Appendix B

Definition of Experimental Based Thermal Parameters for a Standard Thermal Architecture of Electronic Boards and Units based on modular concept and relevant Thermal Mathematical Model Validation

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Abstract

The thermal design and development of Spacecraft, Sub-Systems or Equipments involve the establishment of a Thermal Mathematical Model (TMM), which shall be validated and calibrated by means of dedicated Thermal Survey test campaign; the thermal model calibration is then foreseen when the first representative hardware is available and typically this occurs in a project phase where the thermal design reached a certain maturity and some changes, if any, may have not negligible impact in term of schedule and cost. On the other hand, the space market is pushing for reducing schedule and typically the experimental activities verification is to be substituted with analysis whenever feasible. Defining standard thermal solution according to "re-use" and "modularity" philosophy will reduce the experimental activities and relevant risks and improve reliability of thermal prediction.
With the aid of Thermal Concept Design Tool (TCDT) and ESATAN, thermal analyses and relevant dedicated experimental test campaign have been carried out on a Standard PCB Assembly, designed for a modular concept Electronic Unit architecture
The main results obtained where

- Calibration of analysis parameter as contact resistance and PCB conductance with the aid of dedicated thermal vacuum test
- Definition of a standard PCB layout and architecture
- Issue of a (reduced) thermal model to be used for what-if analysis and for reference for future projects
- Definition of experimental based standard parameters for Thermal Mathematical Model at Board Assembly and Equipment level, reducing the effort of dedicated thermal survey and improving reliability

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Introduction

The thermal design and development of Spacecraft, Sub-Systems or Equipments require the set-up of a **Thermal Mathematical Model (TMM),** which shall be **validated and calibrated** by means of dedicated Thermal Survey **test campaign**;

the thermal model calibration is then foreseen when the first **representative hardware is available**

- In that project phase **thermal design reached a certain maturity**: any **changes may have not negligible impact** in term of schedule and cost.
- the space market is pushing for reducing schedule & cost: the **experimental activities verification** is going to be substituted with **analysis whenever feasible**.
- Defining standard thermal solution according to “re-use” and “modularity” philosophy will reduce the experimental activities and relevant risks and improve reliability of thermal prediction.

Standard Thermal Architecture → «Standard» Thermal Mathematical Model

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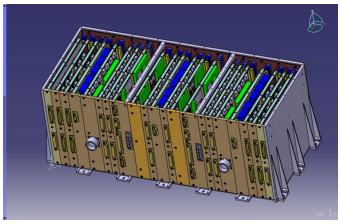
Modular Concept based Standard Unit Architecture-1

Brief overlook to the Selex ES Modularity Concept based Standard architecture for electronic equipment



Guideline

- *Modular based Architecture*
- *Standard layout of PCB modulus according to typical Program requirements*
- *Experience acquired on previous project*

Aim:

- *Standardisation*
- *PCB Modulus design re-use*
- *Modulus Assembling / disassembling optimisation*

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3

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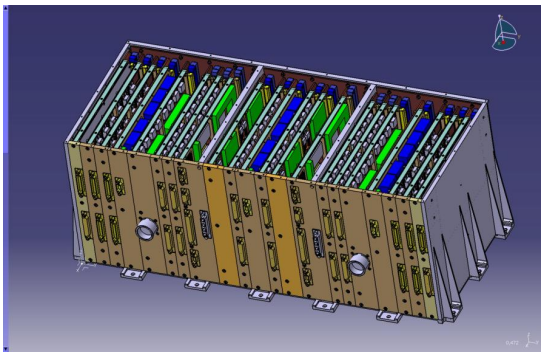
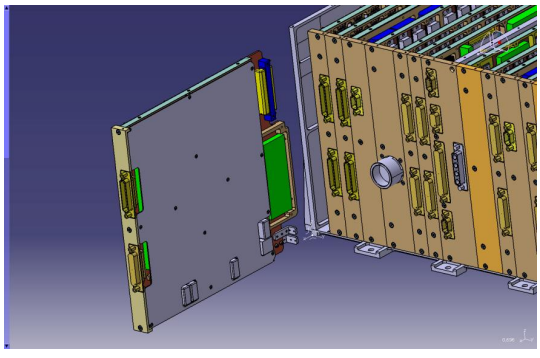
Modular Concept based Standard Unit Architecture-2

