MINISTÉRIO DA CIÊNCIA E TECNOLOGIA
INSTITUTO NACIONAL DE PESQUISAS ESPACIAIS

Experimental Tests of Thermal Contact Resistance between Satellite Electronic Boxes and Honeycomb Panels under Typical Flight Conditions

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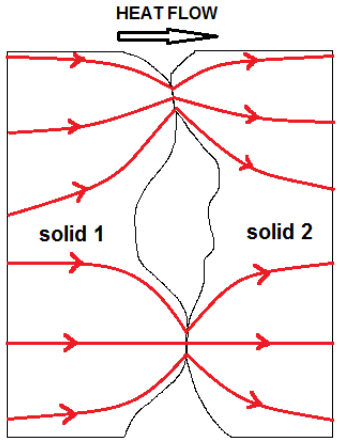
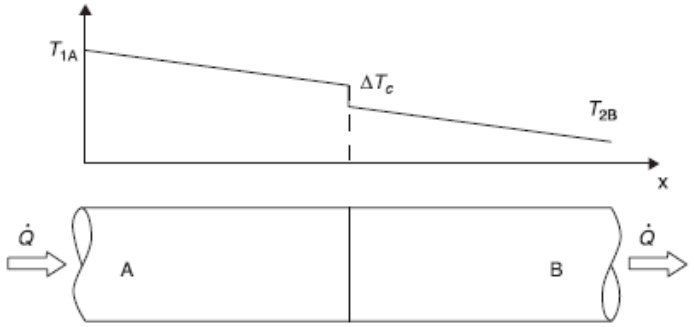
Introduction

- When solids are placed into contact a **Thermal resistance** is created

- Effective contact area < Total interface area

- **Parameters** affecting the thermal contact resistance:
  - Pressure
  - Surface finishing
  - Mechanical properties
  - Presence of interface material

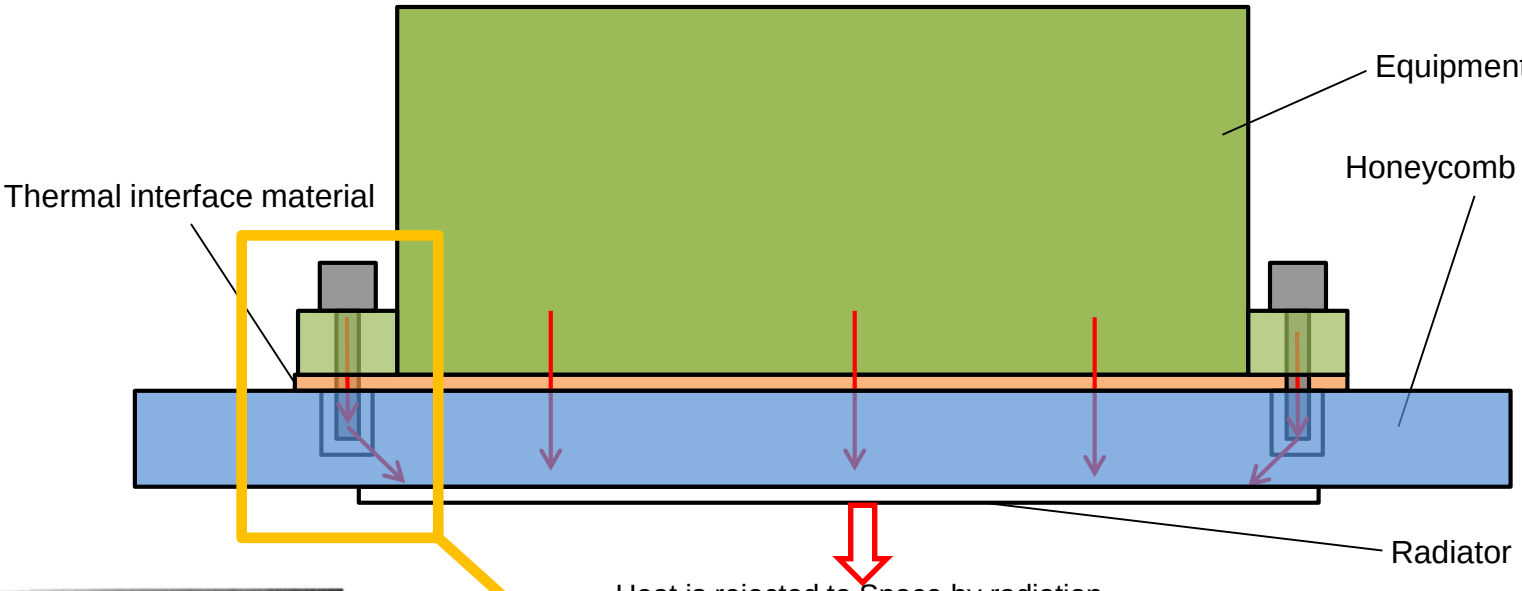


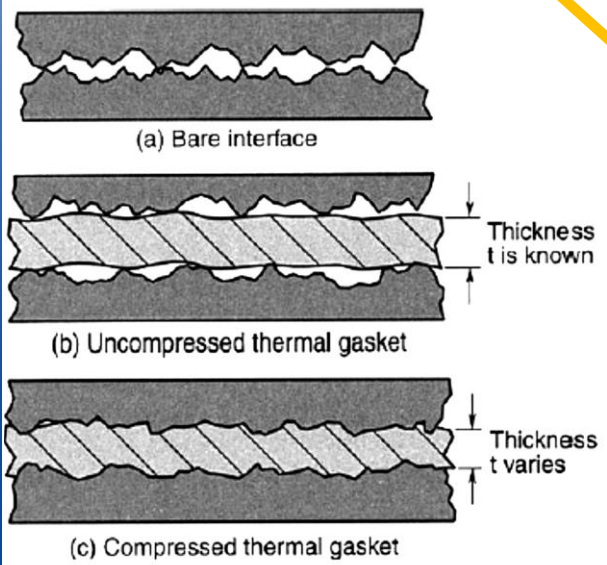


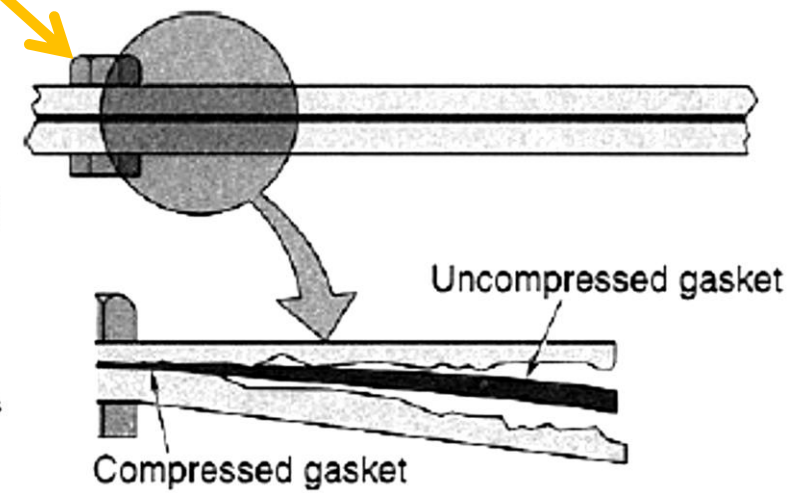
The spacecraft is under **VACUUM** in Space

Introduction

Satellite equipment/panel typical interface







The low contact pressure far from the bolts creates **high contact thermal resistance**

Study objectives

a) Development of a **new test setup** that simulates the thermal interface between satellite equipment baseplates and honeycomb panels and allows multiple sets to be tested simultaneously under vacuum;

b) Experimental distribution of thermal resistance of the interface with different materials;

c) Experimental thermal contact resistance as a function of temperature;

d) Impact of flatness and roughness of the surfaces on the thermal performance;

Study objectives

e) Study of thermal performance stability after temperature cycles;

f) Influence of the non-homogeneous heat dissipation on the equipment;

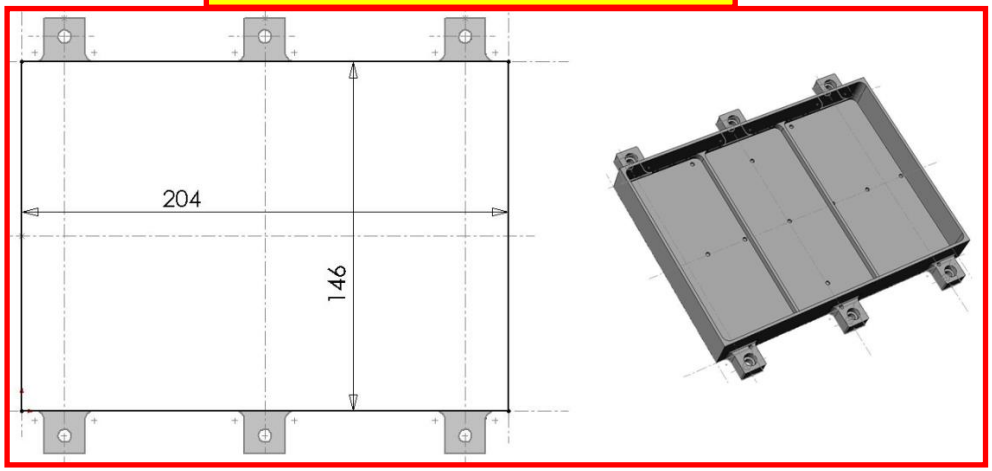
g) Identification of effective thermal resistance of the interface to be used in simplified TMMs;

