hz regulated by a fine control law (PI regulation) is described in Section 3.8.1.2.

Further details can be found in **[TCSRS]**.

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3.5. TCS OPERATIONS MODES

3.5.1. TCS Modes synthesis

The following diagram describes the TCS mode transitions.

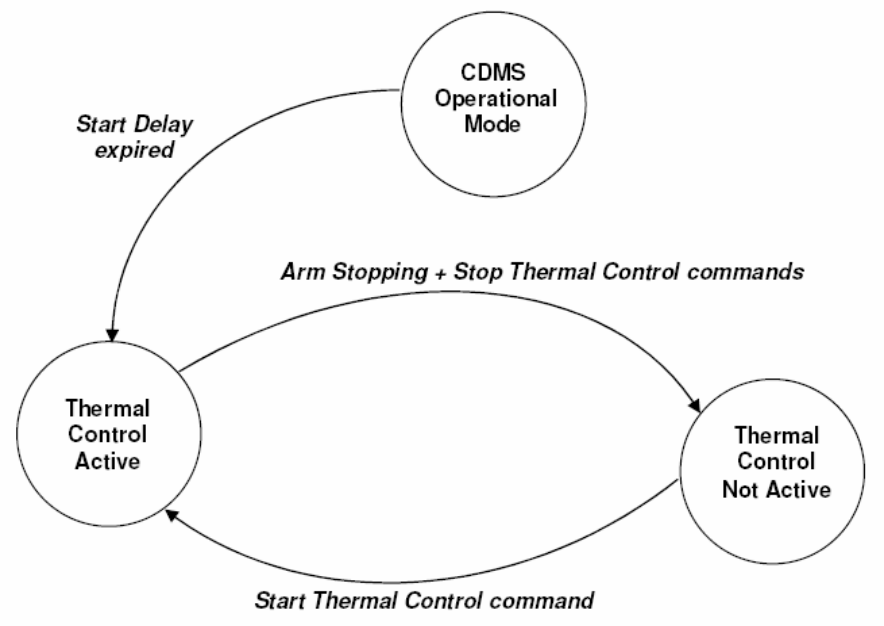

Figure 3-4 TCS Modes Transitions

The Thermal Control Function is active whenever the CDMU is active, starting with a predefined delay stored in EEPROM (now set to 2 minutes) and modifiable via TC after completion of the CDMU ASW bootstrap.

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During this start delay the ASW function is enabled and it can receive and execute commands, but the thermal monitoring and commanding is started after the start delay.

The thermal control operations can be activated during the start delay by the following command sequence:

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- TC (8,4,114,3) “Arm stopping of Thermal Control”;
- TC (8,2,114) “Stop Thermal Control”;
- TC (8,1,114) “Start Thermal Control”.

The start delay value is configurable and can be changed using the TC (8,4,114,17) when the TCS is “Active”.

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3.5.2. TCS Detailed Modes

3.5.2.1. TCS Active Mode

The pre-requisites are the following:

- CDMS in Operational Mode;
- Thermal Control Function Start Delay expired;
- PCDU 1553 TM/TC Module currently in use ON (according to the Unit in Use actual content).

When the PCDU 1553 TM/TC Module currently in use is initialised, the PCDU itself will close all the HPS (Nominal and Redundant).

When the Thermal Control is Active, the CDMS ASW can operate all the Heater Control Switches (HCS) relevant to the HPS currently in use (according to the Unit in Use actual content) to maintain the TCS controlled units /equipments temperatures within their operating / not operating range according to the relevant unit status.

The activation of a single Control Loop depends of the Control Loop Status in the TCT.

If the Control Loop Status is “ENABLED”, the CDMU ASW commands the Heater Control Switch (HCS) to open or close following the Class A or Class B Control Law.

If the Control Loop Status is “DISABLED”, the CDMU ASW commands the Heater Control Switch in open position until the Control Loop will be enabled again.

The transition from the TCS Function Not Active Mode to the TCS Function Active Mode is performed by a TC (8,1,114) Start Thermal Control command.

It is noted that when the Thermal Control Function is Active, it is possible to act on all the modifiable parameters used by TCS Function e.g. the delay time value or the TCT content.

3.5.2.2. TCS Not Active Mode

When the Thermal Control is Not Active, the CDMS ASW can only receive commands to Start or Stop the Thermal Control Function or provide the Thermal Control Status Report Parameters.

Management of the TCT is not possible when the Thermal Control Function is Not Active.

Moreover, if Ground wants to disable the Thermal Control Function, the CDMS ASW will not change the HCS configuration keeping it as it was before the disabling of the TCS Function.

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3.6. TCS INTERFACES

3.6.1. TCS External interfaces

Due to its particular feature, the TCS is spread all over the SVM. For operations purposes, the main items defining the TCS configuration are heaters and thermistors (*active TCS*).

The following figure shows all the external interface of the active TCS.

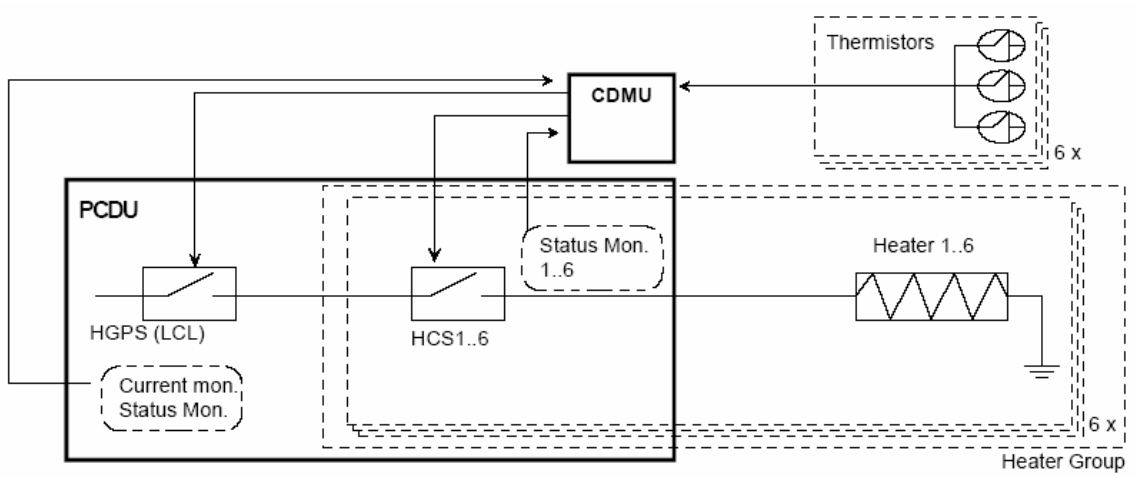

Figure 3-5 TCS External I/Fs

As it can be seen, the external I/Fs of the TCS can be divided in the following categories:

- Power interfaces with the PCDU: heaters are supplied through HPSs and HCSs (commanded and monitored via 1553 S/C bus);
- TM interfaces with the CDMU: thermistors are monitored through I/O channels.

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3.6.2. TCS Internal Interfaces

Table 3-8 and Table 3-9 summarize all the control loops (heater lines and thermistors) and the related ASW control loop as set in the nominal Thermal Control Table (for more details refer to **[HASWTAB]** and **[PASWTAB]**).

The allocation (module) of each HCS and HPS inside the PCDU is reported as well.

CL ID	PCDU used identifier		Heater Line		Heater location	Thermistor 1	Thermistor 2	Thermistor 3	CL class
	Nom	Red	Nom	Red					
6	Grp1Heat 6 (module 1)	Grp18Heat 6 (module 10)	01	55	close to XPND1	THM-49	THM-97	THM-145	A
2	Grp1Heat 2 (module 1)	Grp18Heat 2 (module 10)	02	56	close to XPND2	THM-50	THM-98	THM-146	A
38	Grp7Heat 2 (module 4)	Grp12Heat 2 (module 7)	03	57	inside BATTERY	THM-51	THM-99	THM-147	A
12 (*)	Grp2Heat 6 (module 2)	Grp17Heat 6 (module 9)	04	58	TANKS	THM-52	THM-100	(THM 148)	A
11	Grp2Heat 5 (module 2)	Grp17Heat 5 (module 9)	05	59	close to FPSPU, FPDPU	THM-53	THM-101	THM-149	A
13	Grp3Heat 1 (module 2)	Grp16Heat 1 (module 9)	06	60	close to FPBOLC	THM-54	THM-102	THM-150	A
14	Grp3Heat 2 (module 2)	Grp16Heat 2 (module 9)	07	61	CRS 1	THM-55	THM-103	THM-151	A
15	Grp3Heat 3 (module 2)	Grp16Heat 3 (module 9)	08	62	close to FPDECMEC	THM-56	THM-104	THM-152	A
16	Grp3Heat 4 (module 2)	Grp16Heat 4 (module 9)	09	63	RCS PIPES	THM-57	THM-105	THM-153	A
17	Grp3Heat 5 (module 2)	Grp16Heat 5 (module 9)	10	64	close to CCU, HSDCU, HSFCU	THM-58	THM-106	THM-154	A
5	Grp1Heat 5 (module 1)	Grp18Heat 5 (module 10)	11	65	RCS PIPES	THM-59	THM-107	THM-155	A
20	Grp4Heat 2 (module 3)	Grp15Heat 2 (module 8)	12	66	close to FHWOV	THM-60	THM-108	THM-156	B
43	Grp8Heat 1 (module 5)	Grp11Heat 1 (module 6)	13	67	close to FHHRV	THM-61	THM-109	THM-157	A
53	Grp9Heat 5 (module 1)	Grp10Heat 5 (module 6)	14	68	STR1 Primary Baffle	THM-62	THM-110	THM-158	A
27	Grp5Heat 3 (module 3)	Grp14Heat 3 (module 8)	15	69	close to FHWEV, FHICU	THM-63	THM-111	THM-159	A
39	Grp7Heat 3 (module 4)	Grp12Heat 3 (module 7)	16	70	close to FHWOH	THM-64	THM-112	THM-160	B
40	Grp7Heat 4 (module 4)	Grp12Heat 4 (module 7)	17	71	close to FHWEH	THM-65	THM-113	THM-161	A
26	Grp5Heat 2 (module 3)	Grp14Heat 2 (module 8)	18	72	close to FHHRH	THM-66	THM-114	THM-162	A

Table 3-8 Herschel Control Loops (cont.)

CL ID	PCDU used identifier		Heater Line		Heater location	Thermistor 1	Thermistor 2	Thermistor 3	CL class
	Nom	Red	Nom	Red					
48	Grp8Heat 6 (module 5)	Grp11Heat 6 (module 6)	19	73	close to FHLCU, FHIFH	THM-67	THM-115	THM-163	A
52	Grp9Heat 4 (module 5)	Grp10Heat 4 (module 6)	20	74	close to FHLSU	THM-68	THM-116	THM-164	A
26	Grp6Heat 6 (module 4)	Grp13Heat 6 (module 7)	21	75	on RWL2	THM-69	THM-117	THM-165	A
32	Grp6Heat 2 (module 4)	Grp13Heat 2 (module 7)	22	76	on RWL4	THM-70	THM-118	THM-166	A
33	Grp6Heat 3 (module 4)	Grp13Heat 3 (module 7)	23	77	on RWL1	THM-71	THM-119	THM-167	A
34	Grp6Heat 4 (module 4)	Grp13Heat 4 (module 7)	24	78	on RWL3	THM-72	THM-120	THM-168	A
54	Grp9Heat 6 (module 5)	Grp10Heat 6 (module 6)	25	79	on TANK +Y	THM-73	THM-121	THM-169	A
50	Grp9Heat 2 (module 5)	Grp10Heat 2 (module 6)	26	80	on TANK -Y	THM-74	THM-122	THM-170	A
37	Grp7Heat 1 (module 4)	Grp12Heat 1 (module 7)	27	81	close to STR's	THM-75	THM-123	THM-171	B
35	Grp6Heat 5 (module 4)	Grp13Heat 5 (module 7)	28	82	close to FHIFV	THM-76	THM-124	THM-172	B
22	Grp4Heat 4 (module 3)	Grp15Heat 4 (module 8)	29	83	on FCV A1A	THM-77	THM-125	THM-173	A
23	Grp4Heat 5 (module 3)	Grp15Heat 5 (module 8)	30	84	on FCV C2A	THM-78	THM-126	THM-174	A
41	Grp7Heat 5 (module 4)	Grp12Heat 5 (module 7)	31	85	on FCV C1A	THM-79	THM-127	THM-175	A
42	Grp7Heat 6 (module 4)	Grp12Heat 6 (module 7)	32	86	on FCV A2A	THM-80	THM-128	THM-176	A
51	Grp9Heat 3 (module 5)	Grp10Heat 3 (module 6)	33	87	on FCV C4A	THM-81	THM-129	THM-177	A
44	Grp8Heat 2 (module 5)	Grp11Heat 2 (module 6)	34	88	on FCV C3A	THM-82	THM-130	THM-178	A
45	Grp8Heat 3 (module 5)	Grp11Heat 3 (module 6)	35	89	on RCS PIPES	THM-83	THM-131	THM-179	A
46	Grp8Heat 4 (module 5)	Grp11Heat 4 (module 6)	36	90	STR2 Primary Baffle	THM-84	THM-132	THM-180	A
47	Grp8Heat 5 (module 5)	Grp11Heat 5 (module 6)	37	91	on RCS PIPES	THM-85	THM-133	THM-181	A

Table 3-8 Herschel Control Loops (cont.)

CL ID	PCDU used identifier		Heater Line		Heater location	Thermistor 1	Thermistor 2	Thermistor 3	CL class
	Nom	Red	Nom	Red					
18	Grp3Heat 6 (module 2)	Grp16Hea t6 (module 9)	38	92	close to GYRO	THM-86	THM-134	THM-182	A
3	Grp1Heat 3 (module 1)	Grp18Hea t3 (module 10)	39	93	on FCV A1B	THM-87	THM-135	THM-183	A
4	Grp1Heat 4 (module 1)	Grp18Hea t4 (module 10)	40	94	on FCV C2B	THM-88	THM-136	THM-184	A
8	Grp2Heat 2 (module 2)	Grp17Hea t2 (module 9)	41	95	on FCV C1B	THM-89	THM-137	THM-185	A
9	Grp2Heat 3 (module 2)	Grp17Hea t3 (module 9)	42	96	on FCV A2B	THM-90	THM-138	THM-186	A
10	Grp2Heat 4 (module 2)	Grp17Hea t4 (module 9)	43	97	on FCV C4B	THM-91	THM-139	THM-187	A
28	Grp5Heat 4 (module 3)	Grp14Hea t4 (module 8)	44	98	on FCV C3B	THM-92	THM-140	THM-188	A
21	Grp4Heat 3 (module 3)	Grp15Hea t3 (module 8)	45	99	on RCS PIPES	THM-93	THM-141	THM-189	A
24	Grp4Heat 6 (module 3)	Grp15Hea t6 (module 8)	46	100	on RCS PIPES	THM-94	THM-142	THM-190	A
29	Grp5Heat 5 (module 3)	Grp14Hea t5 (module 8)	47	101	on RCS PIPES	THM-95	THM-143	THM-191	A
30	Grp5Heat 6 (module 3)	Grp14Hea t6 (module 8)	48	102	on unit: PT, LF, LV1, LV2	THM-96	THM-144	THM-192	A
25	Grp5Heat 6 (module 3)	Grp14Hea t6 (module 8)	49	103	CRS 2	THM-12	THM-20	THM-36	A