Brief overlook to the Selex ES Modularity Concept based Standard architecture for electronic equipment





Modular Architecture: The unit is assembled with Standard PCB Modulus design: the unit «connector wall» consist of the different PCB modulus front supports

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4

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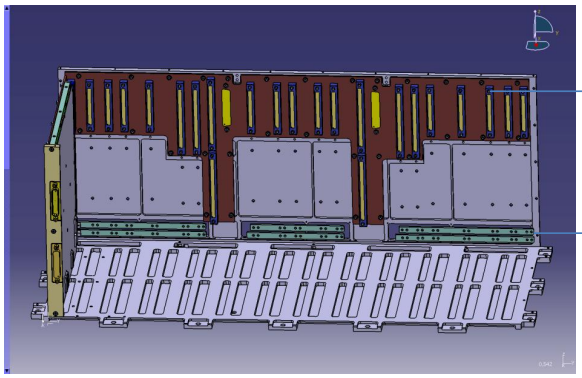
Modular Concept based Standard Unit Architecture-3

Brief overlook to the Selex ES Modularity Concept based Standard architecture for electronic equipment



Modular Architecture: *Standard Mother Board Designs, with different configurations according to connectors layout*

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5

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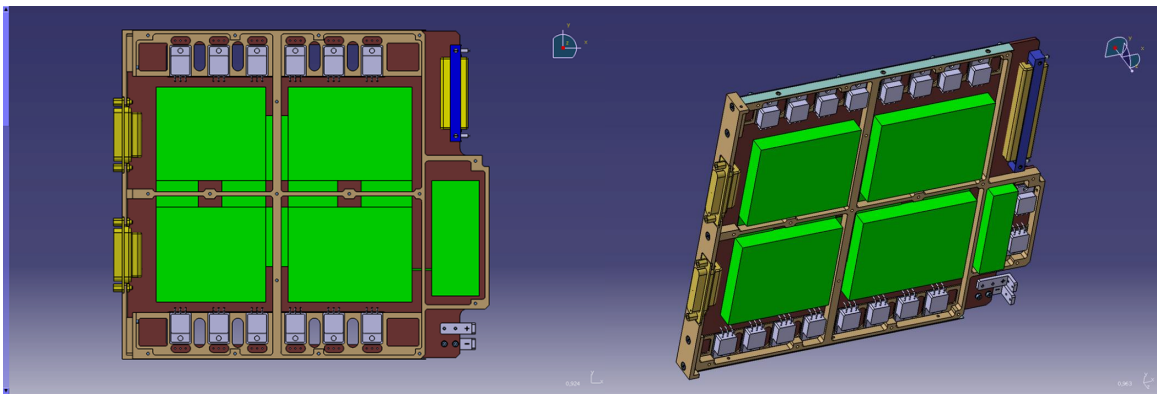
Standard Thermal Design of PCB Modulus

Standard PCB layout, according to the different Modulus functions : DC/DC converter is showed as example



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6

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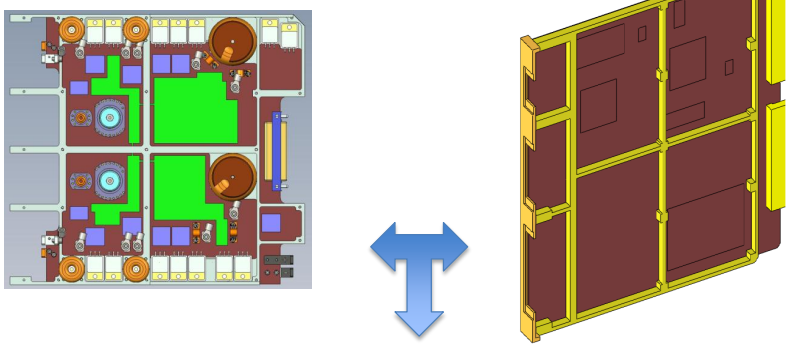
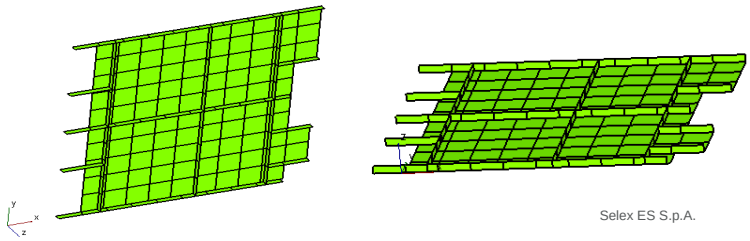
Standard Thermal Design of PCB Modulus