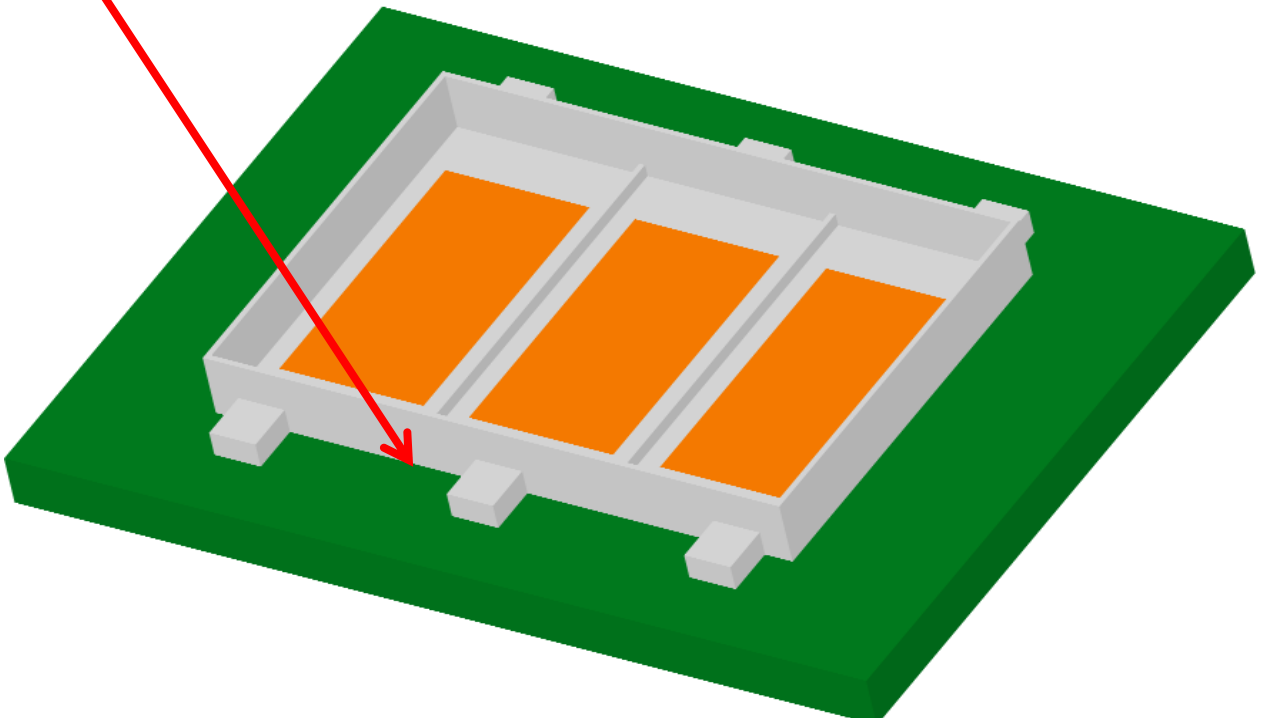
h) Comparison of thermal performance: Vacuum vs P_{amb}

Test setup

- Al **Dummy** for equipment baseplate simulation
- Piece of Al **sandwich honeycomb panel**
- Typical satellite equipment interface

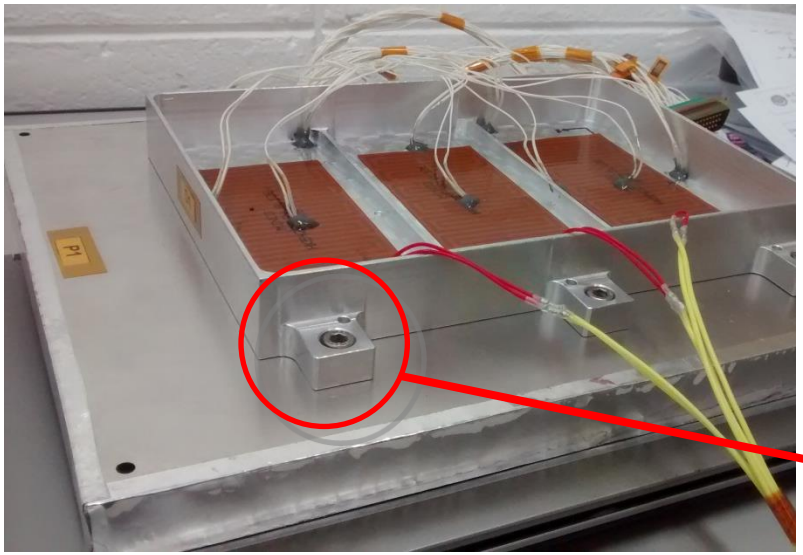
Typical shape and size

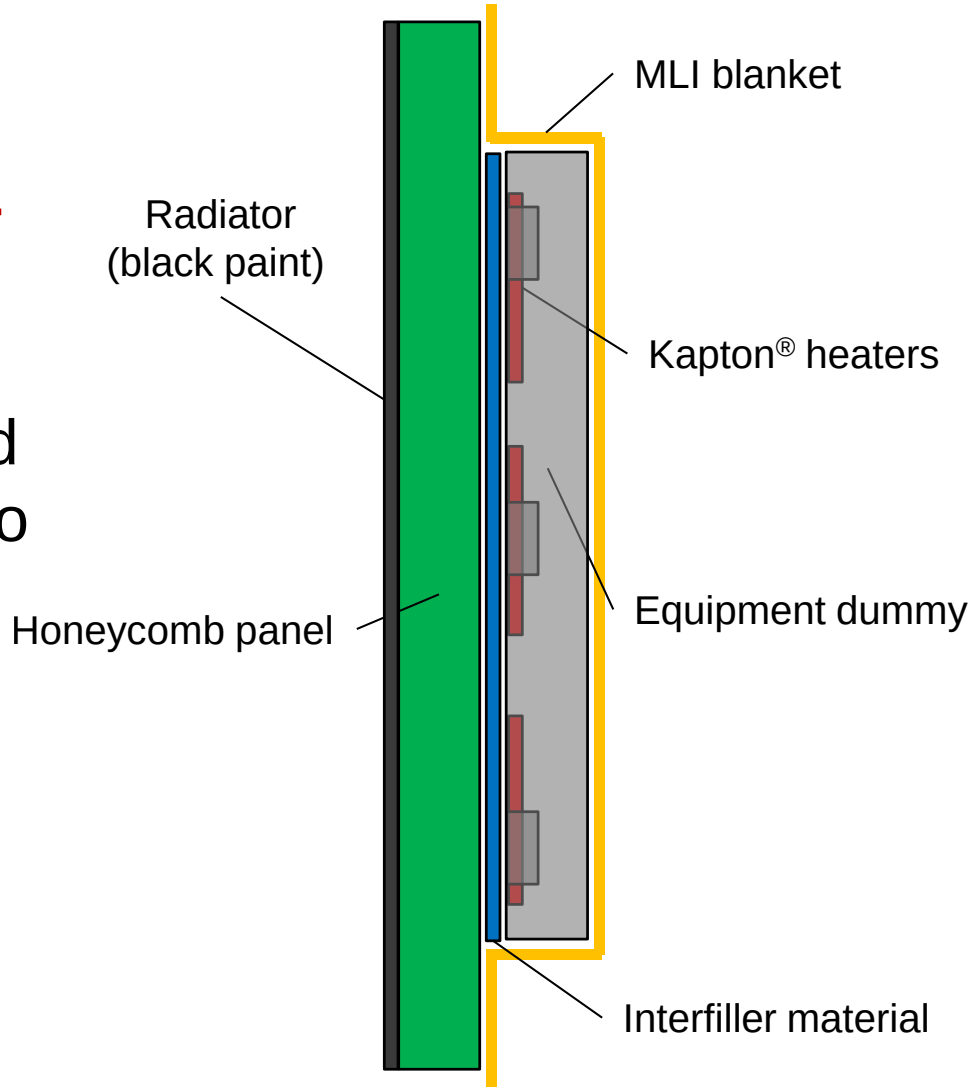




Test setup

- Honeycomb panel **painted in black** to perform like a radiator
- Equipment dummy covered with **MLI blanket** in order to insulate

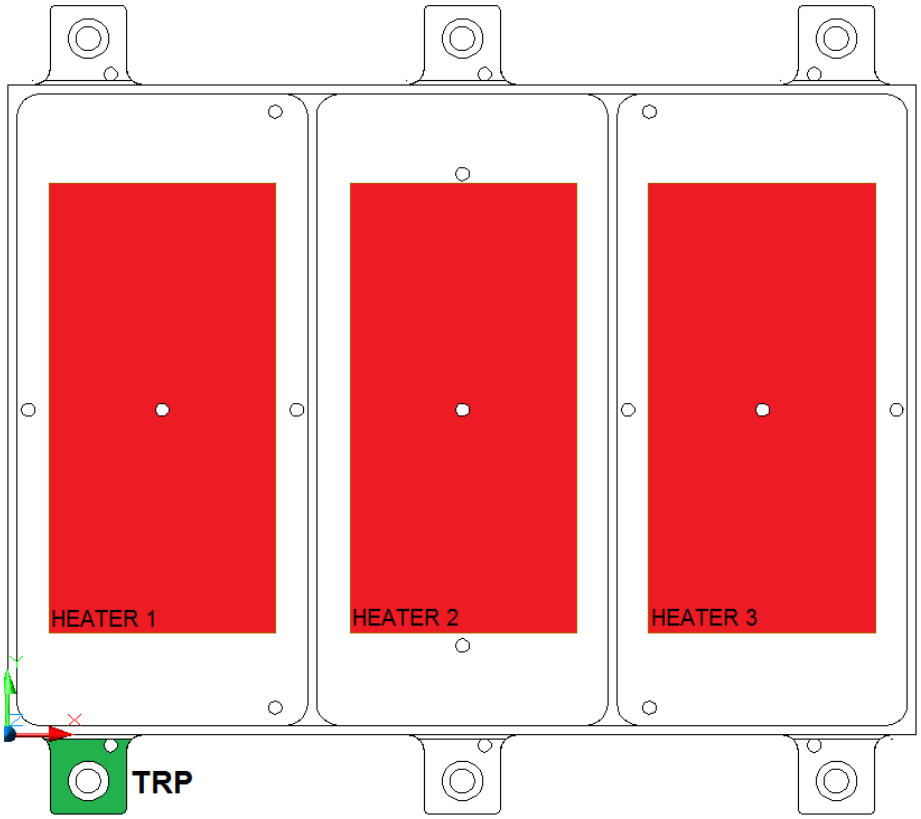


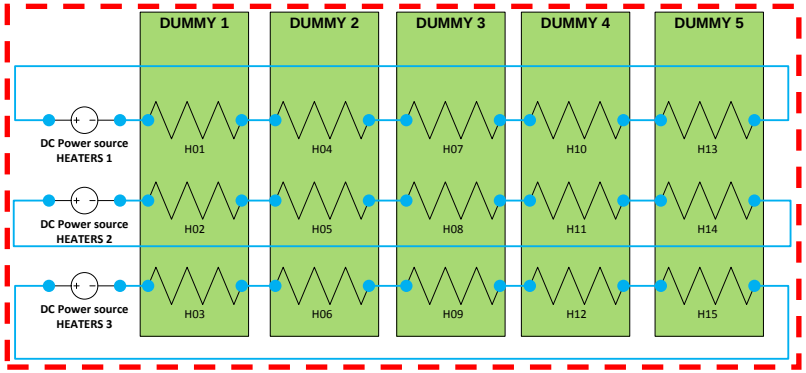


Torque according to the DCS documents
5 Nm for M5 bolts

Test setup

- **Kapton patch heaters** to simulate the equipment components heat dissipation
- Heat flux oriented towards the radiator
  - Through the interface