(*): Control Loop disabled (THM-xxx): spare

Table 3-8 Herschel Control Loops

CL ID	PCDU used identifier		Heater Line		Heater location	Thermistor 1	Thermistor 2	Thermistor 3	CL class
	Nom	Red	Nom	Red					
29	Grp5Heat 5 (module 1)	Grp14Hea t5 (module 10)	01	55	close to STR 1	THM-49	THM-97	THM-145	A
30	Grp5Heat 6 (module 1)	Grp14Hea t6 (module 10)	02	56	close to STR 2	THM-50	THM-98	THM-146	A
6	Grp1Heat 6 (module 4)	Grp18Hea t6 (module 7)	03	57	close to DPU1	THM-51	THM-99	THM-147	A
33	Grp6Heat 3 (module 2)	Grp13Hea t3 (module 9)	04	58	close to DPU2	THM-52	THM-100	THM-148	A
48	Grp8Heat 6 (module 2)	Grp11Hea t6 (module 9)	05	59	close to REU	THM-53	THM-101	THM-149	A
5	Grp1Heat 5 (module 2)	Grp18Hea t5 (module 9)	06	60	close to CCU, CEU	THM-54	THM-102	THM-150	A
13	Grp3Heat 1 (module 2)	Grp16Hea t1 (module 9)	07	61	on Heat Pipes	THM-55	THM-103	THM-151	A
14 (**)	Grp3Heat 2 (module 3)	Grp16Hea t2 (module 8)	08	62	on Heat Pipes	THM-56	THM-104	THM-152	A
8 (**)	Grp2Heat 2 (module 2)	Grp17Hea t2 (module 9)	09	63	on Heat Pipes	THM-57	THM-105	THM-153	A
12 (**)	Grp2Heat 6 (module 2)	Grp17Hea t6 (module 9)	10	64	on Heat Pipes	THM-58	THM-106	(THM-154)	A
32 (**)	Grp6Heat 2 (module 4)	Grp13Hea t2 (module 7)	11	65	on Heat Pipes	THM-59	THM-107	(THM-155)	A
28 (**)	Grp3Heat 6 (module 2)	Grp16Hea t6 (module 9)	12	66	on Heat Pipes	THM-60	THM-108	THM-156	A
27 (**)	Grp5Heat 3 (module 3)	Grp14Hea t3 (module 8)	13	67	on Heat Pipes	THM-61	(THM-109)	(THM-157)	A
18	Grp5Heat 4 (module 3)	Grp14Hea t4 (module 8)	14	68	HELIUM tanks	THM-62	THM-110	THM-158	A
49	Grp9Heat 1 (module 5)	Grp10Hea t1 (module 6)	15	69	PAU	THM-63	THM-111	THM-159	A
50	Grp9Heat 2 (module 5)	Grp10Hea t2 (module 6)	16	70	CRU (4K Reg)	THM-64	THM-112	THM-160	A
37	Grp7Heat 1 (module 4)	Grp12Hea t1 (module 7)	17	71	CRS 1	THM-65	THM-113	THM-161	A
38	Grp7Heat 2 (module 4)	Grp12Hea t2 (module 7)	18	72	CRS 2	THM-66	THM-114	THM-162	A
24	Grp4Heat 6 (module 3)	Grp15Hea t6 (module 8)	19	73	CRS 3	THM-67	THM-115	THM-163	A
20 (*)	Grp4Heat 2 (module 3)	Grp15Hea t2 (module 8)	20	74	Propellant TANKS	(THM-68)	(THM-116)	(THM-164)	A

CL ID	PCDU used identifier		Heater Line		Heater location	Thermistor 1	Thermistor 2	Thermistor 3	CL class
	Nom	Red	Nom	Red					
45	Grp8Heat 3 (module 5)	Grp11Heat 3 (module 6)	21	75	on TANK +Z+Y	THM-69	THM-117	THM-165	A
46	Grp8Heat 4 (module 5)	Grp11Heat 4 (module 6)	22	76	on TANK +Z-Y	THM-70	THM-118	THM-166	A
47	Grp8Heat 5 (module 5)	Grp11Heat 5 (module 6)	23	77	on TANK -Z	THM-71	THM-119	THM-167	A
3	Grp1Heat 3 (module 1)	Grp18Heat 3 (module 10)	24	78	on FCV A1A	THM-72	THM-120	THM-168	A
4	Grp1Heat 4 (module 1)	Grp18Heat 4 (module 10)	25	79	on FCV B1A	THM-73	THM-121	THM-169	A
36	Grp6Heat 6 (module 4)	Grp13Heat 6 (module 7)	26	80	on FCV D1A	THM-74	THM-122	THM-170	A
9	Grp2Heat 3 (module 2)	Grp17Heat 3 (module 9)	27	81	on FCV D2A	THM-75	THM-123	THM-171	A

(*): Control Loop disabled (THM-xxx): spare
(**): Control Loops 8, 12, 14, 27, 28 and 32 use all the same thermistors as Control Loop 13

Table 3-9 Planck Control Loops (cont.)

CL ID	PCDU used identifier		Heater Line		Heater location	Thermistor 1	Thermistor 2	Thermistor 3	CL class
	Nom	Red	Nom	Red					
10	Grp2Heat 4 (module 2)	Grp17Heat 4 (module 9)	28	82	on FCV F1A	THM-76	THM-124	THM-172	A
11	Grp2Heat 5 (module 2)	Grp17Heat 5 (module 9)	29	83	on FCV F2A	THM-77	THM-125	THM-173	A
53	Grp9Heat 5 (module 5)	Grp10Heat 5 (module 6)	30	84	on FCV U1A	THM-78	THM-126	THM-174	A
54	Grp9Heat 5 (module 5)	Grp10Heat 6 (module 6)	31	85	on FCV U2A	THM-79	THM-127	THM-175	A
39	Grp7Heat 3 (module 4)	Grp12Heat 3 (module 7)	32	86	on RCS units	THM-80	THM-128	THM-176	A
40	Grp7Heat 4 (module 4)	Grp12Heat 4 (module 7)	33	87	on RCS PIPES	THM-81	THM-129	THM-177	A
41	Grp7Heat 5 (module 4)	Grp12Heat 5 (module 7)	34	88	on RCS PIPES	THM-82	THM-130	THM-178	A
2	Grp1Heat 2 (module 1)	Grp18Heat 2 (module 10)	35	89	close to CAU	THM-83	THM-131	THM-179	A
15	Grp3Heat 3 (module 2)	Grp16Heat 3 (module 9)	36	90	close to REBA1, REBA2	THM-84	THM-132	THM-180	A
16	Grp3Heat 4 (module 2)	Grp16Heat 4 (module 9)	37	91	inside BATTERY	THM-85	THM-133	THM-181	A
17	Grp3Heat 5 (module 2)	Grp16Heat 5 (module 9)	38	92	on FCV A1B	THM-86	THM-134	THM-182	A

CL ID	PCDU used identifier		Heater Line		Heater location	Thermistor 1	Thermistor 2	Thermistor 3	CL class
	Nom	Red	Nom	Red					
21	Grp4Heat 3 (module 3)	Grp15Heat 3 (module 8)	39	93	on FCV B1B	THM-87	THM-135	THM-183	A
22	Grp4Heat 4 (module 3)	Grp15Heat 4 (module 8)	40	94	on FCV D1B	THM-88	THM-136	THM-184	A
23	Grp4Heat 5 (module 3)	Grp15Heat 5 (module 8)	41	95	on FCV D2B	THM-89	THM-137	THM-185	A
25	Grp5Heat 1 (module 3)	Grp14Heat 1 (module 8)	42	96	on FCV F1B	THM-90	THM-138	THM-186	A
26	Grp5Heat 2 (module 3)	Grp14Heat 2 (module 8)	43	97	on FCV F2B	THM-91	THM-139	THM-187	A
34	Grp6Heat 4 (module 4)	Grp13Heat 4 (module 7)	44	98	on FCV U1B	THM-92	THM-140	THM-188	A
35	Grp6Heat 5 (module 4)	Grp13Heat 5 (module 7)	45	99	on FCV U2B	THM-93	THM-141	THM-189	A
42	Grp7Heat 6 (module 4)	Grp12Heat 6 (module 7)	46	100	on RCS PIPES	THM-94	THM-142	THM-190	A
44	Grp8Heat 2 (module 5)	Grp11Heat 2 (module 6)	47	101	on RCS PIPES	THM-95	THM-143	THM-191	A
51	Grp9Heat 3 (module 5)	Grp10Heat 3 (module 6)	48	102	on RCS PIPES	THM-96	THM-144	THM-192	A

Table 3-9 Planck Control Loops

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3.7. TCS FAILURES

3.7.1. TCS Fault Management and Redundancy Provision

H/P SVM Thermal Control Subsystem has been designed in order to satisfy the requirements of single failure tolerance. The provision of unit redundancy is the main design feature that allows meeting the requirement.

In case one heater or one thermistor fails, TCS shall be capable to maintain all satellite equipments within their temperature ranges defined in the Thermal ICD **[THICD]** for each mode of the S/C.

Heaters thermal regulation is based on the reading of 3 thermistors per temperature point for failure tolerance reason.

Details on the algorithm implemented in the CDMS ASW to discard the wrong temperature readings can be found in the next sections.

It is noted that two different on board algorithms are used for the on board temperature determination.

One is relevant to the nominal process (refer to Section 3.8.1.2) while the other is used for the FDIR processing (refer to Section 3.7.2).

3.7.2. TCS Failures Identification and Recovery Actions

The following TCS failures have been identified:

- Level 2:
  - Class A/B control loop failure
- Level 1:
  - Thermistor failure

Note that the TCS is "re-configured" by the CDMU ASW also during the recovery of failures occurred in other subsystems.

In fact for all units/equipments controlled by TCS, a unit status modification either following a nominal operation or due to an FDIR action results in a change of the relevant TCS control.

A further failure case is represented by the possible HCS high dissipation.

This failure is monitored and recovered through the Monitoring Table (MOT) / Event Action Table (EAT).

More details are given in [SOFDIR], [FDIRSPEC], [CDMUASWRS], [HASWTAB] and [PASWTAB].

3.7.2.1. TCS Level 2 Failure Detection and Recovery

Class A/B Control Loop Failure

For each thermally controlled point, the CDMU ASW acquires temperature values from the 3 associated thermistors (TEMP1, TEMP2, and TEMP3); the value used by level-2 FDIR algorithms (TEMP) shall then be the middle one:

```
IF (TEMP2 ≥ TEMP1 ≥ TEMP3) OR (TEMP3 ≥ TEMP1 ≥ TEMP2)
        SET TEMP = TEMP1
ENDIF

IF (TEMP1 ≥ TEMP2 ≥ TEMP3) OR (TEMP3 ≥ TEMP2 ≥ TEMP1)
        SET TEMP = TEMP2
ENDIF

IF (TEMP1 ≥ TEMP3 ≥ TEMP2) OR (TEMP2 ≥ TEMP3 ≥ TEMP1)
        SET TEMP = TEMP3
ENDIF
```

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For TCS level-2 FDIR purposes, the following temperature thresholds have been defined:

Unit Status	FDIR Control Thresholds
Unit OFF	FDIR Low NOP; FDIR High NOP
Unit ON and Time-out not expired	Cold Start Temp; FDIR High OP
Unit ON and Time-out expired	FDIR Low OP; FDIR High OP

Table 3-10 FDIR Temperature Thresholds

These thresholds are used as inputs by a dedicated CDMS ASW algorithm aiming at identifying a possible Class A/B Control Loop failure (see below).

Parameters listed in Table 3-10, defined for each Class A/B Control loop needing a FDIR action, are contained in the FDIR Cross Correlated Table (FCCT) and can be changed by Ground if needed.

Output of this FDIR algorithm (Cross Correlated flag) is verified against an expected value contained in the Monitoring Table.

If the expected value is violated, an event is triggered and passed to the Event Action Table (EAT).

If the event matches with the EAT content, a TC triggering the related recovery action will be autonomously released by the ASW.

For further details refer to CDMS UM Volume 2.

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Class A/B Control Loop Failure Detection/Isolation

The CDMU ASW monitors TEMP and detects a class A/B control loop failure according to the following algorithm, to be executed every 3 min for class A control loop and every 60 s for class B control loop:

IF (TCT Unit Status = Powered OFF)

IF ((TEMP > FDIR_HIGH_NOP) ***OR*** (TEMP < FDIR_LOW_NOP))
Set RECONFIGURATION [HPS] [HCS] = True
ELSE
Set RECONFIGURATION [HPS] [HCS] = False
ENDIF

ELSEIF ((TCT UNIT Status = Powered ON) ***AND***
(Time from TCT Loop Unit switch-on < TCT Loop Unit time-out))

IF ((TEMP > FDIR_HIGH_OP) *OR* (TEMP < Cold Start Temp))
Set RECONFIGURATION [HPS] [HCS] = True
ELSE
Set RECONFIGURATION [HPS] [HCS]= False
ENDIF

ELSEIF ((TCT UNIT Status = Powered ON) ***AND***
(Time from TCT Loop Unit switch-on >= TCT Loop Unit time-out))

IF ((TEMP > FDIR_HIGH_OP) ***OR*** (TEMP < FDIR_LOW_OP))
Set RECONFIGURATION [HPS] [HCS] = True
ELSE
Set RECONFIGURATION [HPS] [HCS] = False
ENDIF

Where:

- TCT Unit Status = status of the unit in the Unit In Use Table;
- FDIR_HIGH_NOP, FDIR_LOW_NOP, FDIR_HIGH_OP, FDIR_LOW_OP, Cold Start Temp and time-out are parameters defined for each TCT Loop and contained in the FDIR Cross Correlated Checks Table;
- All RECONFIGURATION [HPS] [HCS] are set to False by default before the Algorithm is
- computed for all the HCSs.
- It is noted that RECONFIGURATION [HPS] [HCS] is a 9x6 matrix;

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Deleted: ***ENDIF***¶
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Deleted: ***AND*** (RECONFIGURATION = False)
Deleted: Set Failure of the Unit [NAME] thermal control = True¶
Deleted: Set Failure of the Unit [NAME] thermal co ... [21]
Deleted: ***ENDIF***¶
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Deleted: [NAME]
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– The link between the TCT Loop Unit ID and the related FCCT entry is the following:

– FCCT ID = 18 + TCT Loop Unit

It is noted that when the unit is OFF, the algorithm uses the NOP (Not Operating) thresholds.

When the unit is switched ON, i.e. the minimum switch ON temperature is reached (Cold Start temperature), the algorithm switches its FDIR thresholds from the NOP values to the pair Cold Start Temperature (low value) and OP High temperature (high value).

If the FDIR thresholds are switched from the NOP value to OP values while the unit is still reaching its nominal range, a false FDIR would be likely triggered.

In order to prevent this wrong failure case, a time out is introduced.

This value is set as an estimation of the time needed by a unit to reach its nominal range starting from the switch ON condition.

In principle a time out can be defined for each thermal loop controlled by the CDMS ASW.

Before the time out expiration, FDIR low threshold is set to the unit Cold Start temperature.

After the time out has expired, the FDIR thresholds are moved to the OP values.

The above mentioned definitions are reported in the following sketch:

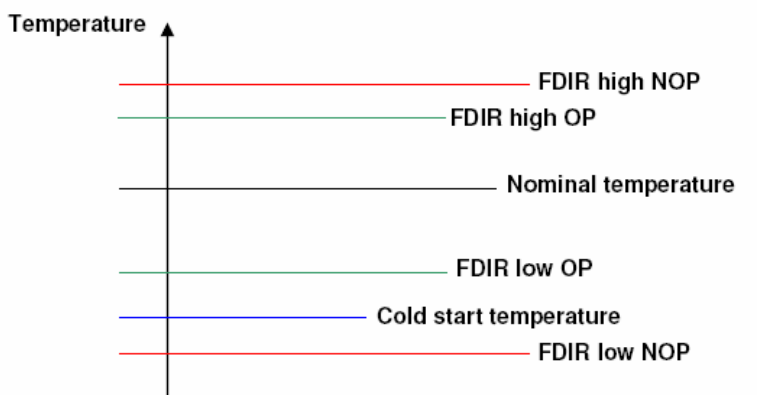

Figure 3-6 FDIR Temperature Limits

The general approach for the FDIR temperature limits definition is the following:

– FDIR operative (OP) limits are defined by applying a 4 ºC margin with respect to the OP limits, i.e. remaining within the acceptance temperatures.