Standard Board Design ➡ Standard Board Thermal Model



«Standard» Reduced Thermal Model



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7

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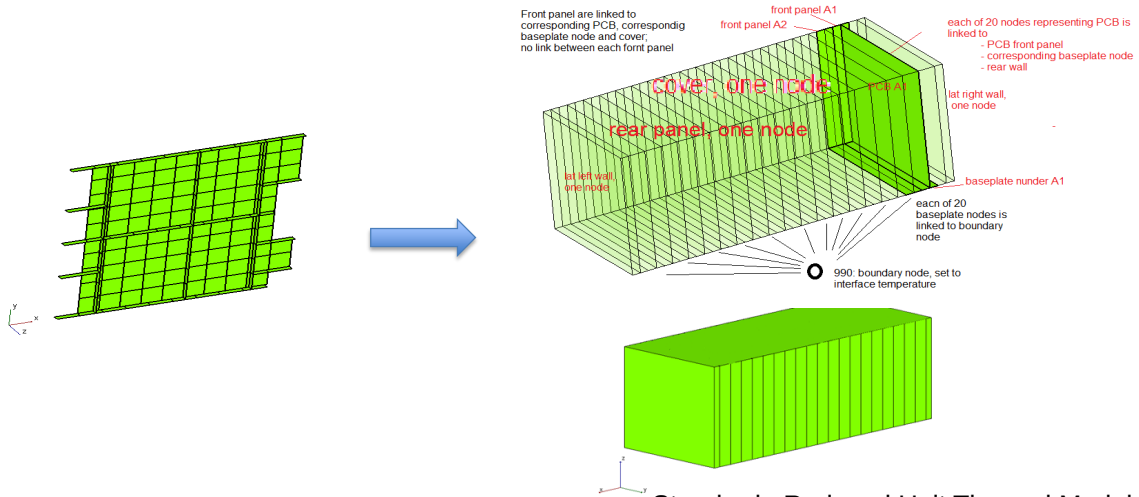
«Standard» Thermal Mathematical & Geometrical Model -1

Basically, the modular Electronic Unit by Selex ES is the sum of the various PCB modulus assembled together , therefore the Unit reduced Thermal Model will be the «**sum» of each board model**



«Standard» Reduced Board Thermal Model ➡ «Standard» Reduced Unit Thermal Model

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8

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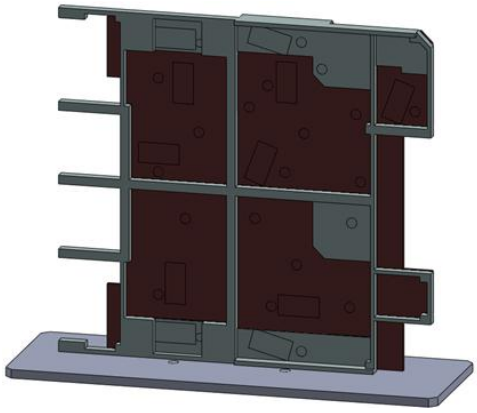
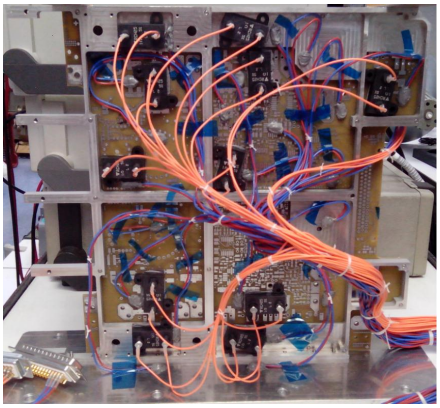
«Standard» Thermal Mathematical & Geometrical Model -2

To become «Standard» the «typical» Board Thermal Mathematical Model needs to be **experimetally calibarted**.