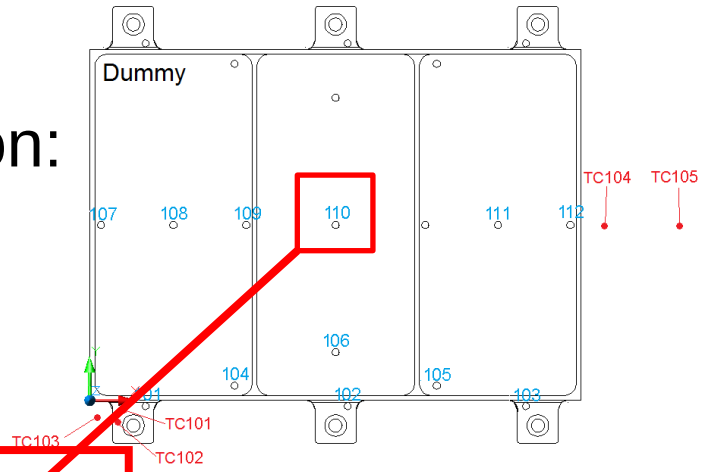
Operation mode	Description
H1+H2+H3	All heaters ON
H1	Only H1 is ON (close to the TRP)
H3	Only H3 is ON (far from the TRP)

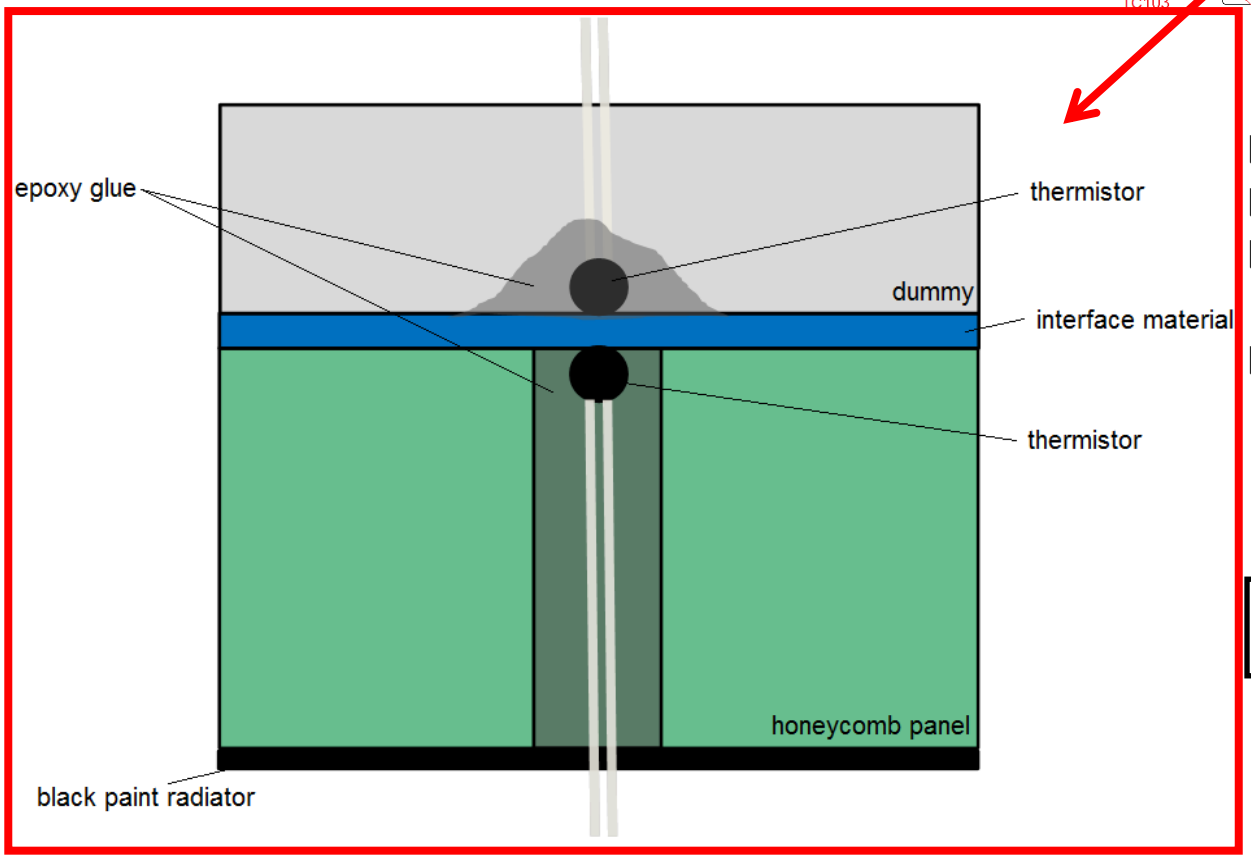
Test setup - sensors

- Temperature sensors distribution: dummy and panel

  10 KΩ@25 °C thermistors

Top view from the dummy



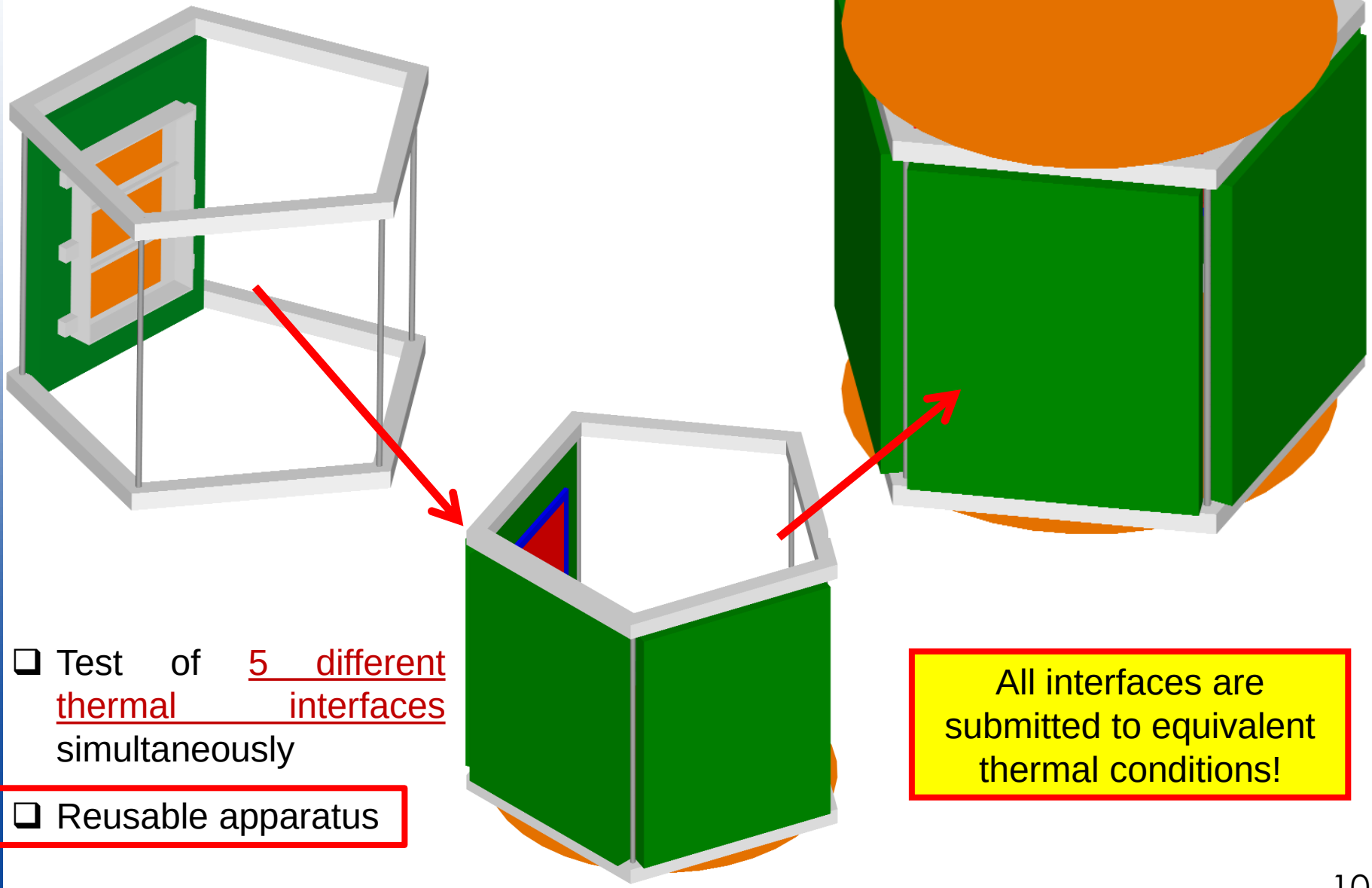


- 12 TMs on the dummy
- 12 TMs on the panel
- Corresponding TMs (in pairs)
- Individually calibrated TMs

Steinhart-Hart equation

$$T = -273.15 + \frac{1}{C1 + C2\ln(R) + C3ln(R)^3}$$

Test setup - assembly



- Test of 5 different thermal interfaces simultaneously
- Reusable apparatus

All interfaces are submitted to equivalent thermal conditions!