– FDIR non-operative (NOP) limits are defined to be as the NOP temperature limits.

The following special cases are hereafter identified:

- RCS

  All RCS equipments (FCVs, pipes, PT, LFs, LVs and propellant tanks) do not have different OP and NOP temperatures and they are not provided with any ON/OFF status.

  The used approach is then to keep the same limits for FDIR OP and NOP limits provided that the main driver for the FDIR low temperatures definition is the Hydrazine freezing temperature (4 ºC).

  Then FDIR low limits (both OP and NOP) are defined to be 2 ºC below the Low OP temperature, keeping a reasonable margin wrt the 4 ºC Hydrazine freezing temperature.

  FDIR High Limits (both OP and NOP) are set to be 4 ºC above the OP temperature.

  Start up temperatures for all RCS equipments are not applicable.

  All the entries in the FCCT relevant to this information for all the RCS equipments will be filled with the lowest temperature read by the relevant thermistors (-60 ºC).

- Battery

  There are 4 internal heaters mounted on each battery; two are controlled by the TCS through the On Board SoftWare (OBSW) while the others are managed through dedicated thermostats and supplied by FCL lines. Thermostat thresholds are set to -5 ºC (heaters switch ON), 0 ºC (heaters switch OFF).

  Moreover it is not possible to define OP and NOP temperatures for the Battery.

  The approach is then to have the same thresholds for OP and NOP FDIR thresholds and fix them applying the general rule to keep a +/- 4 ºC margin.

- CRSs

  CRSs do not have different OP and NOP temperatures and are supposed to be always ON during the whole mission. The approach is then to have the same thresholds for OP and NOP FDIR thresholds and fix them applying the general rule to keep a +/- 4 ºC margin.

- DPU / SPU (Herschel)

  SPU NOP Low temperature, higher than the DPU one, is used as a reference for this line.

– FHWEV /FHICU (Herschel)

  FHWEV temperatures are used as reference for this line.

– REBA (Planck)

  High OP and NOP temperatures are equal.

  A margin of 4 ºC is then applied both for the OP and NOP FDIR High limits.

– He Tank (Planck)

  Start up temperatures for the He Tank is not applicable.

  FCCT entry relevant to this information will be filled with the lowest temperature read by the relevant thermistors (-60 ºC).

Table 3-11 and Table 3-12 summarize the FDIR limits values for both Herschel and Planck:

Table 3-11 Herschel On-Board FDIR Limits (cont'd)

THERMAL LOOP	MIN OP [°C]	FDIR LOW_OP [°C]	MAX OP [°C]	FDIR HIGH_OP [°C]	MIN NOT OP= FDIR LOW NOP [°C]	MAX NOT OP= FDIR HIGH NOP [°C]	START UP TEMP [°C]
FCCT_XPND2_Lp02_CLA	-10	-14	45	49	-20	55	-30
FCCT_FCVA1B_Lp39_CLA	10	8	60	64	8	64	-60
FCCT_FCVC2B_Lp40_CLA	10	8	60	64	8	64	-60
FCCT_RCS_PIPE_2_Lp11_CLA	10	8	50	54	8	54	-60
FCCT_XPND1_ Lp01_CLA	-10	-14	45	49	-20	55	-30
FCCT_FCVC1B_Lp41_CLA	10	8	60	64	8	64	-60
FCCT_FCVA2B_Lp42_CLA	10	8	60	64	8	64	-60
FCCT_FCVC4B_Lp43_CLA	10	8	50	54	8	54	-60
FCCT_DPU/SPU_Lp05_CLA	-15	-19	45	49	-30	60	-30
FCCT_FPBOLC_Lp06_CLA	-15	-19	45	49	-30	60	-30
FCCT_FPDECMEC_Lp08_CLA	-15	-19	45	49	-30	60	-30
FCCT_RCS_PIPE_1_Lp09_CLA	10	8	50	54	8	54	-60
FCCT_CCU_Lp10_CLA	-10	-14	40	44	-20	50	-20
FCCT_GYRO_Lp38_CLA	-15	-19	65	69	-35	75	-30
FCCT_RCS_PIPE_6_Lp45_CLA	10	8	50	54	8	54	-60
FCCT_FCVA1A_Lp29_CLA	10	8	60	64	8	64	-60
FCCT_FCV C2A_Lp30_CLA	10	8	60	64	8	64	-60
FCCT_RCS_PIPE_7_Lp46_CLA	10	8	50	54	8	54	-60
FCCT_FHHRH_Lp18_CLA	-10	-14	40	44	-25	55	-25
FCCT_FHWEV_ICU_Lp15_CLA	0	-4	30	34	-25	55	-25
FCCT_FCVC3B_Lp44_CLA	10	8	60	64	8	64	-60
FCCT_RCS PIPE_8_Lp47_CLA	10	8	50	54	8	54	-60

THERMAL LOOP	MIN OP [°C]	FDIR LOW_OP [°C]	MAX OP [°C]	FDIR HIGH_OP [°C]	MIN NOT OP= FDIR LOW NOP [°C]	MAX NOT OP= FDIR HIGH NOP [°C]	START UP TEMP [°C]
FCCT_PT_LF_LV12_Lp48_CLA	10	8	50	54	8	54	-60
FCCT_RWL4_Lp22_CLA	-10	-14	60	64	-20	70	-15
FCCT_RWL1_Lp23_CLA	-10	-14	60	64	-20	70	-15
FCCT_RWL3_Lp24_CLA	-10	-14	60	64	-20	70	-15
FCCT_RWL2_Lp21_CLA	-10	-14	60	64	-20	70	-15
FCCT_BATTERY_Lp03_CLA	0	-4	35	39	-4	39	0
FCCT_FHWEH_Lp17_CLA	0	-4	30	34	-25	55	-25
FCCT_FCV C1A_Lp31_CLA	10	8	60	64	8	64	-60
FCCT_FCV A2A_Lp32_CLA	10	8	60	64	8	64	-60
FCCT_FHHRV_Lp13_CLA	-10	-14	40	44	-25	55	-25
FCCT_FCV C3A_Lp34_CLA	10	8	60	64	10	60	-60
FCCT_RCS_PIPE_3_Lp35_CLA	10	8	50	54	8	54	-60
FCCT_RCS_PIPE_5_Lp37_CLA	10	8	50	54	8	54	-60
FCCT_FHLCULp19_CLA	-10	-14	40	44	-25	55	-25
FCCT_TANK_-Y_Lp26_CLA	10	8	50	54	8	54	-60
FCCT_FCV C4A_Lp33_CLA	10	8	60	64	8	64	-60
FCCT_FHLSU_Lp20_CLA	-10	-14	40	44	-25	55	-25
FCCT_STR_1_PRIM_BAF_Lp14_CLA	-20	-24	40	44	-30	50	-30
FCCT_TANK_+Y_Lp25_CLA	10	8	50	54	8	54	-60
FCCT_FHWOV_Lp12_CLB	5	1	15	19	-25	55	-25
FCCT_STRs_Lp27_CLB	-20	-24	40	44	-30	50	-30
FCCT_FHWOH_Lp16_CLB	5	1	15	19	-25	55	-25
FCCT_FHIFV_Lp28_CLB	-10	-14	40	44	-25	55	-25
FCCT_CRS_1_Lp07_CLA	-10	-14	60	64	-14	64	-10
FCCT_STR_2_PRIM_BAF_Lp36_CLA	-20	-24	40	44	-30	50	-30
FCCT_CRS_2_Lp49_CLA	-10	-14	60	64	-14	64	-10

Table 3-11 Herschel On-Board FDIR Limits

Table 3-12 Planck On-Board FDIR Limits (cont'd)

THERMAL LOOP	MIN OP [°C]	FDIR LOW_OP [°C]	MAX OP [°C]	FDIR HIGH_OP [°C]	MIN NOT OP= FDIR LOW NOP [°C]	MAX NOT OP= FDIR HIGH NOP [°C]	START UP TEMP [°C]
FCCT_CAU_Lp35_CLA	-10	-14	40	44	-20	50	-20
FCCT_ FCV A1A_Lp24_CLA	10	8	60	64	8	64	-60
FCCT_ FCV B1A_Lp25_CLA	10	8	60	64	8	64	-60
FCCT_CCUCEU_Lp06_CLA	-10	-14	40	44	-20	50	-20
FCCT_DPU1_Lp03_CLA	-10	-14	40	44	-20	50	-20
FCCT_HeatPipe_Lp09_CLA	-10	-14	40	44	-20	50	-10
FCCT_ FCV D2A_Lp27_CLA	10	8	60	64	8	64	-60
FCCT_ FCV F1A_Lp28_CLA	10	8	60	64	8	64	-60
FCCT_ FCV F2A_Lp29_CLA	10	8	60	64	8	64	-60
FCCT_HeatPipe_Lp10_CLA	-10	-14	40	44	-20	50	-10
FCCT_HeatPipe_Lp07_CLA	-10	-14	40	44	-20	50	-10
FCCT_HeatPipe_Lp08_CLA	-10	-14	40	44	-20	50	-10
FCCT_REBA_Lp36_CLA	-20	-24	50	54	-30	54	-30
FCCT_BATTERY_Lp37_CLA	0	-4	35	39	-4	39	0
FCCT_ FCV A1B_Lp38_CLA	10	8	60	64	8	64	-60
FCCT_HeTank_Lp14_CLA	-10	-14	40	44	-20	50	-60
FCCT_ FCV B1B_Lp39_CLA	10	8	60	64	8	64	-60
FCCT_ FCV D1B_Lp40_CLA	10	8	60	64	8	64	-60
FCCT_ FCV D2B_Lp41_CLA	10	8	60	64	8	64	-60
FCCT_ FCV F1B_Lp42_CLA	10	8	60	64	8	64	-60
FCCT_ FCV F2B_Lp43_CLA	10	8	60	64	8	64	-60
FCCT_HeatPipe_Lp13_CLA	-10	-14	40	44	-20	50	-10
FCCT_HeatPipe_Lp12_CLA	-10	-14	40	44	-20	50	-10
FCCT_STR1_Lp01_CLA	-20	-24	40	44	-30	50	-30
FCCT_STR2_Lp02_CLA	-20	-24	40	44	-30	50	-30
FCCT_HeatPipe_Lp11_CLA	-10	-14	40	44	-20	50	-10
FCCT_DPU2_Lp04_CLA	-10	-14	40	44	-20	50	-20
FCCT_ FCV U1B_Lp44_CLA	10	8	60	64	8	64	-60
FCCT_ FCV U2B_Lp45_CLA	10	8	60	64	8	64	-60
FCCT_ FCV D1A_Lp26_CLA	10	8	60	64	8	64	-60
FCCT_PTLV1LV2_Lp32_CLA	10	8	50	54	8	54	-60
FCCT_RCSPipe_Lp33_CLA	10	8	50	54	8	54	-60
FCCT_RCSPipe_Lp34_CLA	10	8	50	54	8	54	-60
FCCT_RCSPipe_Lp46_CLA	10	8	50	54	8	54	-60
FCCT_RCSPipe_Lp47_CLA	10	8	50	54	8	54	-60
FCCT_TANK+Z+Y_Lp21_CLA	10	8	50	54	8	54	-60
FCCT_TANK+Z-Y_Lp22_CLA	10	8	50	54	8	54	-60
FCCT_TANK-Z_Lp23_CLA	10	8	50	54	8	54	-60
FCCT_REU_Lp05_CLA	-10	-14	40	44	-20	50	-20
FCCT_PAU_Lp15_CLA	-10	-14	40	44	-20	50	-20
FCCT_CRU_Lp16_CLA	-10	-14	40	44	-20	50	-20
FCCT_RCSPipe_Lp48_CLA	10	8	50	54	8	54	-60
FCCT_ FCV U1A_Lp30_CLA	10	8	60	64	8	64	-60
FCCT_ FCV U2A_Lp31_CLA	10	8	60	64	8	64	-60

THERMAL LOOP	MIN OP [°C]	FDIR LOW_OP [°C]	MAX OP [°C]	FDIR HIGH_OP [°C]	MIN NOT OP= FDIR LOW NOP [°C]	MAX NOT OP= FDIR HIGH NOP [°C]	START UP TEMP [°C]
FCCT_CRS_1_Lp17_CLA	-10	-14	60	64	-14	64	-10
FCCT_CRS_2_Lp18_CLA	-10	-14	60	64	-14	64	-10
FCCT_CRS_2_Lp19_CLA	-10	-14	60	64	-14	64	-10

Table 3-12 Planck On-Board FDIR Limits

When a Class A/B Control Loop Failure is triggered, the following actions are carried out autonomously by the ASW:

CDMU ASW recovery actions for class A

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IF (Failure of the Unit [NAME] thermal control = TRUE), the CDMU ASW:

- Disable the thermal loops regulation of the 6 units protected by the same HPS [NUMBER] as the failed one.
- Send HPS [NUMBER] _OPEN_CMD to the PCDU to switch OFF the protection switch.
- Send HPS [19 - NUMBER]_CLOSE_CMD to the PCDU to enable the redundant branch.
- Enable the thermal loops regulation of the 6 units protected by the HPS [19 - NUMBER]

CDMU ASW recovery actions for class B

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IF ((Failure of the Class B Unit [NAME] thermal control = TRUE), the CDMU ASW shall:

- Start DB_TCS_CLASSB_FDIR_INSTRUMENTS OBCP (database mnemonic TBC)
- Disable the thermal loops regulation of the 6 units protected by the same HPS [NUMBER] as the failed one.
- Send HPS [NUMBER] _OPEN_CMD to the PCDU to switch OFF the protection switch.
- Send HPS [19 - NUMBER] _CLOSE_CMD to the PCDU to enable the redundant branch.
- Enable the thermal loops regulation of the 6 units protected by the HPS [19 - NUMBER]

Class A/B Control Loops FDIR is always enabled regardless of the Spacecraft Mode.

As part of its autonomous actions, the FDIR will update the relevant on board tables (UIU, MOT and EAT) accordingly.

Following a Level 3 Alarm, the OBSW will retrieve these on board tables from the SGM, maintaining the same thermal configuration as it was before the failure occurrence.

In case of Level 4 Alarm, the TCS configuration is retrieved from EEPROM, as part of the Survival Unit In Use content.

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3.7.2.2. TCS level 1 failures detection and recovery

Thermistor failure

Individual thermistor failures are detected by the CDMU ASW using the following algorithm.

```
IF (|TEMP1 – TEMP2| > 2TOL AND |TEMP1 – TEMP3| > 2TOL)
        Set AVG_TEMP = (TEMP2 + TEMP 3) / 2
        Mark thermistor 1 as failed.

ELSE IF (|TEMP1 – TEMP2| > 2TOL AND |TEMP2 – TEMP3| > 2TOL)
        Set AVG_TEMP = (TEMP1 + TEMP 3) / 2
        Mark thermistor 2 as failed.

ELSE IF (|TEMP1 – TEMP3| > 2TOL AND |TEMP2 – TEMP3| > 2TOL)
        Set AVG_TEMP = (TEMP2 + TEMP 1) / 2
        Mark thermistor 3 as failed.

ELSE
        Set AVG_TEMP = (TEMP2 + TEMP 1 + TEMP 3) / 3
ENDIF
```

Where:

- TEMP1, TEMP2 and TEMP3: temperature values of thermistor 1, 2 and 3
- TOL = thermistor tolerance
- AVG_TEMP = average temperature measured by operational sensors (value used by the nominal temperature control algorithm).

If a thermistor failure is detected, the CDMU ASW raises an event TM (5, 4).

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3.8. TCS ONBOARD SOFTWARE

3.8.1. TCS Software functional description

No on board software is foreseen for the TCS subsystem.

The temperature control of the Herschel and Planck SVM is managed by the CDMU ASW and it is driven through a Thermal Control Table (TCT) as shown in figure below.