With the aid of **Thermal Concept Design Tool (TCDT)** and **ESATAN**, thermal analyses and relevant **dedicated experimental test campaign have been carried out on a Standard PCB Assemblies**, designed for a modular concept Electronic Unit architecture





9

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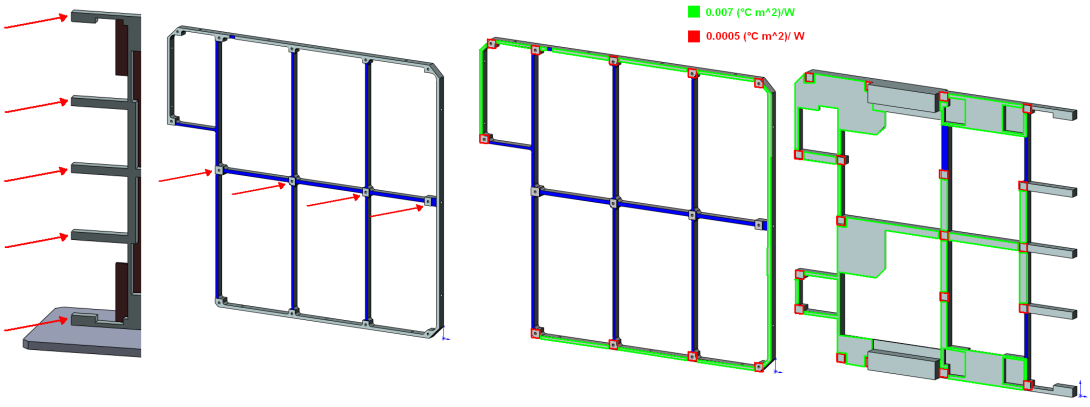
«Standard» Thermal Mathematical Model Calibration -3

The main results obtained, with the aid of dedicated thermal vacuum test, are

- Calibration of analysis parameter:
- contact resistance for each bolted connection type, defined in terms of
  - pitch between screws
  - screws size



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10

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«Standard» Thermal Mathematical Model Calibration -4

- Calibration of analysis parameter:

- PCBs conductivity (in discrete PCB region)
  - In plane : K = 15 to 60 W/mK depending on PCB type and region (*percentage of Cu and Cu layers thickness, vias, thermal layers*)
  - Out of plane: K= 6 to 18 W/mK depending on PCB type and region (*percentage of Cu and Cu layers thickness, vias, thermal layers*)

- Connectors between PCBs & Motherboard: Equivalent thermal conductance of about 13 W/(m x K) (for 62 pin connectors)

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11

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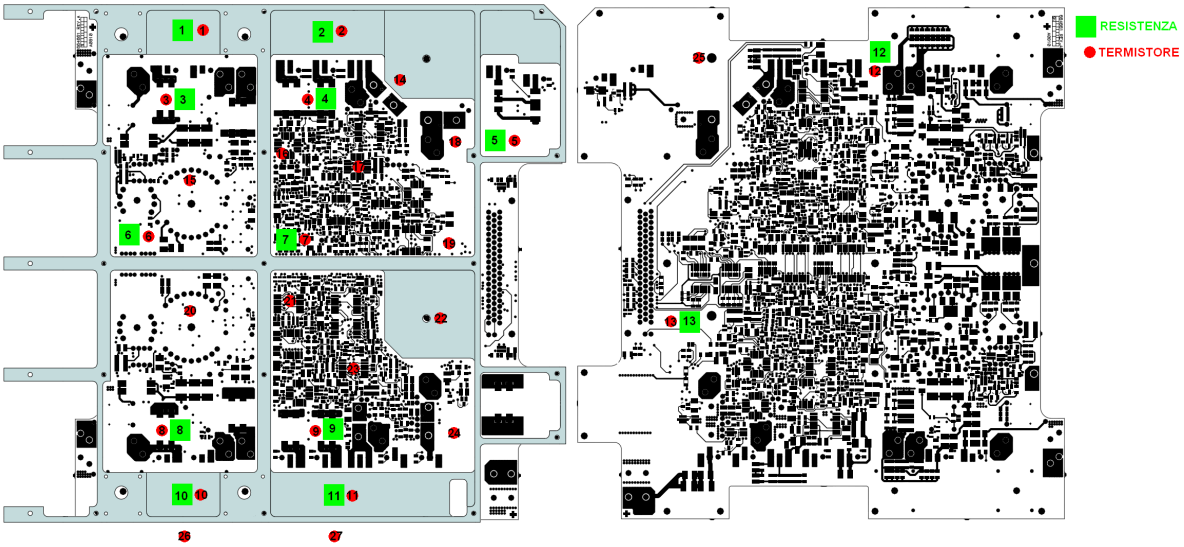
«Standard» Thermal Mathematical Model Calibration -5