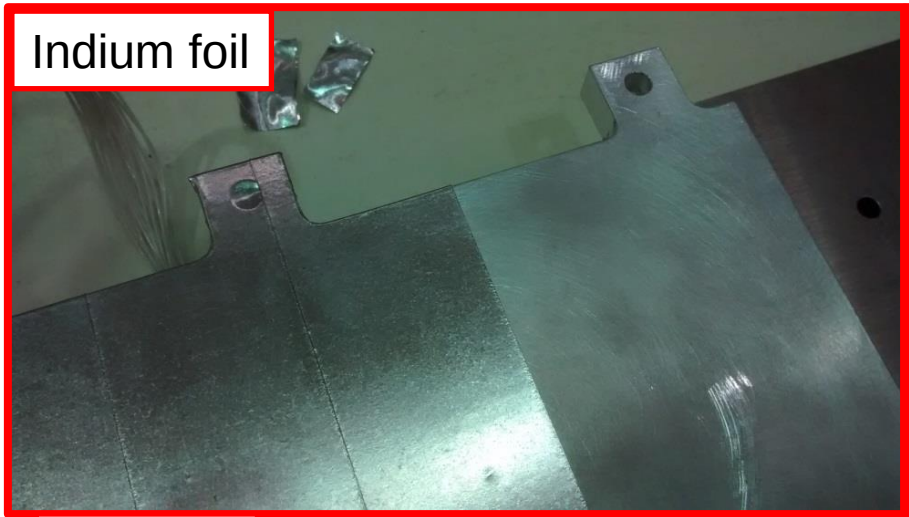
Tested materials

Material	Manufacturer	Thickness (mm)	Thermal conductivity (W/m°C)
Bare (no material)	-	-	-
eGraf® Hitherm™ 1200 Series	Graftech	0.25	10.0 / 150.0
Indium foil (99.995%)	SMC (Shanghai Metal Corporation)	0.20	~90.0
Thermal Grease (340 HS Compound)	Dow Corning	0.20*	~2.0
RTV566 (cured-in)	Momontive	0.20*	0.3