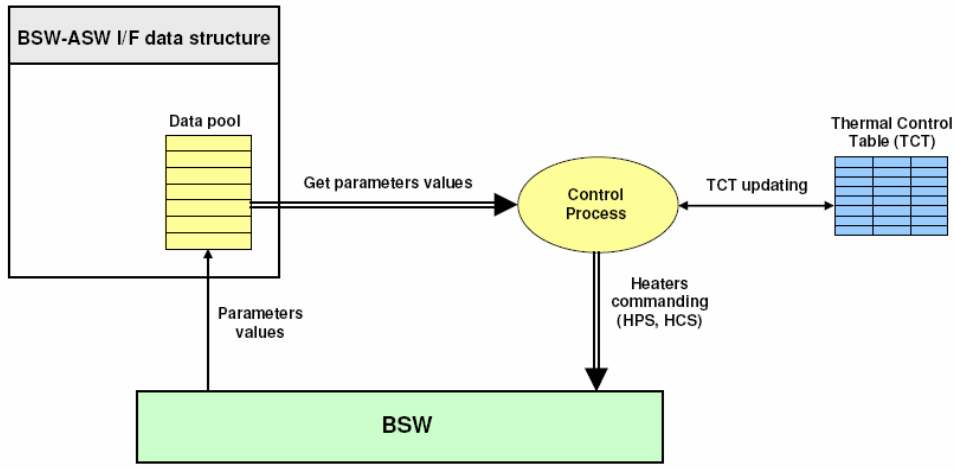

Figure 3-7 Thermal Control Process

To control the temperature, the ASW basically performs the following actions:

- retrieves from the data pool, using BSW SVC, the thermistors values;
- evaluates the temperature by means of an algorithm applied to values acquired;
- heater commanding, if necessary.

The heater commanding is performed in the following way:

- On initialisation of the thermal control function:
  1. following a nominal cold start, no action on the HPSs or HCSs is undertaken;
  2. following a cold start due to a SOHO failure case, the CDMU ASW first opens all (nominal and redundant) HPSs via 1553 commands; then it closes via 1553 commands the required HPSs as per the survival mode configuration stored in EEPROM.
- As part of the nominal control loop mechanism, the CDMU ASW operates on the HCSs only.

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3.8.1.1. Thermal Control Table

The TCT (Thermal Control Table) is structured and sized in order to allow the control of 108 control loops. The CDMU ASW nominally uses the default TCT that is loaded from EEPROM to RAM during the initialisation phase. However, it is possible to modify all the parameters of each TCT entry.

Each entry of the TCT contains the following parameters:

- Control Loop Index;
- Control Loop Status (Enabled, Disabled);
- Monitored Parameter IDs (3);
- Class of the Control Loop;
- Temperature Monitoring Frequency;
- Class A threshold values, two pairs of values based on the relevant unit status [T_{min-on}, T_{max-on}] and [$T_{min-off}$, $T_{max-off}$];
- Heater ID;
- Class B Coefficients (ALPHA, BETA, GAMMA, DELTA, LAMBDA, TREF);
- Qinst, providing the power installed for each control loop

It should be noted that:

- Temperature monitoring is always enabled regardless of the status of a control loop;
- When a control loop is disabled, the associated heater is switched off (i.e. its HCS is opened by the ASW autonomously);
- Regarding threshold values, the right pair for a given loop is selected by ASW based on the status of the associated unit, saved in the Unit-In-use Table. For this purpose, the table also holds the status of a few units managed by the ACMS:
  - Reaction wheels 1,2,3,4 (Herschel)
  - Gyro (Herschel)
  - CRS (1, 2 on Herschel and 1,2,3 on Planck)
  - Star Trackers 1,2 (Herschel, Planck)

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The status of these units is maintained by the CDMU ASW based on events received from the ACC ASW, except for the CRS that are supposed to be always ON and can not be autonomously commanded by the ACC.

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The detailed contents is given in [HASWTAB] and [PASWTAB].

The following notes apply to the Herschel and Planck TCT:

General

Referring to **[HASWTAB] and [PASWTAB],** it is noted that currently the thresholds in the TCT are the same if the units are ON or OFF.

Deleted: Layout of the TCT is now aligned with respect to **[HTDL]**, issue 7 providing the actual on board thermal configuration both for Herschel and Planck satellites.¶
The related XML files defining the OBSW default tables both for Herschel and Planck (Unit In Use, FDIR Cross Check Table, MOonitoring Table, Event Action Table and Thermal Control Table) will be updated accordingly as part of the OBSW V 2.5 delivery. ¶
¶

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The flexibility of having two different sets of thresholds in the CDMS OBSW to perform the TCS control is considered to be still useful in case future analyses and tests (in particular TV/TB Tests) will show the need of differentiate them according to the unit status.

TCS relevant to the following units:

- CCU nominal and redundant units (Herschel);
- STR nominal and redundant units (Herschel);
- REBA nominal and redundant units (Planck)

foresees to have only one heater control loop for both the units.

As a consequence, the TCS control assumes the operative thresholds to be valid if only one of the units' pair is ON.

This processing is executed autonomously by the CDMS ASW without using any direct UIU information.

Reference to the OR of the units' pair status coming from UIU Table (e.g. 0x302 OR 0x502 for the STRs) is reported in TCT for sake of completeness only.

Refer also to the RCS note.

XPNDs

These heater loops only apply to Herschel.

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The relevant lines control the whole XPNDs (RX+TX) and are driven by the RX Status that is supposed to be always ON.

In nominal conditions, the two ON thresholds are always used. Ground can change the thresholds in case of RX loss of power (FCL open).

Propellant Tanks
These heater lines (Lines 4 and 59 on Herschel, lines 20 and 74 on Planck) are always supplied with no CDMS control implemented.

They were introduced to maintain a permanent thermal gradient between gas side and propellant side of the tank (refer to the RCS UM, Vol 5 for further details).

As for the associated thermistors, the THM-52 and THM-100 are used for monitoring only while the THM-148 is spare.

Reference to this line was put for sake of completeness but it is not part of the TCT.

CRSs
CRSs are always ON and can not be switched OFF by the ACMS. These new lines (two for Herschel and three for Planck) have been introduced as part of the modifications due to the EEPROM alert.

No dedicated entry in the UIU is currently foreseen.

Ground can change the thresholds in case the relevant LCLs are open.

CCUs
On Herschel both CCUs are controlled by the same loop (lines 10 and 64), i.e. it is sufficient that one CCU is on for the TCS to apply the operative thresholds.

STR Primary Baffles
These new loops depend on STRs status.

Line close to FHFCU (Line 14) disappeared and it is now used for the STR-1 Primary Baffle.

STRs
On Herschel both STRs are controlled by the same loop, i.e. it is sufficient that one STR is on for the TCS to apply the operative thresholds.

RCS
RCS equipments/units are not provided with a status.

The flexibility of having two different sets of thresholds in the CDMS OBSW to perform the nominal control when the S/C is in Survival Mode or not is carried out by a dedicated CDMS ASW autonomous processing selecting the correct pair of thresholds to be used for the heater ON /OFF.

It is noted that the TCT layout (Unit Status Column from UIU Table) still contains a reference to a dummy entry 0x317 providing the actual S/C Mode (Survival / Not Survival) but this entry is NOT part of the UIU Table.

SCC Heat Pipes
The Heat Pipes Thermal loops are relevant to Planck only.

According to the thermal analyses, TCS Lines 7, 8, 9, 10, 11, 12 and 13 are driven by the same group of thermistors (THM-55, THM-103 and THM-151) to command the heaters.

SCE status is used as input to choose the correct heater thresholds.

Tanks
Three propellant tanks are installed on Planck.

TCS design of the Planck tanks is the following:

- Tank + Z +Y temperature is monitored by the three thermistors THM 69,THM 117 and THM 165;
- Tank + Z –Y temperature is monitored by the Thermistors THM 70, THM 118 and THM 166;
- Tank –Z temperature is monitored by the Thermistors THM 71, THM 119 and the THM 167.

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In order to meet the temperature stability requirement among the three temperature tanks, it was proven necessary to implement a particular control algorithm.

The control Algorithms will be a Class A and the three Loops will be controlled by the coldest group of Thermistors.

In order to do that, the tanks TCS loops will be controlled by the thermistors THM 71, THM 119 and THM 167.

When the thermistors THM 71, THM 119 and THM 167 average temperature becomes lower than the low threshold of the control loop, the three nominal heater lines will be activated at the same time.

After a while the Tanks temperature will increase above the high threshold of the control loop and the three nominal heater lines will be powered-Off at the same time.

The above procedure will maintain an equivalent temperature environment for the three tanks, ensuring the temperature variation will be similar for the three tanks.

In case one tank heater loop fails, the recovery action will re-establish the usage of the default thermistors set for each loop:

- Thermistors THM 69, THM 117 and THM 165 for the tank + Z +Y heater Loop;
- Thermistors THM 70, THM 118 and THM 166 for the tank + Z – Y heater Loop;

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– Thermistors THM 71, THM 119 and the THM 167 for the tank – Z heater Loop.

Note that all the tanks control loops belong to the same HPS.

This approach is used to avoid any temperature drop in the failed heater loop and can be implemented through the TCT without any CDMS ASW change.

REBAs
On Planck both REBAs are controlled by the same loop, i.e. it is sufficient that one REBA is on for the TCS to apply the operative thresholds.

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3.8.1.2. Control Process Description

For both Class A and B loops, the temperature of each thermally controlled point is evaluated by means of the following algorithm, applied to values acquired from the 3 thermistors associated to that point (the same algorithm is used to detect thermistor failures).

TEMP1, TEMP2 and TEMP3 = Temperature value of thermistor 1, 2 and 3

TOL = thermistor tolerance.

AVG_TEMP = average temperature measured by operational sensors.

IF (|TEMP1 – TEMP2| > 2TOL ***AND*** |TEMP1 – TEMP3| > 2TOL)
Set AVG_TEMP = (TEMP2 + TEMP 3) / 2
Mark thermistor 1 as failed.

ELSE IF (|TEMP1 – TEMP2| > 2TOL ***AND*** |TEMP2 – TEMP3| > 2TOL)
Set AVG_TEMP = (TEMP1 + TEMP 3) / 2
Mark thermistor 2 as failed.

ELSE IF (|TEMP1 – TEMP3| > 2TOL ***AND*** |TEMP2 – TEMP3| > 2TOL)
Set AVG_TEMP = (TEMP2 + TEMP 1) / 2
Mark thermistor 3 as failed.

ELSE
Set AVG_TEMP = (TEMP2 + TEMP 1 + TEMP 3) / 3
ENDIF

If one thermistor has failed, Ground should replace it with one of the two remaining ones, whose value will then be used twice in the above algorithm. This can be achieved by modifying the entry “monitored parameter IDs” of the TCT.

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Class A Control Loop

For this class the acquisition frequency is presently set at 60 s. The heater activation (ON/OFF) is based on the algorithm shown in table below.

Condition	Heater commands
AVG_TEMP < T_{min}	Switch ON HCS
AVG_TEMP > T_{max}	Switch OFF HCS
$T_{min} \leq$ AVG_TEMP $\leq T_{max}$	No commands

Table 3-13 Class A Control Algorithm

Where:

- AVG_TEMP: result of temperature evaluation algorithm
- T_{min}, T_{max}: lower and upper thermistor thresholds, dependent on unit status

As it can be seen in the following figure, this heater switching law is characterised by a histeresis cycle between a switching ON temperature and a switching OFF temperature.

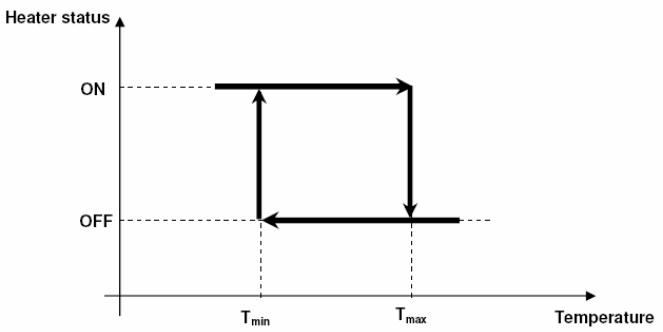

Figure 3-8 Thermostat-like Control Law

Class B Control Loop

For this class the thermistors acquisition frequency is presently set at 10 s; however the relevant heater is commanded at 1Hz to optimise the process The heater activation (ON/OFF) is based on the following algorithm, which calculates the requested heater power on the basis of:

- Max power dissipated by the heater circuit
- Temperature history
- Power history

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– Temperature threshold w.r.t. TREF

```
IF (TIMEN == TACQUISITION+10.0 OR TIMEN == 0.0) THEN
      TK = input temperature value (= AVG_TEMP)

      IF (TK < TREF - THRESHOLD) THEN
            PK = QINST

      ELSE IF (TK > TREF + THRESHOLD)
            PK = 0.0

      ELSE
            PK = - LAMBDA * PPK(10) – DELTA * PPK(9) + ALPHA
* (TREF - TK)
             + BETA * (TREF - AATK(10)) + GAMMA * (TREF -
AATK(9))

            IF (PK < 0.0) THEN
                  PK = 0.0

            ELSE IF (PK > QINST)
                  PK = QINST

            ENDIF

      ENDIF
```

```
        NIMPUL = INT(PK * 10.0 / QINST)
        RESIDUAL = PK * 10.0 / QINST - NIMPUL
        RESIDUAL = RESIDUAL + RESIDUAL_A

        IF (RESIDUAL ≥ 1.0) THEN
                NIMPUL = NIMPUL + 1
                RESIDUAL = RESIDUAL - 1.0
        ENDIF

        RESIDUAL_A = RESIDUAL

        DO I=2,10
            AATK(I-1) = AATK(I)
        ENDDO

        AATK(10) = TK

       DO I=2,10
            PPK(I-1) = PPK(I)
        ENDDO

        PPK(10) = PK
        TACQUISITION = TIMEN

ENDIF

TIMESTEP = INT(TIMEN-TACQUISITION+1.0)

 IF (PK > 0.0 AND NIMPUL > 0.0) THEN

          DO I=1,10
             IF (INT(1+10.0 / NIMPUL*(I-1)) == TIMESTEP) THEN
                ISSUE heater ON command (1s pulse)
                  EXIT Loop

              ELSE IF (INT(1+10.0 / NIMPUL*(I-1)) > TIMESTEP)
```

Where:

- PK: output power as calculated by the class B algorithm
- QINST: max power that can be dissipated by the heater circuit
- AATK[10]: temperature history
- PPK[10]: power history
- THRESHOLD: temperature threshold w.r.t. TREF
- ALPHA, BETA, GAMMA, DELTA, LAMBDA, TREF: constants used by the class B algorithm
- Y = AINT(X): function returning integral part of X (X,Y real)
- Y = INT(X): function returning integral part of X (X real, Y integer)
- RESIDUAL: residual energy
- RESIDUAL_A: residual energy history

The constants used by the algorithm (ALPHA, BETA, GAMMA, DELTA, LAMBDA, TREF) are stored in the TCT, so they are completely configurable via TC.

The other parameters are defined as HPSDB constants.

Class B control loops are only applied on Herschel and for the following units:

- FHWOH, FHIFV and FHWOV units of the HIFI Instrument.
- Star Trackers

The class B algorithm applies only if the controlled unit is ON (or in Standby Mode).

When the unit is OFF, its temperature is controlled on the basis of the simpler class A control law.

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Ground can commands and controls the TCS units through the following ASW TM/TC packets:

– TC packets:

TC(8,1,114): Start TCS Management
It is used for switching ON the function.

TC(8,2,114): Stop TCS Management
It is used for switching OFF the function.
This telecommand is considered critical, and therefore must be armed before use with a TC (8,4,114,3). Note that when the function is stopped, it does not accept any other telecommands than the Start Function and Report Function Status TCs.

TC(8,4,114,1): Enable Control Loop
It is used for enabling a control loop in the TCT.

TC(8,4,114,2): Disable Control Loop
It is used for disabling a control loop in the TCT.