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12

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«Standard» Thermal Mathematical Model Calibration -6

R	P_d [w]	TC	T_0 [°C]	T_{TVT} [°C]	$T_{TVT-NORM}$ [°C]	$T_{analysis}$ [°C]	Δ [°C]
		$TC_{chamber}$			-1.0		
R1	0.884	TC1	1.6	20.2	17.6	20.2	3.7
R2	0.941	TC2	1.3	17.8	15.5	17.8	3.8
R3	0.970	TC3	1.2	24.7	22.5	24.7	-0.8
R4	0.865	TC4	1.1	26.5	24.4	26.5	-3.0
R5	0.792	TC5	1.0	20.0	18.0	20.0	1.8
R6	0.792	TC6	0.8	21.7	19.9	21.7	-2.3
R7	0.774	TC7	0.9	21.5	19.6	21.5	-2.6
R8	0.723	TC8	0.8	15.6	13.8	15.6	-3.1
R9	0.931	TC9	0.7	18.2	16.5	18.2	-3.9
R10	1.082	TC10	0.6	3.6	2.0	3.6	1.2
R11	1.082	TC11	1.1	3.1	1.0	3.1	0.9
R12	1.088	TC12	1.1	26.6	24.5	26.6	-3.4
R13	1.00	TC13	1.2	18.9	16.7	18.9	-2.7
		TC14	1.1	17.2	15.1	17.2	**4.2**
		TC15	1.0	22.9	20.9	22.9	-1.4
		TC16	1.2	24.7	22.5	24.7	-2.1
		TC17	1.3	22.0	19.7	22.0	-1.0
		TC18	1.2	19.3	17.1	19.3	1.9
		TC19	1.1	18.7	16.6	18.7	-0.9
		TC20	1.0	16.4	14.4	16.4	0.3
		TC21	1.1	17.8	15.7	17.8	-1.1
		TC22	1.0	13.3	11.3	13.3	1.2
		TC23	0.9	18.0	16.1	18.0	-2.4
		TC24	0.7	14.0	12.3	14.0	0.1
		TC25	0.8	19.3	17.5	19.3	2.2
		TC26	0.5	0.7	-0.8	0.7	0.1
		TC27	0.3	0.7	-0.6	0.7	-0.1

Average: -0,35°C

Average on absolute values: 1,93°C

Standard Deviation: 2,3°C

* $T_{TVT-NORM} = T_{TVT} - (T_0 - T_{chamber})$

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13

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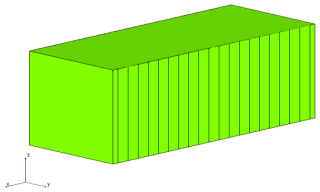
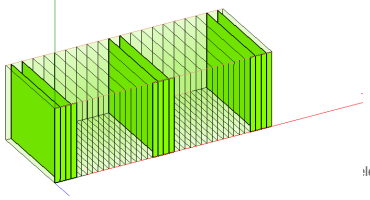
Conclusions

- The thermal design and development of Spacecraft, Sub-Systems or Equipments involve the establishment of a **Thermal Mathematical Model (TMM),** which shall be **validated and calibrated** by means of dedicated Thermal Survey **test campaign**: this is possible when dedicated thermal representative hardware is available
- Defining standard thermal solution according to “re-use” and “modularity” philosophy allows to **reduce the experimental activities** and relevant **risks** and improve reliability of thermal prediction.
- Definition of **experimental based standard parameters** for Thermal Mathematical Model at Board Assembly and Equipment level
- Issue of a (reduced) thermal models for different PCB board type (DC DC Converter, Control Board, Data Interface Board) to be used for what-if analysis and for reference for future projects





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14

28th European Space Thermal Analysis Workshop

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