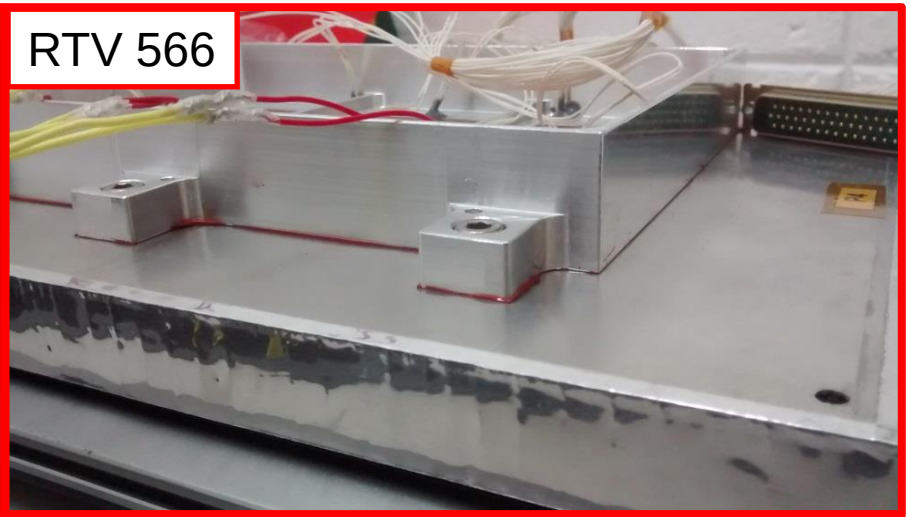
*at installation moment

Apparatus photos

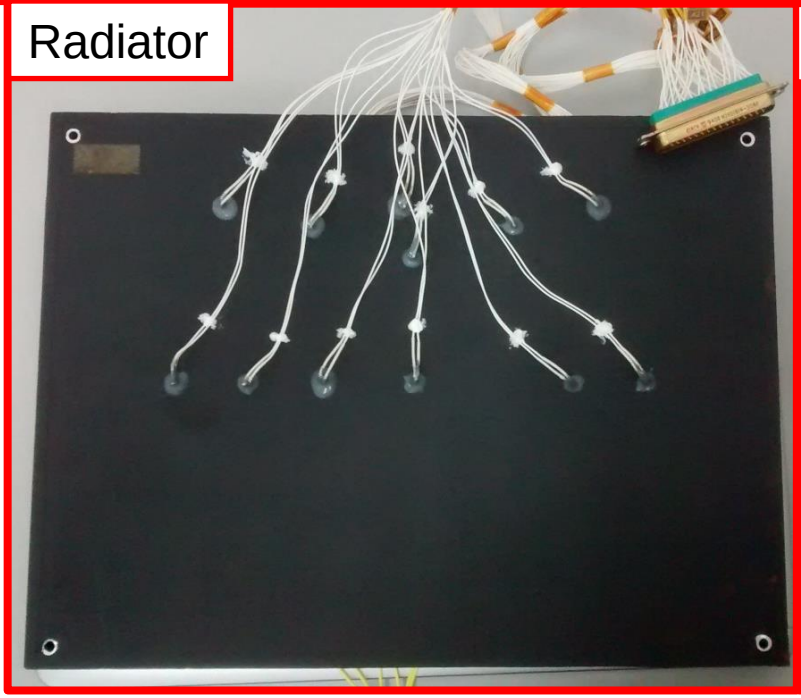
Indium foil



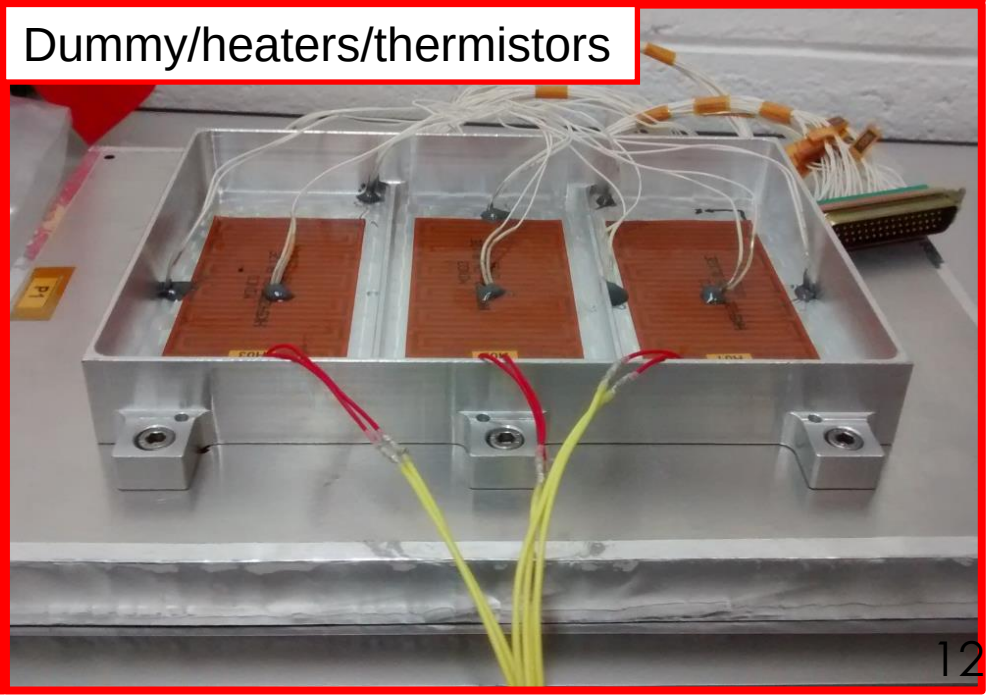
RTV 566



Radiator



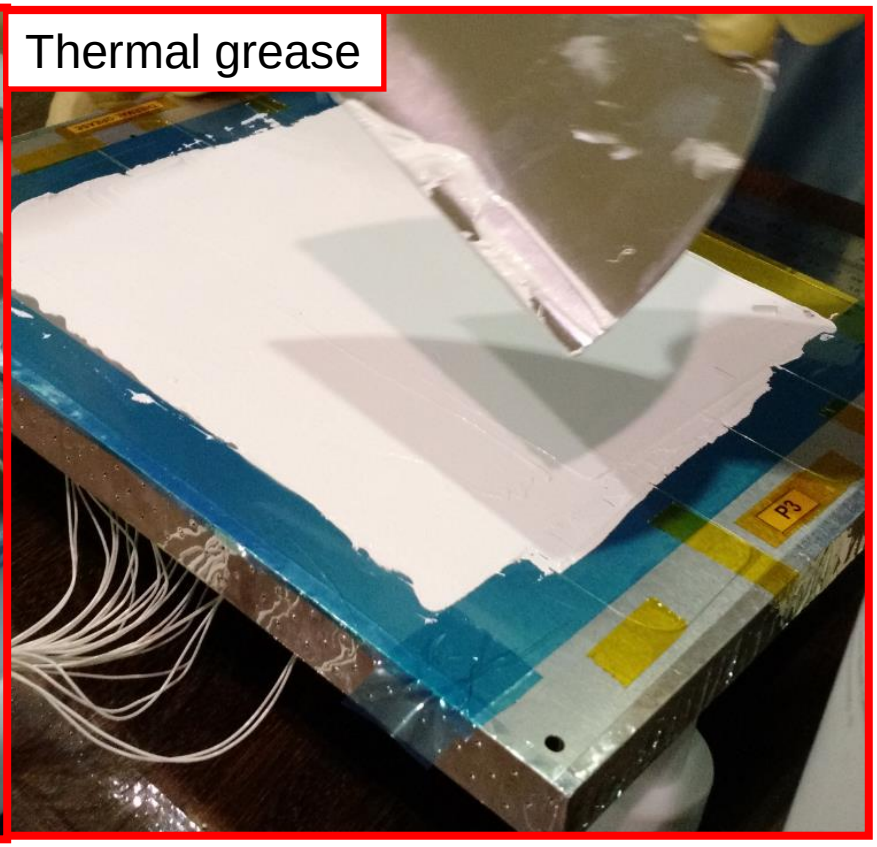
Dummy/heaters/thermistors



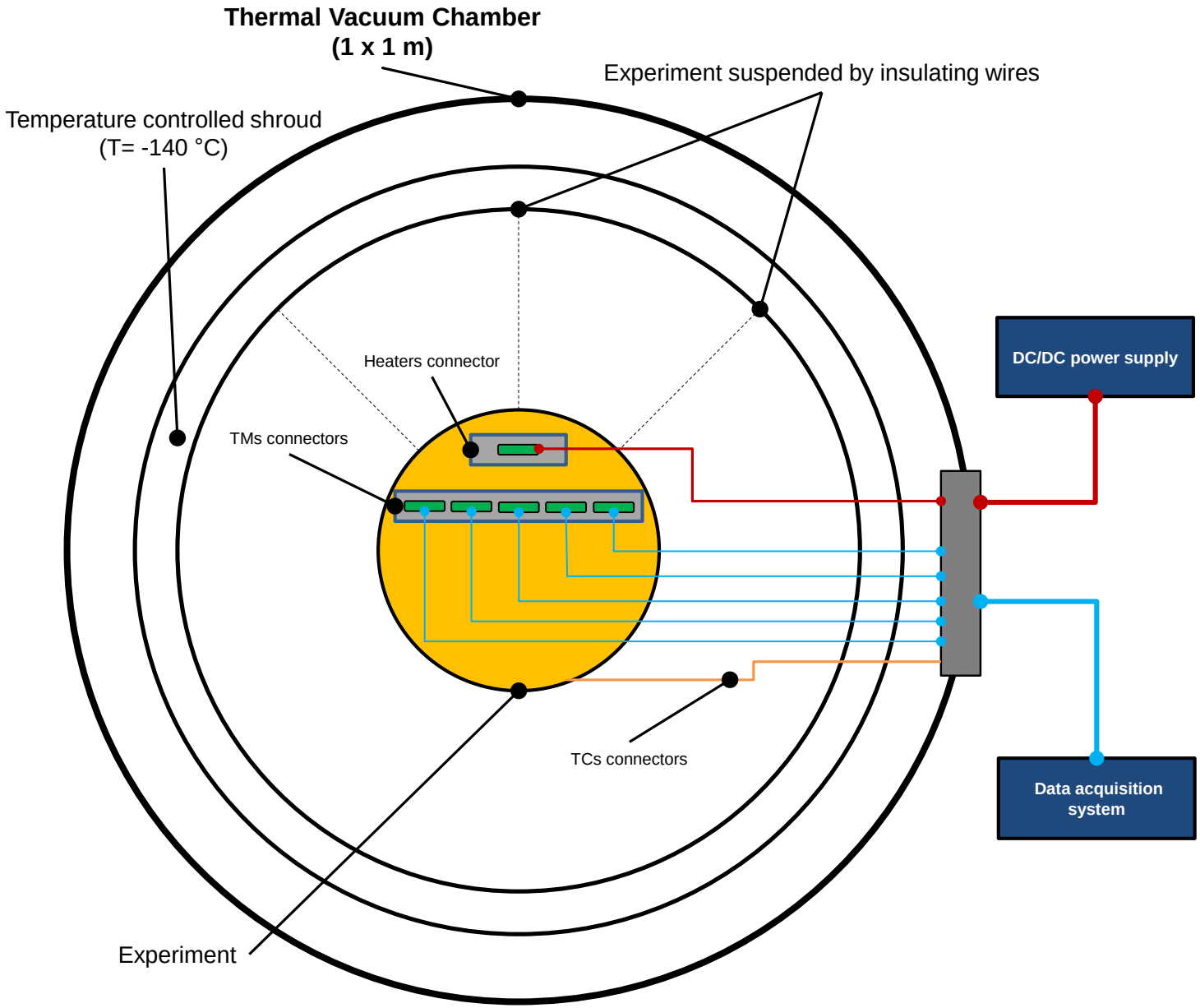
Apparatus photos

eGraf®

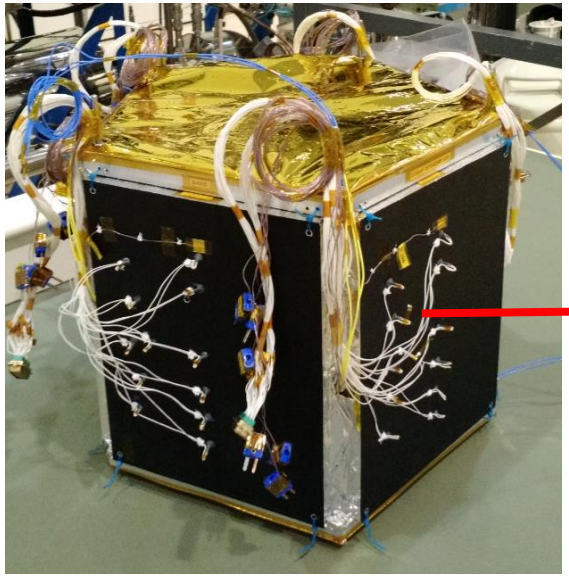
Thermal grease

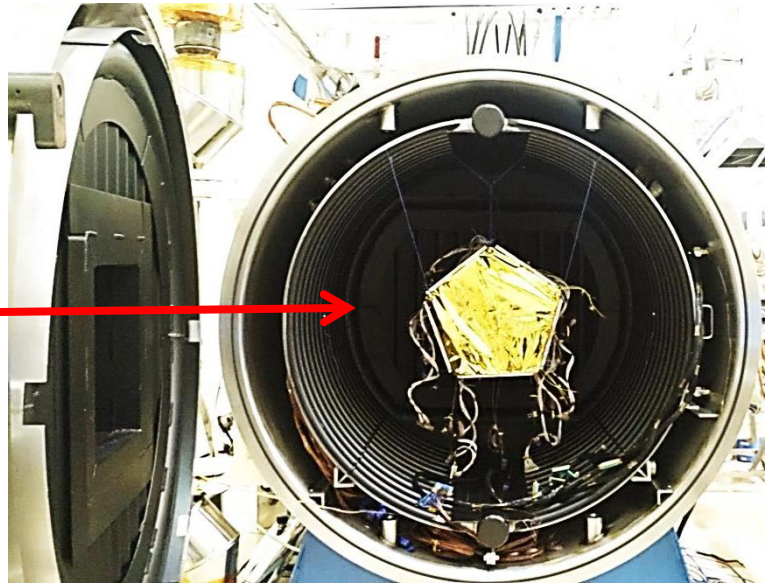


Test configuration scheme



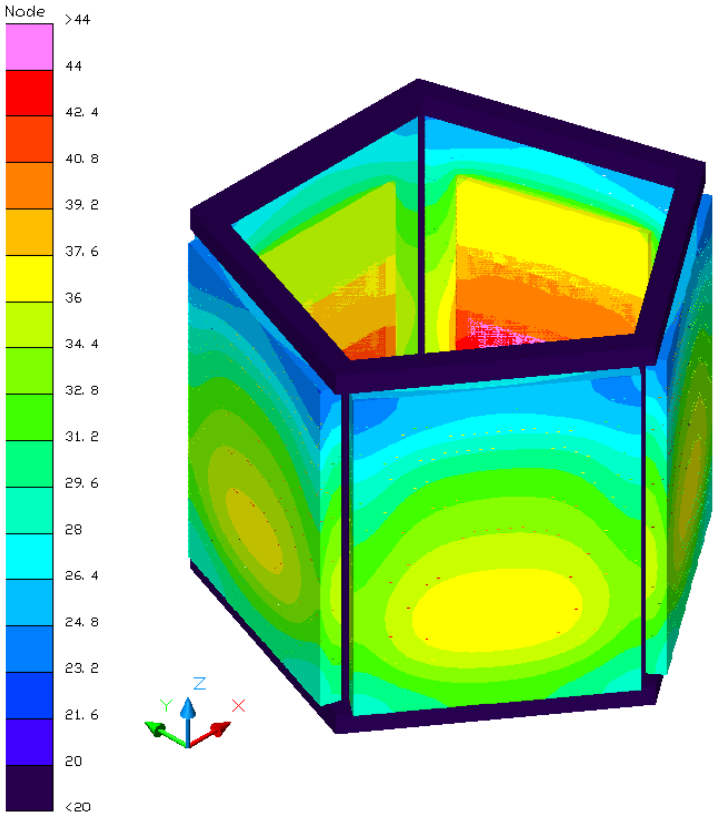
Test configuration photos

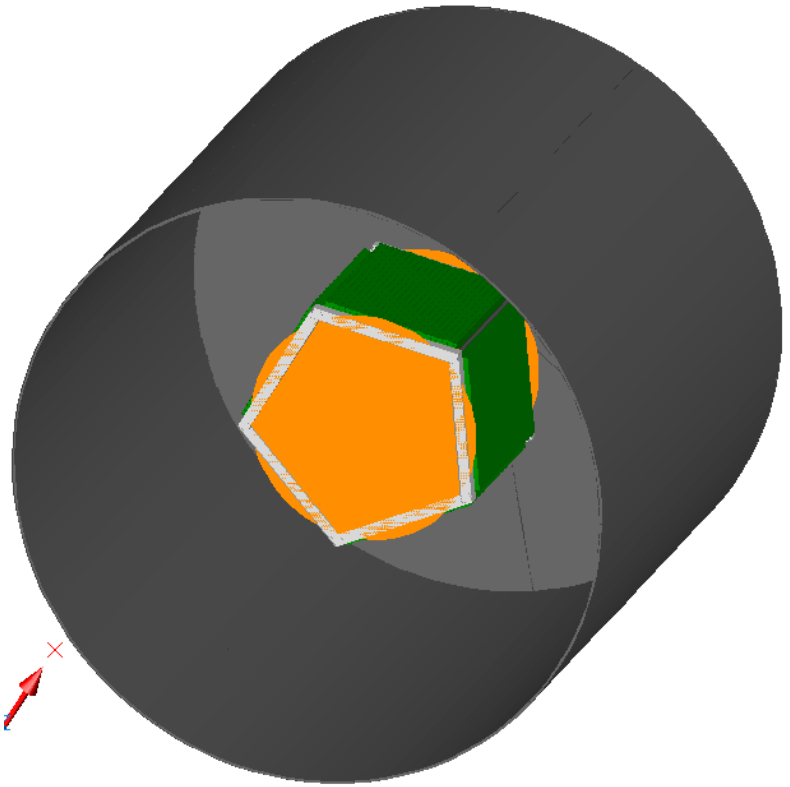




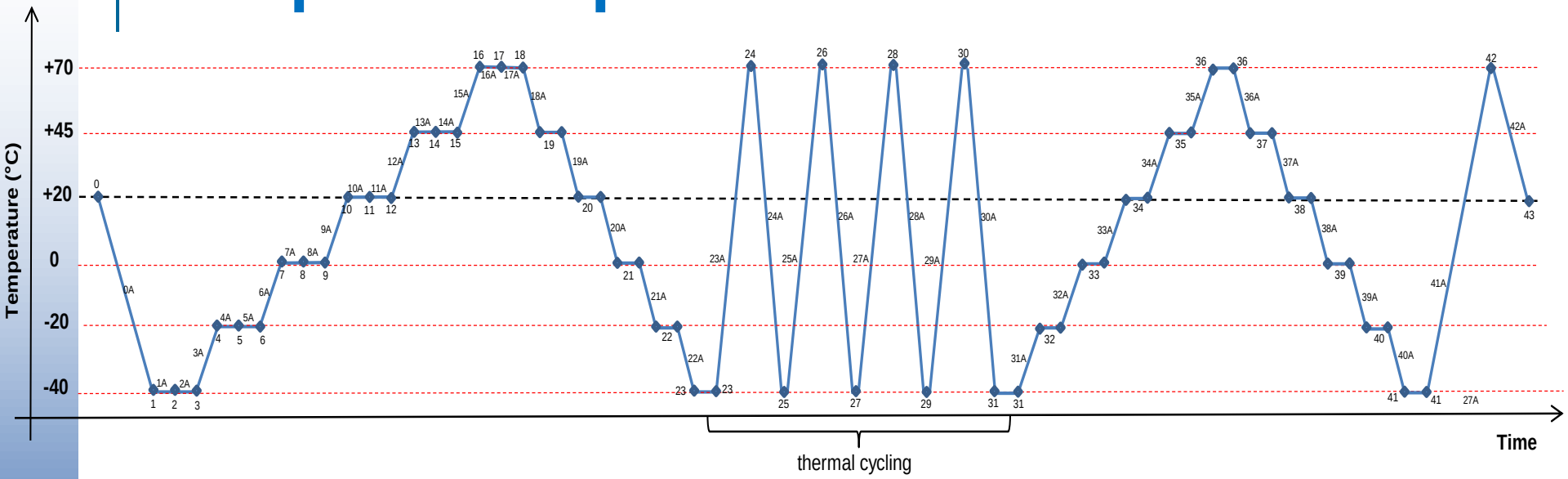