TC(8,4,114,3): Arm Stopping of Thermal Control
It must be used before stopping the function with TC(8,2,114).

TC(8,4,114,16): Modify TCT Entry (16 bit)
It is used for modifying 16 bit parameters in the TCT.
The monitoring frequency affects only Class A loops, since for Class B the frequency is implicit from the algorithm. Note that when the monitoring frequency is changed it affects all the Class A loops that control heaters in the same heater group. For performance reasons the maximum of 5 Class B loops should be enabled at the same time. If the class of a loop is changed, the user should also make sure that the corresponding entry in the Event/Action table is also modified to perform the recovery of the correct class in case of TCS FDIR triggers for the modified loop.

TC(8,4,114,17: Modify Start Delay
It is used for modifying the thermal control start delay parameter.
After ASW initialisation, the thermal control function is activated after this start delay.

TC(8,4,114,18: Modify TCT Entry (32 bit)
It is used for modifying 32 bit parameters in the TCT.

TC(8,5,114): Report Thermal Control Status
It is used to require the status of the function as a telemetry packet.

– TM packets:

TM(1,1): Telecommand Acceptance Report – Success
It is sent after a successful verification of a telecommand packet

TM(1,2): Telecommand Acceptance Report – Failure
It is sent when the verification of the application data of a telecommand has failed.

TM(1,8): Telecommand Execution Report – Failure
It is sent when the execution of a telecommand has to be stopped because of a problem in its execution

TM(8,6,114): Thermal Control Status Report
It is sent as a reply for the Report TCS Management Status TC(8,5,114)).
One telemetry packet contains all the modifiable information of one or more control loop entry. As a reply to the TC(8,5,114) all entries in the TCT will be reported with one or more of these telemetry packets.

TM(5,1,114,1): Class A Temperature Anomaly
This telemetry packet is generated when the average temperature of an enabled class A loop drops below the lower limit, or rises above the higher limit. Note that if the unit controlled by a class B loop is OFF, the loop will act like class A loop, and use this event to report anomalies.

TM(5,1,114,2): Class A Temperature Anomaly Ended
This telemetry packet is generated when the average temperature of an enabled class A loop returns between lower and higher limits. Note that if the unit controlled by a class B loop is OFF, the loop will act like class A loop, and use this event to report anomalies.

TM(5,1,114,3): Class B Temperature Anomaly
This telemetry packet is generated when the average temperature of an enabled class B loop drops below the lower limit (TREF - THRESHOLD), or rises above the higher limit (TREF + THRESHOLD).

TM(5,1,114,4): Class B Temperature Anomaly Ended
This telemetry packet is generated when the average temperature of an enabled class B loop returns between lower (TREF - THRESHOLD) and higher (TREF + THRESHOLD) limits.

TM(5,4,114,5): Class A Thermistor Failure
This telemetry packet is generated when the average temperature calculation of an enabled class A loop suggests a failed thermistor.

TM(5,4,114,6): Class B Thermistor Failure
This telemetry packet is generated when the average temperature calculation of an enabled class B loop suggests a failed thermistor.

TM(5,4,114,7): Disabled Loop Thermistor Failure
This telemetry packet is generated when the average temperature calculation of a disabled thermal control loop (meaning both nominal and redundant loops are disabled) suggests a failed thermistor.

TM(5,1,114,8): Disabled Loop Temperature Anomaly
This telemetry packet is generated when the average temperature of a disabled class A loop drops below the lower limit, or rises above the higher limit, or a disabled class B loop drops below the lower limit (TREF - THRESHOLD), or rises above the higher limit (TREF + THRESHOLD).

TM(5,1,114,9): Disabled Loop Temperature Anomaly Ended
This telemetry packet is generated when the average temperature of a disabled class A loop returns between lower and higher limits, or a disabled class B loop returns between lower (TREF - THRESHOLD) and higher (TREF + THRESHOLD) limits.

The following list of BSW service calls is used by the ASW to manage the TCS:

BswSvc_Dat_Get: It is used for reading temperature values from the data pool.

BswSvc_Sdb_PutMsg: It is used for commanding HPS and HCS in PCDU via 1553.

BswSvc_Ptm_ExecReport: It is used for sending the execution failure report telemetry packet.

BswSvc_Ptm_AccReport: It is used to send the TC Acceptance Report with a parameter informing if the TC was accepted or rejected. Also a failure code shall be used to inform the reason for the rejection.

BswSvc_Evt_Report: It is used for sending the Event Report telemetry packet for the temperature anomaly events, and thermistor failures.

BswSvc_Ptm_PutPkt: It is used for sending Thermal Control Status Report telemetry packet.

More details can be found in [CDMUASWRS], [CDMUASWICD], [CDMUBSWICD], [FDIRSPEC] and [PSICD].

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3.9. TCS OPERATION PROCEDURES

3.9.1. TCS Operational constraints and warnings

The following constraints imply a Ground control intervention:

- Moon transit for Planck: the SCC and SCE thresholds set to operating levels will have to be lowered to acceptance levels during Moon transit (refer to Planck Moon transit, [PMOON]).
- Herschel HIFI Prime mode (TBC after thermal test run): the pre-switching of the HIFI units in Prime mode shall be performed from 30 minutes up three hours before the start of scientific observation to take into account the need for thermal stability (refer to [HIFIIDDB])
- Planck units switching sequence (TBC after thermal test run): in order to guarantee the operating temperature range on DCCU, the LFI REBA shall be switched ON before the HFI DCE (refer to [SVMTCSTO]). The instrument switch ON sequence shall be such that each step is long enough to reach the minimum operational temperature of each instrument unit
- Planck SCS switch ON (TBC after thermal test run): the SCC and SCE thermal thresholds shall be increased by 4 degrees before SCE switch ON and until SCC switch ON where the SCC and SCE thermal thresholds shall be set to their nominal values.

The attitude of Herschel satellite shall be constrained according to [HEPLMRS], to meet the thermal performance. From launcher separation, the H-EPLM shall remain in the following Sun centre directions:

- Between -3° and +3° from the (XHSC, ZHSC) plane
- Between +60° and +120° from the +XHSC axis.

For DTCP longer than 3 hours when Herschel telecommunication with New Norcia, it is necessary to maintain the satellite within [0; +30°] SAA range (cold SAA) to avoid exceeding of temperature on TTC-S units.

From launcher separation to the end of the mission, Planck attitude is constrained so that the Sun direction remains below 10° from Xs spacecraft axis.

At CDMS ASW level the following constraint is identified.

In case Ground wants to stop the Thermal Control Function, it must take care of all the HCS status as no autonomous actions on them are performed by the OBSW as a consequence of the Thermal Control Function disabling (refer to Section 3.5.2.2).

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Deleted: Herschel S/C design impact of HIFI IIDB 3.2 implementation, doc. H-P-TN-AI-0093

Deleted: SVM TCS transfer orbit, doc. **H-P-RP-AI-0067**

Deleted: H-EPLM Requirements Specification, doc. H-P-2-ASPI-SP-0250

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3.9.2. TCS Procedures

In the following tables are listed the identified Nominal and Contingencies procedures.

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Nominal Procedures	
Satellite	**Name**
H-P	Thermal Control Table Maintenance
H-P	Redundant HPS switch ON
H-P	Redundant HPS switch OFF
H-P	Nominal HPS switch ON
H-P	Nominal HPS switch OFF
H-P	Switch ON HCS of HPS1
H-P	Switch OFF HCS of HPS1
H-P	Switch ON HCS of HPS2
H-P	Switch OFF HCS of HPS2
H-P	Switch ON HCS of HPS3
H-P	Switch OFF HCS of HPS3
H-P	Switch ON HCS of HPS4
H-P	Switch OFF HCS of HPS4
H-P	Switch ON HCS of HPS5
H-P	Switch OFF HCS of HPS5
H-P	Switch ON HCS of HPS6
H-P	Switch OFF HCS of HPS6
H-P	Switch ON HCS of HPS7
H-P	Switch OFF HCS of HPS7
H-P	Switch ON HCS of HPS8
H-P	Switch OFF HCS of HPS8
H-P	Switch ON HCS of HPS9
H-P	Switch OFF HCS of HPS9
H-P	Switch ON HCS of HPS10

Table 3-14 Nominal Procedures (cont'd)

Nominal Procedures	
Satellite	**Name**
H-P	Switch OFF HCS of HPS10
H-P	Switch ON HCS of HPS11
H-P	Switch OFF HCS of HPS11
H-P	Switch ON HCS of HPS12
H-P	Switch OFF HCS of HPS12
H-P	Switch ON HCS of HPS13
H-P	Switch OFF HCS of HPS13
H-P	Switch ON HCS of HPS14
H-P	Switch OFF HCS of HPS14
H-P	Switch ON HCS of HPS15
H-P	Switch OFF HCS of HPS15
H-P	Switch ON HCS of HPS16
H-P	Switch OFF HCS of HPS16
H-P	Switch ON HCS of HPS17
H-P	Switch OFF HCS of HPS17
H-P	Switch ON HCS of HPS18
H-P	Switch OFF HCS of HPS18
H-P	TCS Subsystem Checkout

Table 3-14 Nominal Procedures

Contingencies Procedures	
Satellite	**Name**

Table 3-15 Contingency Procedures

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3.10. TCS TM/TC

The thermistors are monitored via I/O channels, while the heaters are actuated acting, via 1553 S/C bus, on the HPSs and HCSs.

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Thermistors TM Channels

In the following table are listed only the thermistors used by the TCS.

THM #	HERSCHEL		PLANCK	
	Monitor	Source	Monitor	Source
12	TCS Line 49 Th I	CRS2		
20	TCS Line 49 Th II	CRS2		
36	TCS Line 49 Th III	CRS2		
49	TCS Line 01 Th I	XPND1	TCS Line 01 Th I	STR1
50	TCS Line 02 Th I	XPND2	TCS Line 02 Th I	STR2
51	TCS Line 03 Th I	BATTERY Conn.	TCS Line 03 Th	PHBA-N (HFI DPU1)
52	FPDPU Temp N	FPDPU	TCS Line 04 Th I	PHBA-R (HFI DPU2)
53	TCS Line 05 Th I	FPSPU	TCS Line 05 Th I	PHCBC (REU)
54	TCS Line 06 Th I	FPBOLC	TCS Line 06 Th I	PHDA (4KCCU)
55	TCS Line 07 Th I	CRS1	TCS Line 07 Th I	Heat Pipe
56	TCS Line 08 Th I	FPMECDEC	PLAEF (LFI DAE Power) Temp N	PLAEF (LFI DAE Power)
57	TCS Line 09 Th I	RCS piping	PLBEU (LFI BEU) Temp N	PLBEU (LFI BEU)
58	TCS Line 10 Th I	CCU	PHEB (HFI 0.1K DCCU) Temp N	PHEB (HFI 0.1K DCCU)
59	TCS Line 11 Th I	RCS piping	PHEAAD (HFI He4-3) Temp N	PHEAAD (HFI He4-3, -Y)
60	TCS Line 12 Th I	FHWOV	PHDC (HFI 4KCDE) Temp N	PHDC (HFI 4KCDE)
61	TCS Line 13 Th I	FHHRV	PHEAAB (HFI He4-1) Temp N	PHEAAB (HFI He4-1, +Y)
62	TCS Line 14 Th I	STR1 baffle	TCS Line 14 Th	PHEAAC (HFI He4-2, -Z)
63	TCS Line 15 Th I	FHWEV	TCS Line 15 Th	PHCBA (HFI PAU)
64	TCS Line 16 Th I	FHWOH	TCS Line 16 Th I	PHDJ (HFI 4K Reg)
65	TCS Line 17 Th I	FHWEH	TCS Line 17 Th I	CRS1
66	TCS Line 18 Th I	FHHRH	TCS Line 18 Th I	CRS2
67	TCS Line 19 Th I	FHLCU	TCS Line 19 Th I	CRS3
68	TCS Line 20 Th I	FHLSU	TCS Line 20 Th I – spare	spare
69	TCS Line 21 Th I	RWA2	TCS Line 21 Th I	TANK +Z+Y
70	TCS Line 22 Th I	RWA4	TCS Line 22 Th I	TANK +Z-Y
71	TCS Line 23 Th I	RWA1	TCS Line 23 Th I	TANK –Z
72	TCS Line 24 Th I	RWA3	TCS Line 24 Th I	1 N FCV A1A
73	TCS Line 25 Th I	Tank +Y	TCS Line 25 Th I	1 N FCV B1A
74	TCS Line 26 Th I	Tank –Y	TCS Line 26 Th I	20 N FCV D1A
75	TCS Line 27 Th I	STR	TCS Line 27 Th I	20N FCV D2A
76	TCS Line 28 Th I	FHWEV	TCS Line 28 Th I	20N FCV F1A
77	TCS Line 29 Th I	FCV A1A	TCS Line 29 Th I	20N FCV F2A
78	TCS Line 30 Th I	FCV C2A	TCS Line 30 Th I	20N FCV U1A
79	TCS Line 31 Th I	FCV C1A	TCS Line 31 Th I	20N FCV U2A
80	TCS Line 32 Th I	FCV A2A	TCS Line 32 Th I	RCS unit
81	TCS Line 33 Th I	FCV C4A	TCS Line 33 Th I	RCS piping
82	TCS Line 34 Th I	FCV C3A	TCS Line 34 Th I	RCS piping
83	TCS Line 35 Th I	RCS piping	TCS Line 35 Th	PHDB (4KCAU)
84	TCS Line 36 Th I	STR2 baffle	TCS Line 36 Th I	PLREN (REBA)
85	TCS Line 37 Th I	RCS piping	TCS Line 37 Th I	BATTERY
86	TCS Line 38 Th I	GYRO	TCS Line 38 Th I	1 N FCV A1B
87	TCS Line 39 Th I	FCV A1B	TCS Line 39 Th I	1 N FCV B1B