Test planning

- Thermal Desktop® SINDA/FLUINT simplified TMM
- Heaters heat dissipation estimation
  - Target temperature levels: (-40, -20, 0, +20, +45, +70) °C

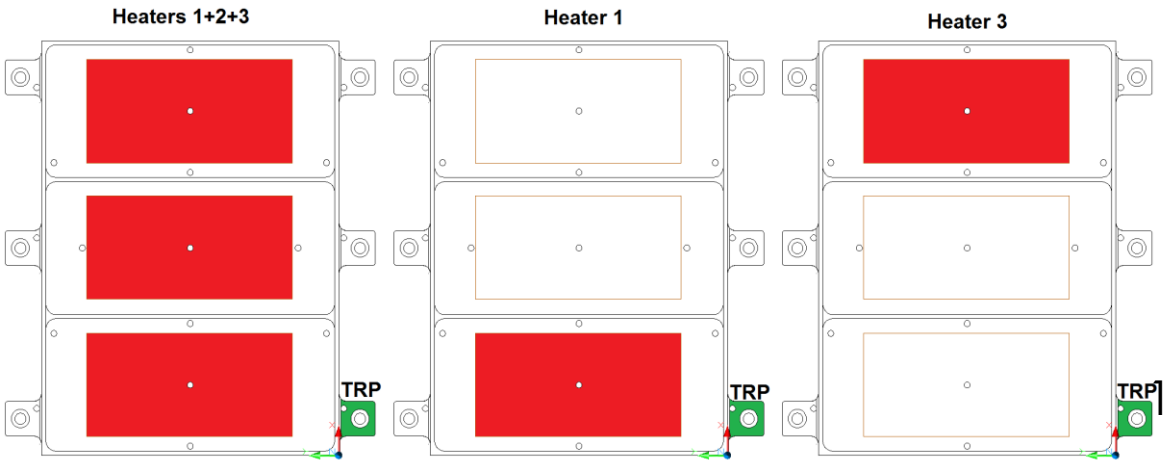




Test phases - plan



- 6 temperature levels: from -40 to + 70 °C
- Electronic equipment qualification levels (20 °C margin)
- 3 dissipation modes
  - Simulates the non-homogeneous heat dissipation (redundancy or operation modes)

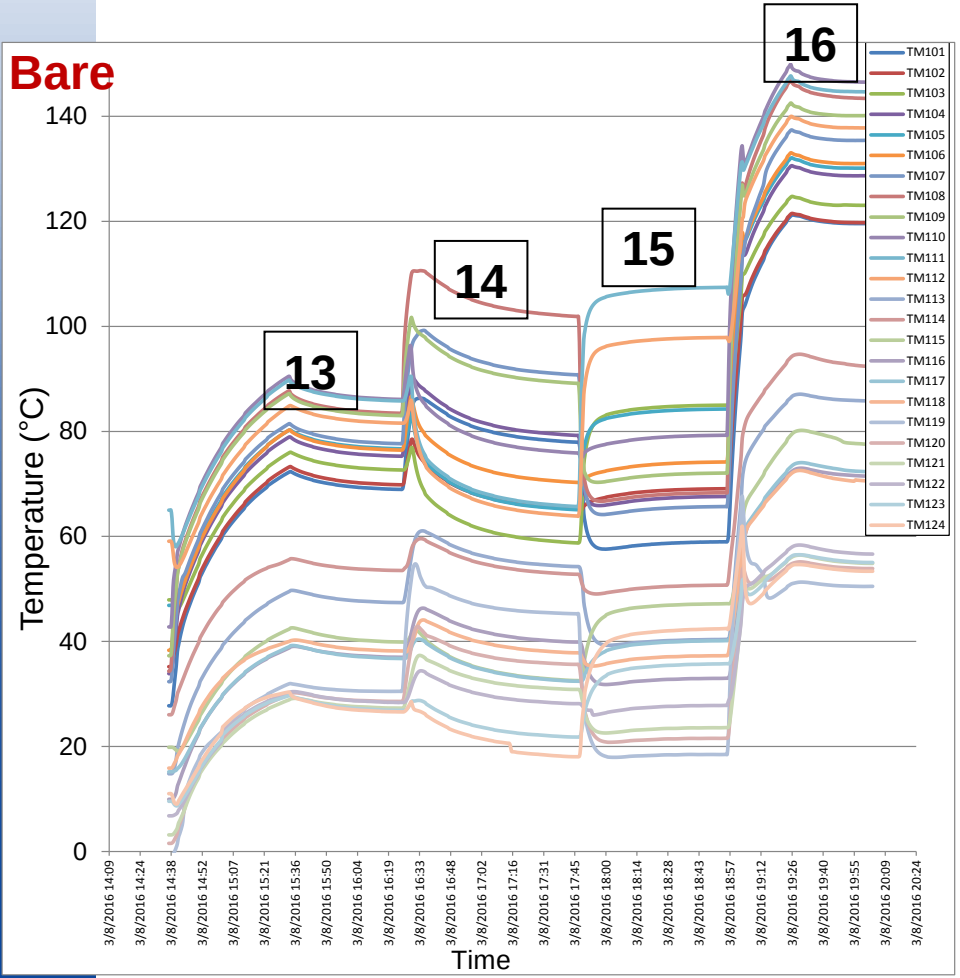


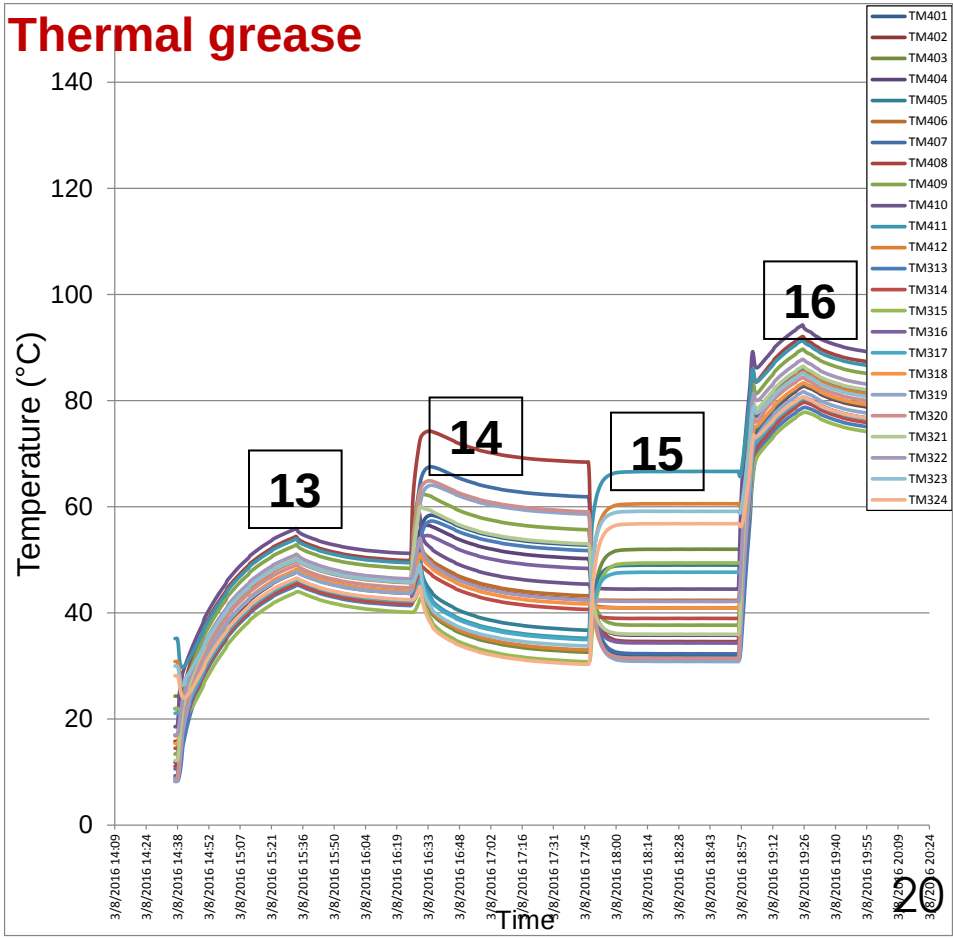
Preliminary test results

Test phases - executed

Bare vs Thermal Grease (vacuum)