Table 3-16 List of Thermistors Signals

THM #	HERSCHEL		PLANCK	
	Monitor	Source	Monitor	Source
88	TCS Line 40 Th I	FCV C2B	TCS Line 40 Th I	20N FCV D1B
89	TCS Line 41 Th I	FCV C1B	TCS Line 41 Th I	20N FCV D2B
90	TCS Line 42 Th I	FCV A2B	TCS Line 42 Th I	20N FCV F1B
91	TCS Line 43 Th I	FCV C4B	TCS Line 43 Th I	20N FCV F2B
92	TCS Line 44 Th I	FCV C3B	TCS Line 44 Th I	20N FCV U1B
93	TCS Line 45 Th I	RCS piping	TCS Line 45 Th I	20N FCV U2B
94	TCS Line 46 Th I	RCS piping	TCS Line 46 Th I	RCS piping
95	TCS Line 47 Th I	RCS piping	TCS Line 47 Th I	RCS piping
96	TCS Line 48 Th I	PT	TCS Line 48 Th I	RCS piping
97	TCS Line 01 Th II	XPND1	TCS Line 01 Th II	STR1
98	TCS Line 02 Th II	XPND2	TCS Line 02 Th II	STR2
99	TCS Line 03 Th II	BATTERY Conn.	TCS Line 03 Th II	PHBA-N (HFI DPU1)
100	FPDPU Temp R	FPDPU	TCS Line 04 Th II	PHBA-R (HFI DPU2)
101	TCS Line 05 Th II	FPSPU	TCS Line 05 Th II	PHCBC (REU)
102	TCS Line 06 Th II	FPBOLC	TCS Line 06 Th II	PHDA (4KCCU)
103	TCS Line 07 Th II	CRS1	TCS Line 07 Th II	Heat Pipe
104	TCS Line 08 Th II	FPMECDEC	PLAEF (LFI DAE Power) Temp R	PLAEF (LFI DAE Power)
105	TCS Line 09 Th II	RCS piping	PHEAAA (HFI He3) Temp N	PHEAAA (HFI He3, +Z)
106	TCS Line 10 Th II	CCU	PHEB (HFI 0.1K DCCU) Temp R	PHEB (HFI 0.1K DCCU)
107	TCS Line 11 Th II	RCS piping	PHEAAD (HFI He4-3) Temp R	PHEAAD (HFI He4-3, -Y)
108	TCS Line 12 Th II	FHWOV	PHDC (HFI 4KCDE) Temp R	PHDC (HFI 4KCDE)
109	TCS Line 13 Th II	FHHRV	spare	spare
110	TCS Line 14 Th II	STR1 baffle	TCS Line 14 Th II	PHEAAC (HFI He4-2, -Z)
111	TCS Line 15 Th II	FHWEV	TCS Line 15 Th II	PHCBA (HFI PAU)
112	TCS Line 16 Th II	FHWOH	TCS Line 16 Th II	PHDJ (HFI 4K Reg)
113	TCS Line 17 Th II	FHWEH	TCS Line 17 Th II	CRS1
114	TCS Line 18 Th II	FHHRH	TCS Line 18 Th II	CRS2
115	TCS Line 19 Th II	FHLCU	TCS Line 19 Th II	CRS3
116	TCS Line 20 Th II	FHLSU	TCS Line 20 Th II - spare	spare
117	TCS Line 21 Th II	RWA2	TCS Line 21 Th II	TANK +Z+Y
118	TCS Line 22 Th II	RWA4	TCS Line 22 Th II	TANK +Z-Y
119	TCS Line 23 Th II	RWA1	TCS Line 23 Th II	TANK -Z
120	TCS Line 24 Th II	RWA3	TCS Line 24 Th II	1 N FCV A1A
121	TCS Line 25 Th II	Tank +Y	TCS Line 25 Th II	1 N FCV B1A
122	TCS Line 26 Th II	Tank -Y	TCS Line 26 Th II	20 N FCV D1A
123	TCS Line 27 Th II	STR	TCS Line 27 Th II	20N FCV D2A
124	TCS Line 28 Th II	FHWEV	TCS Line 28 Th II	20N FCV F1A
125	TCS Line 29 Th II	FCV A1A	TCS Line 29 Th II	20N FCV F2A
126	TCS Line 30 Th II	FCV C2A	TCS Line 30 Th II	20N FCV U1A
127	TCS Line 31 Th II	FCV C1A	TCS Line 31 Th II	20N FCV U2A
128	TCS Line 32 Th II	FCV A2A	TCS Line 32 Th II	RCS unit
129	TCS Line 33 Th II	FCV C4A	TCS Line 33 Th II	RCS piping
130	TCS Line 34 Th II	FCV C3A	TCS Line 34 Th II	RCS piping
131	TCS Line 35 Th II	RCS piping	TCS Line 35 Th II	PHDB (4KCAU)
132	TCS Line 36 Th II	STR2 baffle	TCS Line 36 Th II	PLREN (REBA)
133	TCS Line 37 Th II	RCS piping	TCS Line 37 Th II	BATTERY
134	TCS Line 38 Th II	GYRO	TCS Line 38 Th II	1 N FCV A1B
135	TCS Line 39 Th II	FCV A1B	TCS Line 39 Th II	1 N FCV B1B
136	TCS Line 40 Th II	FCV C2B	TCS Line 40 Th II	20N FCV D1B
137	TCS Line 41 Th II	FCV C1B	TCS Line 41 Th II	20N FCV D2B

Table 3-16 List of Thermistors Signals

THM #	HERSCHEL		PLANCK	
	Monitor	Source	Monitor	Source
138	TCS Line 42 Th II	FCV A2B	TCS Line 42 Th II	20N FCV F1B
139	TCS Line 43 Th II	FCV C4B	TCS Line 43 Th II	20N FCV F2B
140	TCS Line 44 Th II	FCV C3B	TCS Line 44 Th II	20N FCV U1B
141	TCS Line 45 Th II	RCS piping	TCS Line 45 Th II	20N FCV U2B
142	TCS Line 46 Th II	RCS piping	TCS Line 46 Th II	RCS piping
143	TCS Line 47 Th II	RCS piping	TCS Line 47 Th II	RCS piping
144	TCS Line 48 Th II	PT	TCS Line 48 Th II	RCS piping
145	TCS Line 01 Th III	XPND1	TCS Line 01 Th III	STR1
146	TCS Line 02 Th III	XPND2	TCS Line 02 Th III	STR2
147	TCS Line 03 Th III	BATTERY Conn.	TCS Line 03 Th	PHBA-N (HFI DPU1)
148	spare	spare	TCS Line 04 Th III	PHBA-R (HFI DPU2)
149	TCS Line 05 Th III	FPSPU	TCS Line 05 Th III	PHCBC (REU)
150	TCS Line 06 Th III	FPBOLC	TCS Line 06 Th III	PHDA (4KCCU)
151	TCS Line 07 Th III	CRS1	TCS Line 07 Th III	Heat Pipe
152	TCS Line 08 Th III	FPMECDEC	PLBEU (LFI BEU) Temp R	PLBEU (LFI BEU)
153	TCS Line 09 Th III	RCS piping	PHEAAA (HFI He3) Temp R	PHEAAA (HFI He3, +Z)
154	TCS Line 10 Th III	CCU	spare	spare
155	TCS Line 11 Th III	RCS piping	spare	spare
156	TCS Line 12 Th III	FHWOV	PHEAAB (HFI He4-1) Temp R	PHEAAB (HFI He4-1, +Y)
157	TCS Line 13 Th III	FHHRV	spare	spare
158	TCS Line 14 Th III	STR1 baffle	TCS Line 14 Th III	PHEAAC (HFI He4-2, -Z)
159	TCS Line 15 Th III	FHWEV	TCS Line 15 Th III	PHCBA (HFI PAU)
160	TCS Line 16 Th III	FHWOH	TCS Line 16 Th III	PHDJ (HFI 4K Reg)
161	TCS Line 17 Th III	FHWEH	TCS Line 17 Th III	CRS1
162	TCS Line 18 Th III	FHHRH	TCS Line 18 Th III	CRS2
163	TCS Line 19 Th III	FHLCU	TCS Line 19 Th III	CRS3
164	TCS Line 20 Th III	FHLSU	TCS Line 20 Th III - spare	spare
165	TCS Line 21 Th III	RWA2	TCS Line 21 Th III	TANK +Z+Y
166	TCS Line 22 Th III	RWA4	TCS Line 22 Th III	TANK +Z-Y
167	TCS Line 23 Th III	RWA1	TCS Line 23 Th III	TANK -Z
168	TCS Line 24 Th III	RWA3	TCS Line 24 Th III	1 N FCV A1A
169	TCS Line 25 Th III	Tank +Y	TCS Line 25 Th III	1 N FCV B1A
170	TCS Line 26 Th III	Tank -Y	TCS Line 26 Th III	20 N FCV D1A
171	TCS Line 27 Th III	STR	TCS Line 27 Th III	20N FCV D2A
172	TCS Line 28 Th III	FHWEV	TCS Line 28 Th III	20N FCV F1A
173	TCS Line 29 Th III	FCV A1A	TCS Line 29 Th III	20N FCV F2A
174	TCS Line 30 Th III	FCV C2A	TCS Line 30 Th III	20N FCV U1A
175	TCS Line 31 Th III	FCV C1A	TCS Line 31 Th III	20N FCV U2A
176	TCS Line 32 Th III	FCV A2A	TCS Line 32 Th III	RCS unit
177	TCS Line 33 Th III	FCV C4A	TCS Line 33 Th III	RCS piping
178	TCS Line 34 Th III	FCV C3A	TCS Line 34 Th III	RCS piping
179	TCS Line 35 Th III	RCS piping	TCS Line 35 Th II	PHDB (4KCAU)
180	TCS Line 36 Th III	STR2 baffle	TCS Line 36 Th III	PLREN (REBA)
181	TCS Line 37 Th III	RCS piping	TCS Line 37 Th III	BATTERY
182	TCS Line 38 Th III	GYRO	TCS Line 38 Th III	1 N FCV A1B
183	TCS Line 39 Th III	FCV A1B	TCS Line 39 Th III	1 N FCV B1B
184	TCS Line 40 Th III	FCV C2B	TCS Line 40 Th III	20N FCV D1B
185	TCS Line 41 Th III	FCV C1B	TCS Line 41 Th III	20N FCV D2B
186	TCS Line 42 Th III	FCV A2B	TCS Line 42 Th III	20N FCV F1B
187	TCS Line 43 Th III	FCV C4B	TCS Line 43 Th III	20N FCV F2B
188	TCS Line 44 Th III	FCV C3B	TCS Line 44 Th III	20N FCV U1B

Table 3-16 List of Thermistors Signals

THM #	HERSCHEL		PLANCK	
	Monitor	Source	Monitor	Source
189	TCS Line 45 Th III	RCS piping	TCS Line 45 Th III	20N FCV U2B
190	TCS Line 46 Th III	RCS piping	TCS Line 46 Th III	RCS piping
191	TCS Line 47 Th III	RCS piping	TCS Line 47 Th III	RCS piping
192	TCS Line 48 Th III	PT	TCS Line 48 Th III	RCS piping

Table 3-16 List of Thermistors Signals

Heaters TM/TC channels

It is recalled that HPSs and HCSs.that physically belong to the PCDU.

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Heaters TM channels

Type	Monitor	Function
1553 S/C bus	Grp_iHeat_j_STS	Latch status of the HCS_j in Grp_i
	Grp_i_HPS_STS	Output status of the HPS_i
	Grp_i_HPS_ITLM	Current telemetry for the HCSs associated with Grp_i
	Grp_i_Therm_TLM	T° telemetry for the HCSs associated with Grp_i

Table 3-17 List of Heaters TM Channels

Heaters TC Channels

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Type	Command	Function
1553 S/C bus	Grp_iHeat_j_ON	Switches ON the corresponding HCS
	Grp_iHeat_j_OFF	Switches OFF the corresponding HCS
	ON/OFF_Grp_i_HPS	Switches ON/OFF the corresponding HPS

Table 3-18 List of Heaters TC Channels

3.10.1. TCS TC Packets Summary

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- See attached Reports (To Be Extracted from HPSDB) -

3.10.2. TCS TC Parameters Summary

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- See attached Reports (To Be Extracted from HPSDB) -

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3.10.3. TCS TM Packets Summary

- See attached Reports (To Be Extracted from HPSDB) -

3.10.4. TCS TM Parameters Summary

- See attached Reports (To Be Extracted from HPSDB) -

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3.11. TCS BUDGETS

3.11.1. TCS Power budgets

- **Refer to [PWRBDG] and [TCSMPBDG]**

3.11.2. TCS Data Budgets

- **Refer to [TMTCBDG] and [SVMHKPK]**

3.11.3. TCS Mass Budgets

- **Refer to [MASSBDG], [PWRBDG] and [TCSMPBDG]**

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Set Failure of the Unit [NAME] thermal control = False

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AND (RECONFIGURATION = False)

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Set Failure of the Unit [NAME] thermal control = True

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Set Failure of the Unit [NAME] thermal control = False

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time-out are parameters defined for each TCT Loop and contained in the FDIR Cross Correlated Checks Table;

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computed for all the HCSs.

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Loop Index	Heater's location Herschel	Control Loop Status	THM 1 Used	THM 2 Used	THM 3 Used	Control Loop Class	Temperature Monitoring Frequency	Unit Status Column from Unit in Use Table (hex)	Tmin-on (Tref for Cl B)	T
1	close to XPND1	Enabled	THM-49	THM-97	THM-145	A	60 sec	0x201	-9	
2	close to XPND2	Enabled	THM-50	THM-98	THM-146	A	60 sec	0x401	-9	
3	Inside Battery	Enabled	THM-51	THM-99	THM-147	A	60 sec	0x317	1	
4	Propellant Tanks	Disabled	THM-52	THM-100	THM-148	A	60 sec	N/A	N/A	
5	close to FPSPU, FPDPU	Enabled	THM-53	THM-101	THM-149	A	60 sec	0x30B	-14	
6	close to FPBOLC	Enabled	THM-54	THM-102	THM-150	A	60 sec	0x309	-14	
7	CRS-1	Enabled	THM-55	THM-103	THM-151	A	60 sec	N/A	50.5	
8	close to FPDEC MEC	Enabled	THM-56	THM-104	THM-152	A	60 sec	0x30A	-14	
9	RCS PIPES	Enabled	THM-57	THM-105	THM-153	A	60 sec	0x317	23	
10	close to CCU, HSDCU, HSFCU	Enabled	THM-58	THM-106	THM-154	A	60 sec	0x316 OR 0x516	-9	
11	RCS PIPES	Enabled	THM-59	THM-107	THM-155	A	60 sec	0x317	23	
12	close to FHWOV	Enabled	THM-60	THM-108	THM-156	B	10sec	0x30C	T Ref = 9	

Loop Index	Heater's location Herschel	Control Loop Status	THM 1 Used	THM 2 Used	THM 3 Used	Control Loop Class	Temperature Monitoring Frequency	Unit Status Column from Unit in Use Table (hex)	Tmin-on (Tref for Cl B)	T
13	close to FHHRV	Enabled	THM-61	THM-109	THM-157	A	60 sec	0x30D	-9	
14	STR 1 Primary Baffle	Enabled	THM-62	THM-110	THM-158	A	60 sec	0x302	14	
15	close to FHWEV, FHICU	Enabled	THM-63	THM-111	THM-159	A	60 sec	0x30E	1	
16	close to FHWOH	Enabled	THM-64	THM-112	THM-160	B	10sec	0x30F	T Ref = 9	
17	close to FHWEH	Enabled	THM-65	THM-113	THM-161	A	60 sec	0x310	1	
18	close to FHHRH	Enabled	THM-66	THM-114	THM-162	A	60 sec	0x311	-9	
19	close to FHLCU, FHIFH	Enabled	THM-67	THM-115	THM-163	A	60 sec	0x312	-9	
20	close to FHLSU	Enabled	THM-68	THM-116	THM-164	A	60 sec	0x314	11	
21	on RWL2	Enabled	THM-69	THM-117	THM-165	A	60 sec	0x305	1	
22	on RWL4	Enabled	THM-70	THM-118	THM-166	A	60 sec	0x307	1	
23	on RWL1	Enabled	THM-71	THM-119	THM-167	A	60 sec	0x304	1	
24	on RWL3	Enabled	THM-72	THM-120	THM-168	A	60 sec	0x306	1	
25	on TANK +Y	Enabled	THM-73	THM-121	THM-169	A	60 sec	0x317	11	
26	on TANK -Y	Enabled	THM-74	THM-122	THM-170	A	60 sec	0x317	11	
27	close to STR's	Enabled	THM-75	THM-123	THM-171	B	10sec	0x302 OR 0x502	T Ref =- 2	
28	close to FHIFV	Enabled	THM-76	THM-124	THM-172	B	10sec	0x313	T Ref = 7	

Loop Index	Heater's location Herschel	Control Loop Status	THM 1 Used	THM 2 Used	THM 3 Used	Control Loop Class	Temperature Monitoring Frequency	Unit Status Column from Unit in Use Table (hex)	Tmin-on (Tref for Cl B)	T
29	on FCV A1A	Enabled	THM-77	THM-125	THM-173	A	60 sec	0x317	11	
30	on FCV C2A	Enabled	THM-78	THM-126	THM-174	A	60 sec	0x317	11	
31	on FCV C1A	Enabled	THM-79	THM-127	THM-175	A	60 sec	0x317	11	
32	on FCV A2A	Enabled	THM-80	THM-128	THM-176	A	60 sec	0x317	11	
33	on FCV C4A	Enabled	THM-81	THM-129	THM-177	A	60 sec	0x317	11	
34	on FCV C3A	Enabled	THM-82	THM-130	THM-178	A	60 sec	0x317	11	
35	on RCS PIPES	Enabled	THM-83	THM-131	THM-179	A	60 sec	0x317	23	
36	STR 2 Primary Baffle	Enabled	THM-84	THM-132	THM-180	A	60 sec	0x502	14	
37	on RCS PIPES	Enabled	THM-85	THM-133	THM-181	A	60 sec	0x317	23	
38	close to GYRO	Enabled	THM-86	THM-134	THM-182	A	60 sec	0x303	62.5	
39	on FCV A1B	Enabled	THM-87	THM-135	THM-183	A	60 sec	0x317	11	
40	on FCV C2B	Enabled	THM-88	THM-136	THM-184	A	60 sec	0x317	11	
41	on FCV C1B	Enabled	THM-89	THM-137	THM-185	A	60 sec	0x317	11	
42	on FCV A2B	Enabled	THM-90	THM-138	THM-186	A	60 sec	0x317	11	
43	on FCV C4B	Enabled	THM-91	THM-139	THM-187	A	60 sec	0x317	11	
44	on FCV C3B	Enabled	THM-92	THM-140	THM-188	A	60 sec	0x317	11	
45	on RCS PIPES	Enabled	THM-93	THM-141	THM-189	A	60 sec	0x317	23	
46	on RCS PIPES	Enabled	THM-94	THM-142	THM-190	A	60 sec	0x317	23	
47	on RCS PIPES	Enabled	THM-95	THM-143	THM-191	A	60 sec	0x317	23	

Loop Index	Heater's location Herschel	Control Loop Status	THM 1 Used	THM 2 Used	THM 3 Used	Control Loop Class	Temperature Monitoring Frequency	Unit Status Column from Unit in Use Table (hex)	Tmin-on (Tref for Cl B)	T
48	on unit: PT, LF, LV1, LV2	Enabled	THM-96	THM-144	THM-192	A	60 sec	0x317	23	
49	CRS-2	Enabled	THM-12	THM-20	THM-36	A	60 sec	N/A	50.5	
50	SPARE	Disabled						N/A		
51	SPARE	Disabled						N/A		
52	SPARE	Disabled						N/A		
53	SPARE	Disabled						N/A		
54	SPARE	Disabled						N/A		
55	close to XPND1	Disabled	THM-49	THM-97	THM-145	A	60 sec	0x201	-9	
56	close to XPND2	Disabled	THM-50	THM-98	THM-146	A	60 sec	0x401	-9	
57	inside BATTERY	Disabled	THM-51	THM-99	THM-147	A	60 sec	0x317	1	
58	SPARE Note 3	Disabled	THM-52	THM-100	THM-148	A	60 sec	N/A	N/A	
59	close to FPSPU, FPDPU	Disabled	THM-53	THM-101	THM-149	A	60 sec	0x30B	-14	
60	close to FPBOLC	Disabled	THM-54	THM-102	THM-150	A	60 sec	0x309	-14	
61	CRS-1	Disabled	THM-55	THM-103	THM-151	A	60 sec	N/A	50.5	
62	close to FPDECMEC	Disabled	THM-56	THM-104	THM-152	A	60 sec	0x30A	-14	
63	RCS PIPES	Disabled	THM-57	THM-105	THM-153	A	60 sec	0x317	23	
64	close to CCU, HSDCU, HSFCU	Disabled	THM-58	THM-106	THM-154	A	60 sec	0x316 OR 0x516	-9	
65	RCS PIPES	Disabled	THM-59	THM-107	THM-155	A	60 sec	0x317	23	
66	close to FHWOV	Disabled	THM-60	THM-108	THM-156	B	10 sec	0x30C	T Ref = 9	
67	close to FHHRV	Disabled	THM-61	THM-109	THM-157	A	60 sec	0x30D	-9	

Loop Index	Heater's location Herschel	Control Loop Status	THM 1 Used	THM 2 Used	THM 3 Used	Control Loop Class	Temperature Monitoring Frequency	Unit Status Column from Unit in Use Table (hex)	Tmin-on (Tref for Cl B)	T
68	STR-1 Primary Baffle	Disabled	THM-62	THM-110	THM-158	A	60 sec	0x302	14	
69	close to FHWEV, FHICU	Disabled	THM-63	THM-111	THM-159	A	60 sec	0x30E	1	
70	close to FHWOH	Disabled	THM-64	THM-112	THM-160	B	10 sec	0x30F	T Ref = 9	
71	close to FHWEH	Disabled	THM-65	THM-113	THM-161	A	60 sec	0x310	1	
72	close to FHHRH	Disabled	THM-66	THM-114	THM-162	A	60 sec	0x311	-9	
73	close to FHLCU, FHIFH	Disabled	THM-67	THM-115	THM-163	A	60 sec	0x312	-9	
74	close to FHLSU	Disabled	THM-68	THM-116	THM-164	A	60 sec	0x314	11	
75	on RWL2	Disabled	THM-69	THM-117	THM-165	A	60 sec	0x305	1	
76	on RWL4	Disabled	THM-70	THM-118	THM-166	A	60 sec	0x307	1	
77	on RWL1	Disabled	THM-71	THM-119	THM-167	A	60 sec	0x304	1	
78	on RWL3	Disabled	THM-72	THM-120	THM-168	A	60 sec	0x306	1	
79	on TANK +Y	Disabled	THM-73	THM-121	THM-169	A	60 sec	0x317	11	
80	on TANK -Y	Disabled	THM-74	THM-122	THM-170	A	60 sec	0x317	11	
81	close to STR's	Disabled	THM-75	THM-123	THM-171	B	10 sec	0x302 OR 0x502	T Ref =- 2	
82	close to FHIFV	Disabled	THM-76	THM-124	THM-172	B	10 sec	0x313	T Ref = 7	

Loop Index	Heater's location Herschel	Control Loop Status	THM 1 Used	THM 2 Used	THM 3 Used	Control Loop Class	Temperature Monitoring Frequency	Unit Status Column from Unit in Use Table (hex)	Tmin-on (Tref for Cl B)	T
83	on FCV A1A	Disabled	THM-77	THM-125	THM-173	A	60 sec	0x317	11	
84	on FCV C2A	Disabled	THM-78	THM-126	THM-174	A	60 sec	0x317	11	
85	on FCV C1A	Disabled	THM-79	THM-127	THM-175	A	60 sec	0x317	11	
86	on FCV A2A	Disabled	THM-80	THM-128	THM-176	A	60 sec	0x317	11	
87	on FCV C4A	Disabled	THM-81	THM-129	THM-177	A	60 sec	0x317	11	
88	on FCV C3A	Disabled	THM-82	THM-130	THM-178	A	60 sec	0x317	11	
89	on RCS PIPES	Disabled	THM-83	THM-131	THM-179	A	60 sec	0x317	23	
90	STR-2 Primary Baffle	Disabled	THM-84	THM-132	THM-180	A	60 sec	0x502	14	
91	on RCS PIPES	Disabled	THM-85	THM-133	THM-181	A	60 sec	0x317	23	
92	close to GYRO	Disabled	THM-86	THM-134	THM-182	A	60 sec	0x303	62.5	
93	on FCV A1B	Disabled	THM-87	THM-135	THM-183	A	60 sec	0x317	11	
94	on FCV C2B	Disabled	THM-88	THM-136	THM-184	A	60 sec	0x317	11	
95	on FCV C1B	Disabled	THM-89	THM-137	THM-185	A	60 sec	0x317	11	
96	on FCV A2B	Disabled	THM-90	THM-138	THM-186	A	60 sec	0x317	11	
97	on FCV C4B	Disabled	THM-91	THM-139	THM-187	A	60 sec	0x317	11	
98	on FCV C3B	Disabled	THM-92	THM-140	THM-188	A	60 sec	0x317	11	
99	on RCS PIPES	Disabled	THM-93	THM-141	THM-189	A	60 sec	0x317	23	
100	on RCS PIPES	Disabled	THM-94	THM-142	THM-190	A	60 sec	0x317	23	
101	on RCS PIPES	Disabled	THM-95	THM-143	THM-191	A	60 sec	0x317	23	
102	on unit: PT, LF, LV1,	Disabled	THM-96	THM-144	THM-192	A	60 sec	0x317	23	

Loop Index	Heater's location Herschel	Control Loop Status	THM 1 Used	THM 2 Used	THM 3 Used	Control Loop Class	Temperature Monitoring Frequency	Unit Status Column from Unit in Use Table (hex)	Tmin-on (Tref for Cl B)	T
	LV2									
103	CRS-2	Disabled	THM-12	THM-20	THM-36	A	60 sec	N/A	50.5	
104	SPARE	Disabled						N/A		
105	SPARE	Disabled						N/A		
106	SPARE	Disabled						N/A		
107	SPARE	Disabled						N/A		
108	SPARE	Disabled						N/A		

Table 13: Herschel Thermal Control Table (TCT)

Loop Index	Heater's location Herschel	Control Loop Status	THM1Used	THM2Used	THM3Used	ControlLoopClass	Temperature Monitoring Frequency	Unit Status Column from Unit in Use Table (hex)	Tmin-on (Tref for Cl B)	Tmax-on	Tmin-off	Tmax-off	HeaterLineIDHPS (HCS)	Class-B Thermal loop constant ([W/°C]) ALPHA, BETA, GAMMA, DELTA, LAMBDA
1	close to STR 1	Enabled	THM-49	THM-97	THM-145	A	60 sec	0x302	-19	-16	-19	-16	5 (5)	
2	close to STR 2	Enabled	THM-50	THM-98	THM-146	A	60 sec	0x502	-19	-16	-19	-16	5 (6)	
3	close to DPU1	Enable	TH	TH	TH	A	60 sec	0x304	-9	-6	-9	-6	1 (	

Loop Index	Heater's location Herschel	Control Loop Status	THM1 Used	THM2 Used	THM3 Used	ControlLoopClass	Temperature Monitoring Frequency	Unit Status Column from Unit in Use Table (hex)	Tmin-on (Tref for ClB)	Tmax-on	Tmin-off	Tmax-off	HeaterLineIDHPS (HCS)	Class-B Thermal loop constant ([W/°C]) ALPHA, BETA, GAMMA, DELTA, LAMBDA
		d	M-51	M-99	M-147								6)	
4	close to DPU2	Enabled	THM-52	THM-100	THM-148	A	60 sec	0x305	-9	-6	-9	-6	6(3)	
5	close to REU	Enabled	THM-53	THM-101	THM-149	A	60 sec	0x306	-9	-6	-9	-6	8(6)	
6	close to CCU, CEU	Enabled	THM-54	THM-102	THM-150	A	60 sec	0x307	-9	-6	-9	-6	1(5)	
7	on Heat Pipes	Enabled	THM-55	THM-103	THM-151	A	60 sec	0x30B	-13	-12	-13	-12	3(1)	
8	on Heat Pipes	Enabled	THM-55	THM-103	THM-151	A	60 sec	0x30B	-14	-13	-14	-13	3(2)	

Loop Index	Heater's location Herschel	Control Loop Status	THM1 Used	THM2 Used	THM3 Used	ControlLoopClass	Temperature Monitoring Frequency	Unit Status Column from Unit in Use Table (hex)	Tmin-on (Tref for ClB)	Tmax-on	Tmin-off	Tmax-off	HeaterLineIDHPS (HCS)	Class-B Thermal loop constant ([W/°C]) ALPHA, BETA, GAMMA, DELTA, LAMBDA
9	on Heat Pipes	Enabled	THM-55	THM-103	THM-151	A	60 sec	0x30B	-15	-14	-15	-14	2(2)	
10	on Heat Pipes	Enabled	THM-55	THM-103	THM-151	A	60 sec	0x30B	-16	-15	-16	-15	2(6)	
11	on Heat Pipes	Enabled	THM-55	THM-103	THM-151	A	60 sec	0x30B	-17	-16	-17	-16	6(2)	
12	on Heat Pipes	Enabled	THM-55	THM-103	THM-151	A	60 sec	0x30B	-18	-17	-18	-17	5(4)	
13	on Heat Pipes	Enabled	THM-55	THM-103	THM-151	A	60 sec	0x30B	-19	-18	-19	-18	5(3)	
14	HELIUM tanks	Enabled	THM-	THM-11	THM-	A	60 sec	0x317	-9	-6	-9	-6	3(6)	

Loop Index	Heater's location Herschel	Control Loop Status	THM1 Used	THM2 Used	THM3 Used	Control Loop Class	Temperature Monitoring Frequency	Unit Status Column from Unit in Use Table (hex)	Tmin-on (Tref for ClB)	Tmax-on	Tmin-off	Tmax-off	Heater Line ID HPS (HCS)	Class-B Thermal loop constant ([W/°C]) ALPHA, BETA, GAMMA, DELTA, LAMBDA
			62	0	158									
15	PAU	Enabled	THM-63	THM-1111	THM-159	A	60 sec	0x30A	-9	-6	-9	-6	9(1)	
16	CRU (4K Reg)	Enabled	THM-64	THM-1112	THM-160	A	60 sec	0x309	-9	-6	-9	-6	9(2)	
17	CRS-1	Enabled	THM-65	THM-1113	THM-161	A	60 sec	N/A	50.5	51	50.5	51	7(1)	
18	CRS-2	Enabled	THM-66	THM-1114	THM-162	A	60 sec	N/A	50.5	51	50.5	51	7(2)	
19	CRS-3	Enabled	THM-67	THM-1115	THM-163	A	60 sec	N/A	50.5	51	50.5	51	4(6)	
20	SPARE	Disabl	TH	TH	TH	A	60 sec	N/A	N/A	N/	N/A	N/	4(	

Loop Index	Heater's location Herschel	Control Loop Status	THM1 Used	THM2 Used	THM3 Used	ControlLoopClass	Temperature Monitoring Frequency	Unit Status Column from Unit in Use Table (hex)	Tmin-on (Tref for ClB)	Tmax-on	Tmin-off	Tmax-off	HeaterLineIDHPS (HCS)	Class-B Thermal loop constant ([W/°C]) ALPHA, BETA, GAMMA, DELTA, LAMBDA
		ed	M-68	M-116	M-164					A		A	2)	
21	on TANK +Z+Y Note 1	Enabled	THM-71	THM-119	THM-167	A	60 sec	0x317	11	14	11	14	8(3)	
22	on TANK +Z-Y Note 1	Enabled	THM-71	THM-119	THM-167	A	60 sec	0x317	11	14	11	14	8(4)	
23	on TANK –Z Note 1	Enabled	THM-71	THM-119	THM-167	A	60 sec	0x317	11	14	11	14	8(5)	
24	on FCV A1A	Enabled	THM-72	THM-120	THM-168	A	60 sec	0x317	14	17	14	17	1(3)	
25	on FCV B1A	Enabled	THM-73	THM-121	THM-169	A	60 sec	0x317	14	17	14	17	1(4)	

Loop Index	Heater's location Herschel	Control Loop Status	THM1 Used	THM2 Used	THM3 Used	ControlLoopClass	Temperature Monitoring Frequency	Unit Status Column from Unit in Use Table (hex)	Tmin-on (Tref for ClB)	Tmax-on	Tmin-off	Tmax-off	HeaterLineIDHPS (HCS)	Class-B Thermal loop constant ([W/°C]) ALPHA, BETA, GAMMA, DELTA, LAMBDA
26	on FCV D1A	Enabled	THM-74	THM-122	THM-170	A	60 sec	0x317	14	17	14	17	6(6)	
27	on FCV D2A	Enabled	THM-75	THM-123	THM-171	A	60 sec	0x317	14	17	14	17	2(3)	
28	on FCV F1A	Enabled	THM-76	THM-124	THM-172	A	60 sec	0x317	14	17	14	17	2(4)	
29	on FCV F2A	Enabled	THM-77	THM-125	THM-173	A	60 sec	0x317	14	17	14	17	2(5)	
30	on FCV U1A	Enabled	THM-78	THM-126	THM-174	A	60 sec	0x317	14	17	14	17	9(5)	
31	on FCV U2A	Enabled	THM-	THM-12	THM-	A	60 sec	0x317	14	17	14	17	9(6)	