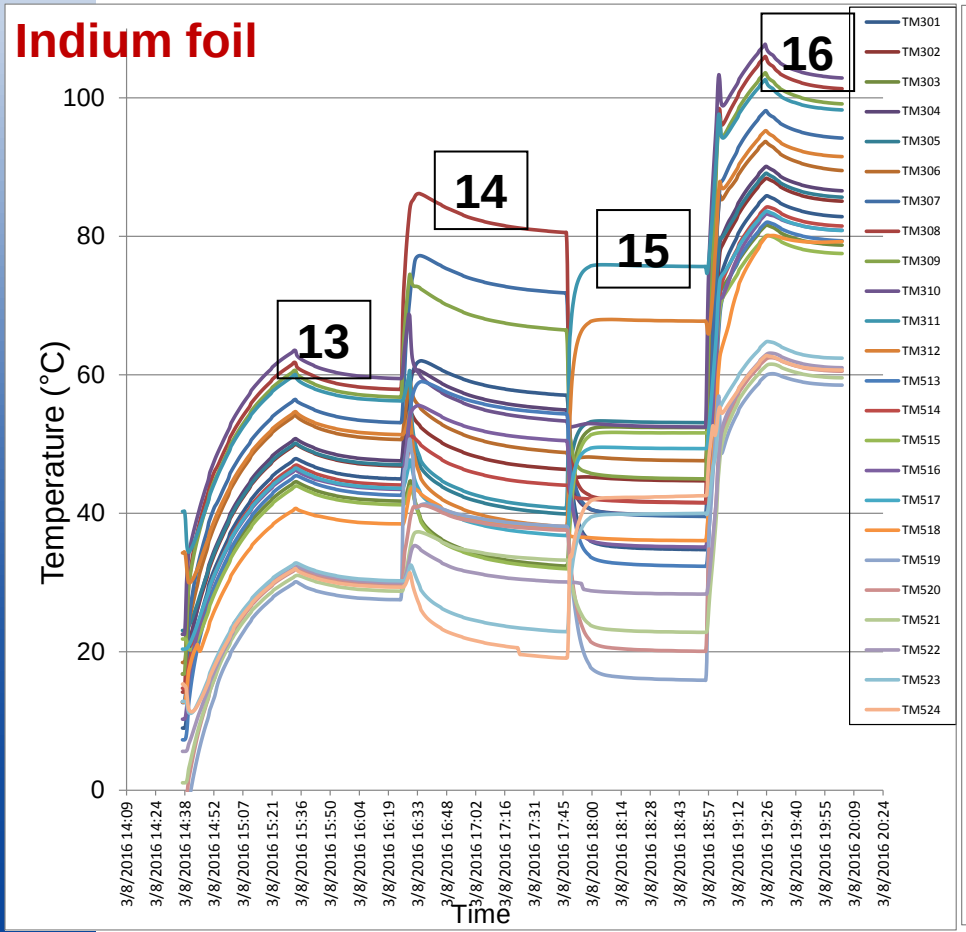
- **Phase 13**: H1+H2+H3 @ 33.3W
- **Phase 14**: H1 @ 33.3W
- **Phase 15**: H3 @ 33.3W
- **Phase 16**: H1+H2+H3 @ 47.8W

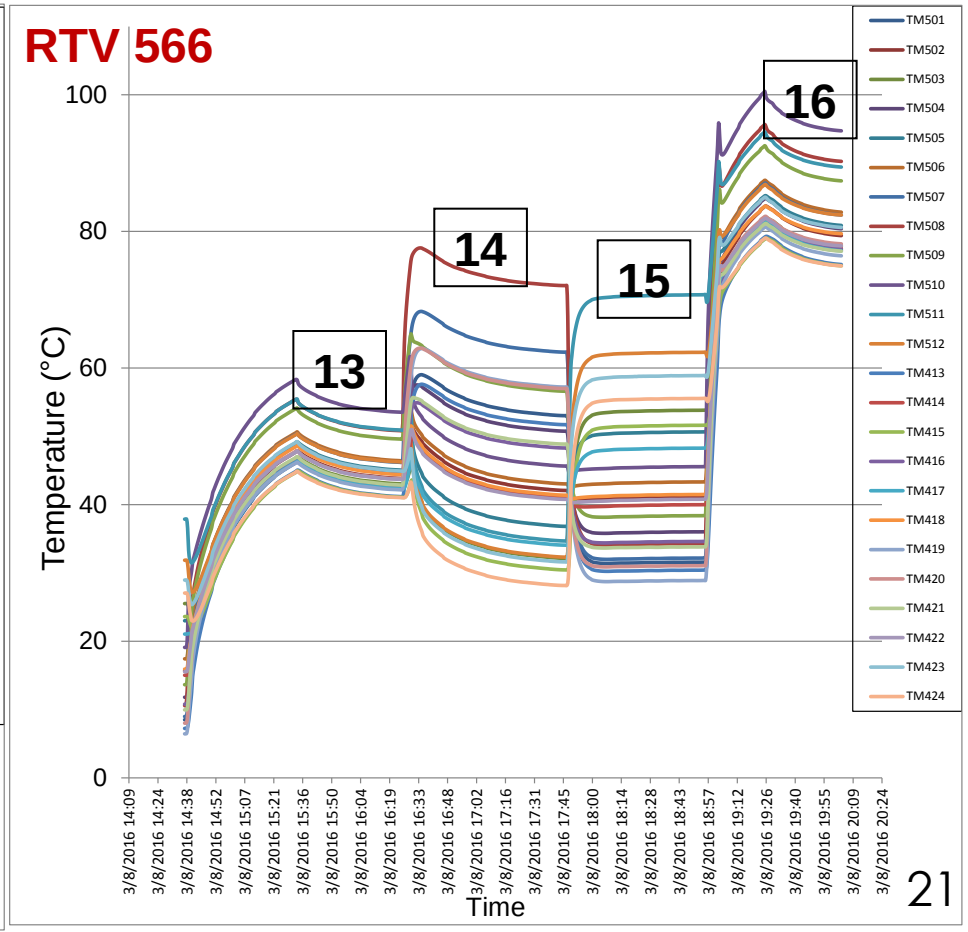




Indium foil vs RTV 566 (vacuum)

- **Phase 13**: H1+H2+H3 @ 33.3W
- **Phase 14**: H1 @ 33.3W
- **Phase 15**: H3 @ 33.3W
- **Phase 16**: H1+H2+H3 @ 47.8W