Loop Index	Heater's location Herschel	Control Loop Status	THM1 Used	THM2 Used	THM3 Used	ControlLoopClass	Temperature Monitoring Frequency	Unit Status Column from Unit in Use Table (hex)	Tmin-on (Tref for ClB)	Tmax-on	Tmin-off	Tmax-off	HeaterLineIDHPS (HCS)	Class-B Thermal loop constant ([W/°C]) ALPHA, BETA, GAMMA, DELTA, LAMBDA
			79	7	175									
32	on RCS units	Enabled	THM-80	THM-128	THM-176	A	60 sec	0x317	19	20	19	20	7(3)	
33	on RCS PIPES	Enabled	THM-81	THM-129	THM-177	A	60 sec	0x317	23	24	23	24	7(4)	
34	on RCS PIPES	Enabled	THM-82	THM-130	THM-178	A	60 sec	0x317	23	24	23	24	7(5)	
35	close to CAU	Enabled	THM-83	THM-131	THM-179	A	60 sec	0x308	-9	-6	-9	-6	1(2)	
36	close to REBA1, REBA2	Enabled	THM-84	THM-132	THM-180	A	60 sec	0x303 OR 0x503	-19	-16	-19	-16	3(3)	
37	inside BATTERY	Enable	TH	TH	TH	A	60 sec	0x317	1	4	1	4	3(	

Loop Index	Heater's location Herschel	Control Loop Status	THM1 Used	THM2 Used	THM3 Used	ControlLoopClass	Temperature Monitoring Frequency	Unit Status Column from Unit in Use Table (hex)	Tmin-on (Tref for ClB)	Tmax-on	Tmin-off	Tmax-off	HeaterLineIDHPS (HCS)	Class-B Thermal loop constant ([W/°C]) ALPHA, BETA, GAMMA, DELTA, LAMBDA
		d	M-85	M-133	M-181								4)	
38	on FCV A1B	Enabled	THM-86	THM-134	THM-182	A	60 sec	0x317	14	17	14	17	3(5)	
39	on FCV B1B	Enabled	THM-87	THM-135	THM-183	A	60 sec	0x317	14	17	14	17	4(3)	
40	on FCV D1B	Enabled	THM-88	THM-136	THM-184	A	60 sec	0x317	14	17	14	17	4(4)	
41	on FCV D2B	Enabled	THM-89	THM-137	THM-185	A	60 sec	0x317	14	17	14	17	4(5)	
42	on FCV F1B	Enabled	THM-90	THM-138	THM-186	A	60 sec	0x317	14	17	14	17	5(1)	

Loop Index	Heater's location Herschel	Control Loop Status	THM1 Used	THM2 Used	THM3 Used	ControlLoopClass	Temperature Monitoring Frequency	Unit Status Column from Unit in Use Table (hex)	Tmin-on (Tref for ClB)	Tmax-on	Tmin-off	Tmax-off	HeaterLineIDHPS (HCS)	Class-B Thermal loop constant ([W/°C]) ALPHA, BETA, GAMMA, DELTA, LAMBDA
43	on FCV F2B	Enabled	THM-91	THM-139	THM-187	A	60 sec	0x317	14	17	14	17	5 (2)	
44	on FCV U1B	Enabled	THM-92	THM-140	THM-188	A	60 sec	0x317	14	17	14	17	6 (4)	
45	on FCV U2B	Enabled	THM-93	THM-141	THM-189	A	60 sec	0x317	14	17	14	17	6 (5)	
46	on RCS PIPES	Enabled	THM-94	THM-142	THM-190	A	60 sec	0x317	23	24	23	24	7 (6)	
47	on RCS PIPES	Enabled	THM-95	THM-143	THM-191	A	60 sec	0x317	23	24	23	24	8 (2)	
48	on RCS PIPES	Enabled	THM-	THM-14	THM-	A	60 sec	0x317	30	31	30	31	9 (3)	

Loop Index	Heater's location Herschel	Control Loop Status	THM1 Used	THM2 Used	THM3 Used	ControlLoopClass	Temperature Monitoring Frequency	Unit Status Column from Unit in Use Table (hex)	Tmin-on (Tref for ClB)	Tmax-on	Tmin-off	Tmax-off	HeaterLineIDHPS (HCS)	Class-B Thermal loop constant ([W/°C]) ALPHA, BETA, GAMMA, DELTA, LAMBDA
			96	4	192									
49	SPARE	Disabled						N/A						
50	SPARE	Disabled						N/A						
51	SPARE	Disabled						N/A						
52	SPARE	Disabled						N/A						
53	SPARE	Disabled						N/A						
54	SPARE	Disabled						N/A						
55	close to STR 1	Disabled	THM-49	THM-97	THM-145	A	60 sec	0x302	-19	-16	-19	-16	14(5)	
56	close to STR 2	Disabled	THM-50	THM-98	THM-146	A	60 sec	0x502	-19	-16	-19	-16	14(6)	
5	close to	Dis	T	T	T	A	60	0x304	-9	-	-9	-	1	

Loop Index	Heater's location Herschel	Control Loop Status	THM1 Used	THM2 Used	THM3 Used	Control Loop Class	Temperature Monitoring Frequency	Unit Status Column from Unit in Use Table (hex)	Tmin-on (Tref for ClB)	Tmax-on	Tmin-off	Tmax-off	Heater Line ID HPS (HCS)	Class-B Thermal loop constant ([W/°C]) ALPHA, BETA, GAMMA, DELTA, LAMBDA
7	DPU1	abled	HM-51	HM-99	HM-147		sec			6		6	8 (6)	
58	close to DPU2	Disabled	THM-52	THM-100	THM-148	A	60 sec	0x305	-9	-6	-9	-6	13 (3)	
59	close to REU	Disabled	THM-53	THM-101	THM-149	A	60 sec	0x306	-9	-6	-9	-6	11 (6)	
60	close to CCU, CEU	Disabled	THM-54	THM-102	THM-150	A	60 sec	0x307	-9	-6	-9	-6	18 (5)	
61	on Heat Pipes Note 2	Disabled	THM-55	THM-103	THM-151	A	60 sec	0x30B	-13	-12	-13	-12	16 (1)	
62	on Heat Pipes Note 2	Disabled	THM-5	THM-103	THM-15	A	60 sec	0x30B	-14	-13	-14	-13	16 (2)	

Loop Index	Heater's location Herschel	Control Loop Status	THM1 Used	THM2 Used	THM3 Used	ControlLoopClass	Temperature Monitoring Frequency	Unit Status Column from Unit in Use Table (hex)	Tmin-on (Tref for ClB)	Tmax-on	Tmin-off	Tmax-off	HeaterLineIDHPS (HCS)	Class-B Thermal loop constant ([W/°C]) ALPHA, BETA, GAMMA, DELTA, LAMBDA
			5		1									
63	on Heat Pipes Note 2	Disabled	THM-55	THM-103	THM-151	A	60 sec	0x30B	-15	-14	-15	-14	17(2)	
64	on Heat Pipes Note 2	Disabled	THM-55	THM-103	THM-151	A	60 sec	0x30B	-16	-15	-16	-15	17(6)	
65	on Heat Pipes Note 2	Disabled	THM-55	THM-103	THM-151	A	60 sec	0x30B	-17	-16	-17	-16	13(2)	
66	on Heat Pipes Note 2	Disabled	THM-55	THM-103	THM-151	A	60 sec	0x30B	-18	-17	-18	-17	14(4)	
67	on Heat Pipes Note 2	Disabled	THM-55	THM-103	THM-151	A	60 sec	0x30B	-19	-18	-19	-18	14(3)	
68	HELIUM tanks	Disabled	THM	THM-	THM	A	60 sec	0x317	-9	-6	-9	-6	16(	

Loop Index	Heater's location Herschel	Control Loop Status	THM1 Used	THM2 Used	THM3 Used	ControlLoopClass	Temperature Monitoring Frequency	Unit Status Column from Unit in Use Table (hex)	Tmin-on (Tref for ClB)	Tmax-on	Tmin-off	Tmax-off	HeaterLineIDHPS (HCS)	Class-B Thermal loop constant ([W/°C]) ALPHA, BETA, GAMMA, DELTA, LAMBDA
			-62	110	-158								6)	
69	PAU	Disabled	THM-63	THM-111	THM-159	A	60 sec	0x30A	-9	-6	-9	-6	10(1)	
70	CRU (4K Reg)	Disabled	THM-64	THM-112	THM-160	A	60 sec	0x309	-9	-6	-9	-6	10(2)	
71	CRS-1	Disabled	THM-65	THM-113	THM-161	A	60 sec	N/A	50.5	51	50.5	51	12(1)	
72	CRS-2	Disabled	THM-66	THM-114	THM-162	A	60 sec	N/A	50.5	51	50.5	51	12(2)	
73	CRS-3	Disabled	THM-67	THM-115	THM-163	A	60 sec	N/A	50.5	51	50.5	51	15(6)	
7	SPARE	Dis	T	T	T	A	60	N/A	N/	N	N/	N	1	

Loop Index	Heater's location Herschel	Control Loop Status	THM1 Used	THM2 Used	THM3 Used	ControlLoopClass	Temperature Monitoring Frequency	Unit Status Column from Unit in Use Table (hex)	Tmin-on (Tref for ClB)	Tmax-on	Tmin-off	Tmax-off	HeaterLineIDHPS (HCS)	Class-B Thermal loop constant ([W/°C]) ALPHA, BETA, GAMMA, DELTA, LAMBDA
4		abled	HM-68	HM-116	HM-164		sec		A	/A	A	/A	5 (2)	
75	on TANK +Z+Y Note 1	Disabled	THM-69	THM-117	THM-165	A	60 sec	0x317	11	14	11	14	11 (3)	
76	on TANK +Z-Y Note 1	Disabled	THM-70	THM-118	THM-166	A	60 sec	0x317	11	14	11	14	11 (4)	
77	on TANK –Z Note 1	Disabled	THM-71	THM-119	THM-167	A	60 sec	0x317	11	14	11	14	11 (5)	
78	on FCV A1A	Disabled	THM-72	THM-120	THM-168	A	60 sec	0x317	14	17	14	17	18 (3)	
79	on FCV B1A	Disabled	THM-7	THM-121	THM-16	A	60 sec	0x317	14	17	14	17	18 (4)	

Loop Index	Heater's location Herschel	Control Loop Status	THM1 Used	THM2 Used	THM3 Used	ControlLoopClass	Temperature Monitoring Frequency	Unit Status Column from Unit in Use Table (hex)	Tmin-on (Tref for ClB)	Tmax-on	Tmin-off	Tmax-off	HeaterLineIDHPS (HCS)	Class-B Thermal loop constant ([W/°C]) ALPHA, BETA, GAMMA, DELTA, LAMBDA
			3		9									
80	on FCV D1A	Disabled	THM-74	THM-122	THM-170	A	60 sec	0x317	14	17	14	17	13 (6)	
81	on FCV D2A	Disabled	THM-75	THM-123	THM-171	A	60 sec	0x317	14	17	14	17	17 (3)	
82	on FCV F1A	Disabled	THM-76	THM-124	THM-172	A	60 sec	0x317	14	17	14	17	17 (4)	
83	on FCV F2A	Disabled	THM-77	THM-125	THM-173	A	60 sec	0x317	14	17	14	17	17 (5)	
84	on FCV U1A	Disabled	THM-78	THM-126	THM-174	A	60 sec	0x317	14	17	14	17	10 (5)	
85	on FCV U2A	Disabled	THM	THM-	THM	A	60 sec	0x317	14	17	14	17	10 (	

Loop Index	Heater's location Herschel	Control Loop Status	THM1 Used	THM2 Used	THM3 Used	Control Loop Class	Temperature Monitoring Frequency	Unit Status Column from Unit in Use Table (hex)	Tmin-on (Tref for ClB)	Tmax-on	Tmin-off	Tmax-off	Heater Line ID HPS (HCS)	Class-B Thermal loop constant ([W/°C]) ALPHA, BETA, GAMMA, DELTA, LAMBDA
			-79	127	-175								6)	
86	on RCS units	Disabled	THM-80	THM-128	THM-176	A	60 sec	0x317	19	20	19	20	12(3)	
87	on RCS PIPES	Disabled	THM-81	THM-129	THM-177	A	60 sec	0x317	23	24	23	24	12(4)	
88	on RCS PIPES	Disabled	THM-82	THM-130	THM-178	A	60 sec	0x317	23	24	23	24	12(5)	
89	close to CAU	Disabled	THM-83	THM-131	THM-179	A	60 sec	0x308	-9	-6	-9	-6	18(2)	
90	close to REBA1, REBA2	Disabled	THM-84	THM-132	THM-180	A	60 sec	0x303 OR 0x503	-19	-16	-19	-16	16(3)	
9	inside	Dis	T	T	T	A	60	0x317	1	4	1	4	1	

Loop Index	Heater's location Herschel	Control Loop Status	THM1 Used	THM2 Used	THM3 Used	ControlLoopClass	Temperature Monitoring Frequency	Unit Status Column from Unit in Use Table (hex)	Tmin-on (Tref for ClB)	Tmax-on	Tmin-off	Tmax-off	HeaterLineIDHPS (HCS)	Class-B Thermal loop constant ([W/°C]) ALPHA, BETA, GAMMA, DELTA, LAMBDA
1	BATTERY	abled	HM-85	HM-133	HM-181		sec						6(4)	
92	on FCV A1B	Disabled	THM-86	THM-134	THM-182	A	60 sec	0x317	14	17	14	17	16(5)	
93	on FCV B1B	Disabled	THM-87	THM-135	THM-183	A	60 sec	0x317	14	17	14	17	15(3)	
94	on FCV D1B	Disabled	THM-88	THM-136	THM-184	A	60 sec	0x317	14	17	14	17	15(4)	
95	on FCV D2B	Disabled	THM-89	THM-137	THM-185	A	60 sec	0x317	14	17	14	17	15(5)	
96	on FCV F1B	Disabled	THM-9	THM-138	THM-18	A	60 sec	0x317	14	17	14	17	14(1)	

Loop Index	Heater's location Herschel	Control Loop Status	THM1 Used	THM2 Used	THM3 Used	ControlLoopClass	Temperature Monitoring Frequency	Unit Status Column from Unit in Use Table (hex)	Tmin-on (Tref for ClB)	Tmax-on	Tmin-off	Tmax-off	HeaterLineIDHPS (HCS)	Class-B Thermal loop constant ([W/°C]) ALPHA, BETA, GAMMA, DELTA, LAMBDA
			0		6									
97	on FCV F2B	Disabled	THM-91	THM-139	THM-187	A	60 sec	0x317	14	17	14	17	14(2)	
98	on FCV U1B	Disabled	THM-92	THM-140	THM-188	A	60 sec	0x317	14	17	14	17	13(4)	
99	on FCV U2B	Disabled	THM-93	THM-141	THM-189	A	60 sec	0x317	14	17	14	17	13(5)	
100	on RCS PIPES	Disabled	THM-94	THM-142	THM-190	A	60 sec	0x317	23	24	23	24	12(6)	
101	on RCS PIPES	Disabled	THM-95	THM-143	THM-191	A	60 sec	0x317	23	24	23	24	11(2)	
102	on RCS PIPES	Disabled	THM	THM-	THM	A	60 sec	0x317	30	31	30	31	10(	

Loop Index	Heater's location Herschel	Control Loop Status	THM1 Used	THM2 Used	THM3 Used	ControlLoopClass	Temperature Monitoring Frequency	Unit Status Column from Unit in Use Table (hex)	Tmin-on (Tref for ClB)	Tmax-on	Tmin-off	Tmax-off	HeaterLineIDHPS (HCS)	Class-B Thermal loop constant ([W/°C]) ALPHA, BETA, GAMMA, DELTA, LAMBDA
			-96	144	-192								3)	
103	SPARE	Disabled						N/A						
104	SPARE	Disabled						N/A						
105	SPARE	Disabled						N/A						
106	SPARE	Disabled						N/A						
107	SPARE	Disabled						N/A						
108	SPARE	Disabled						N/A						