Vacuum vs P_{atm}

Vacuum

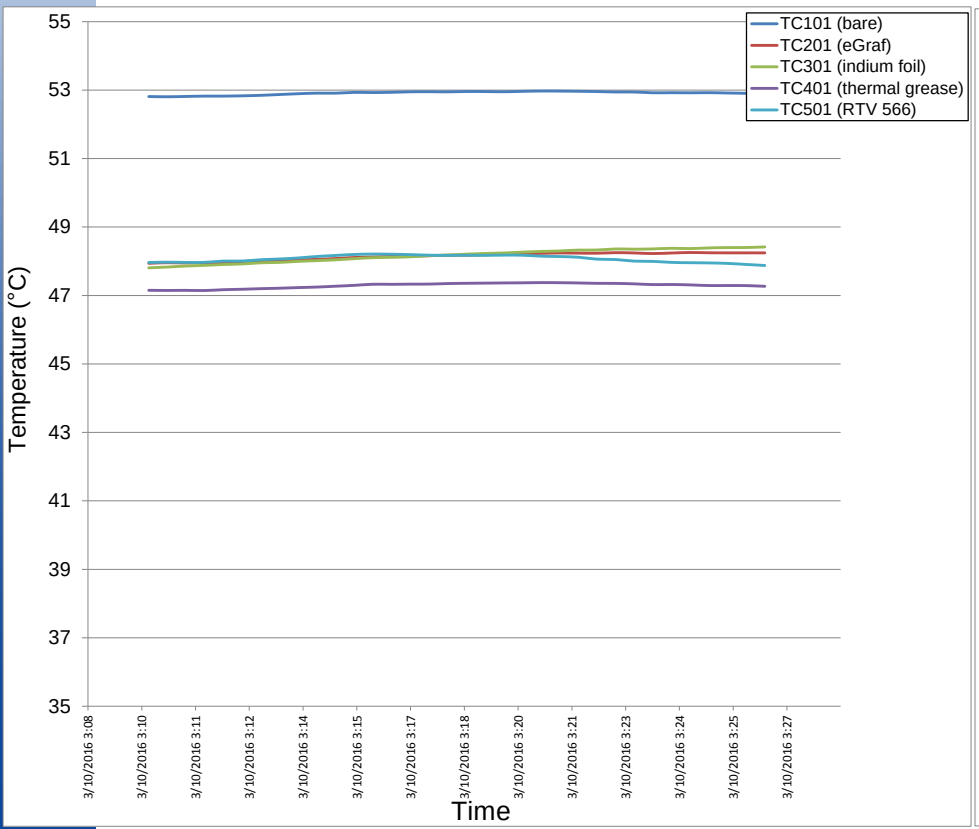
Q= 9.4 W

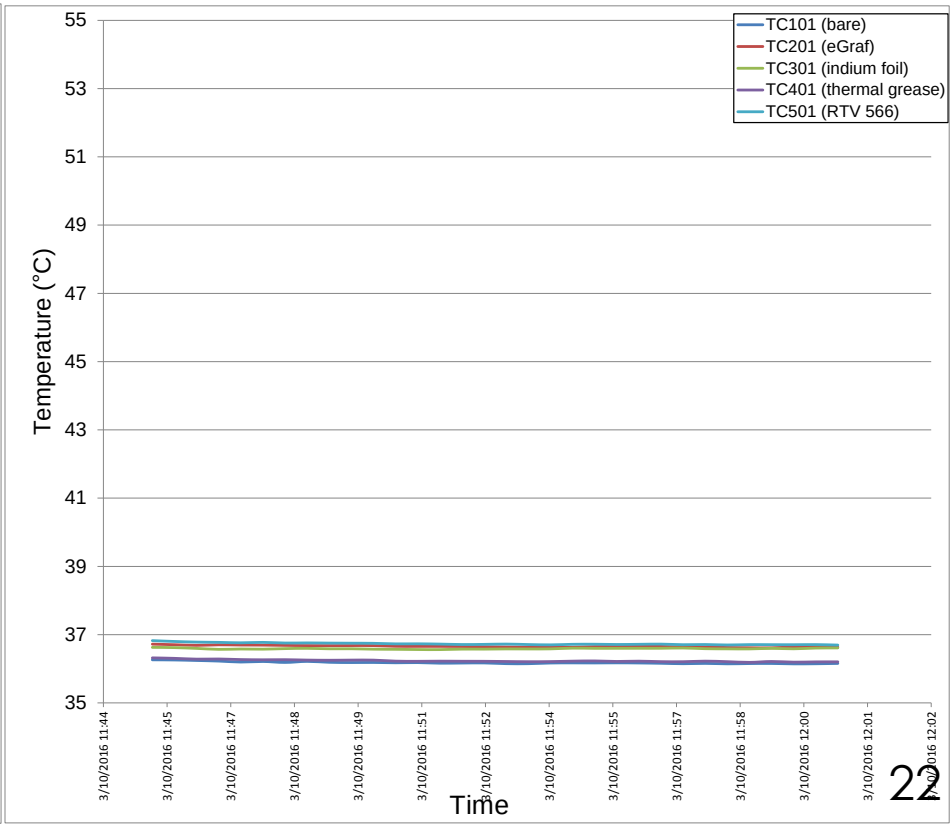
T_{shroud}= 25 °C

P_{atm}

Q= 9.4 W

T_{air}= 22 °C



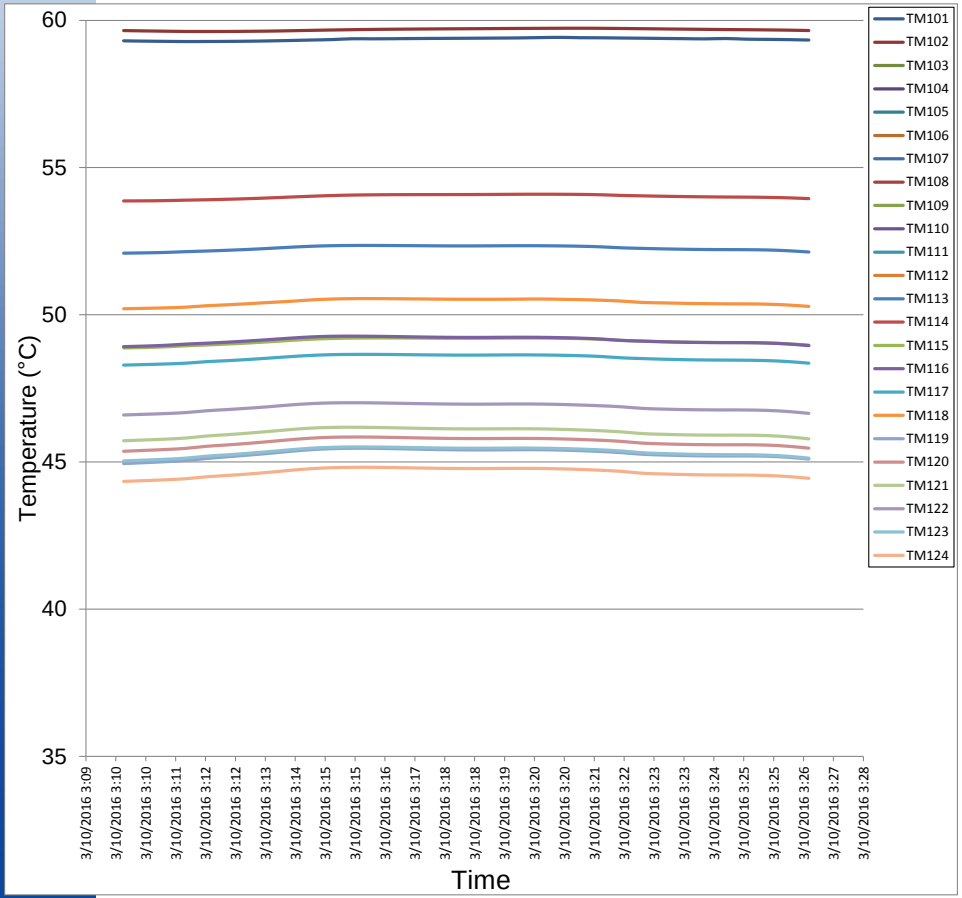


Vacuum vs P_{atm} – bare interface

Vacuum

Q= 9.4 W

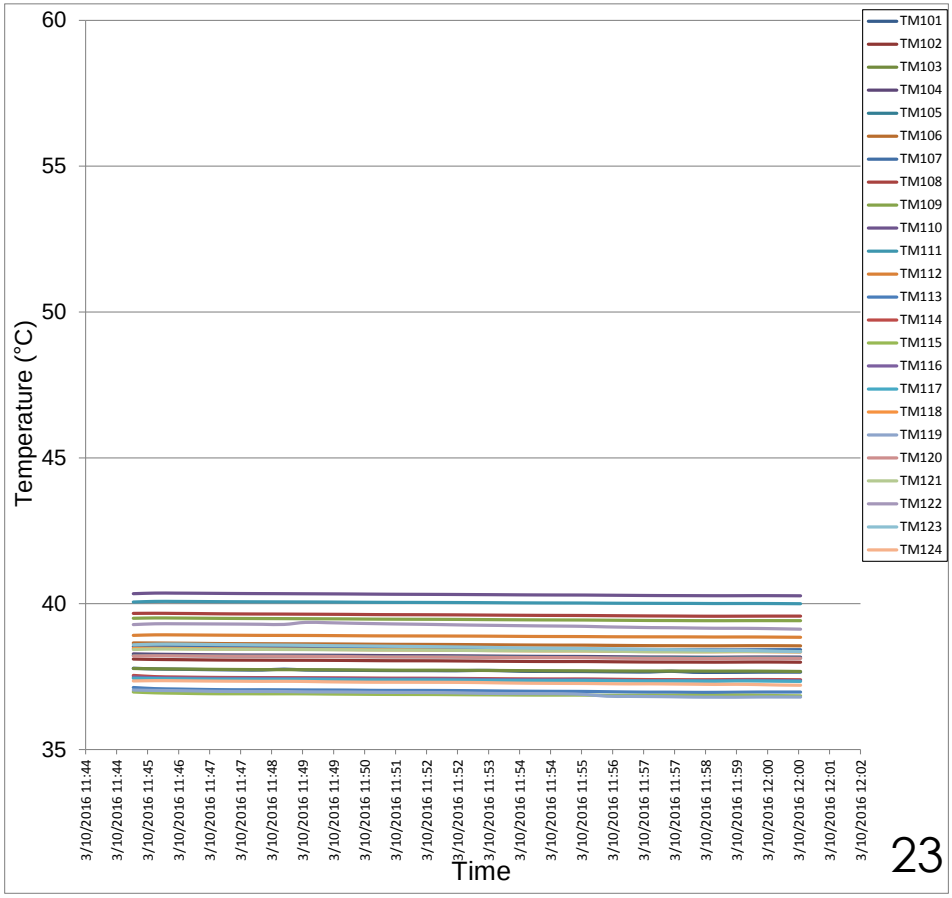
T_{shroud}= 25 °C



P_{atm}

Q= 9.4 W

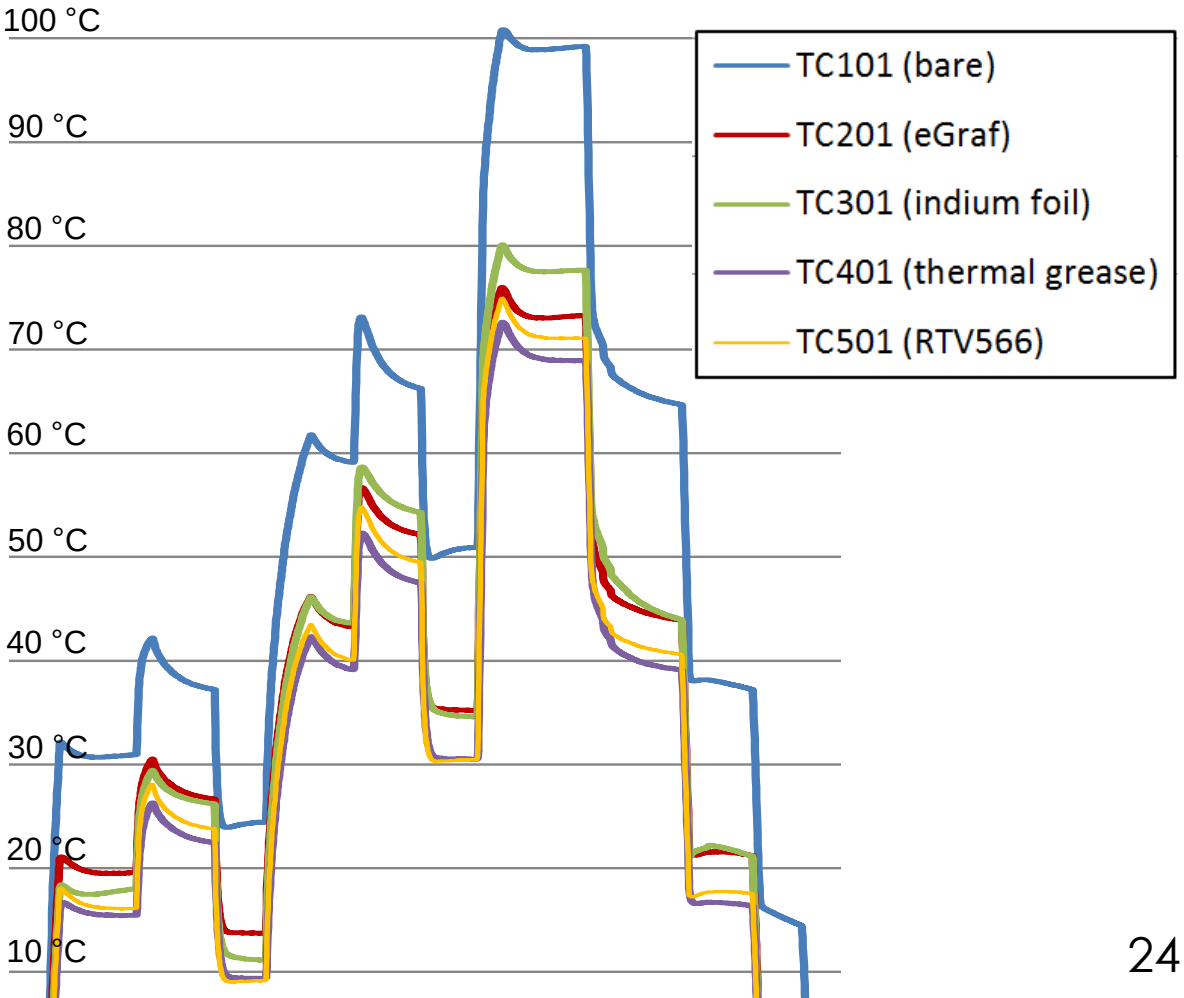
T_{air}= 22 °C



Preliminary rank (in vacuum)

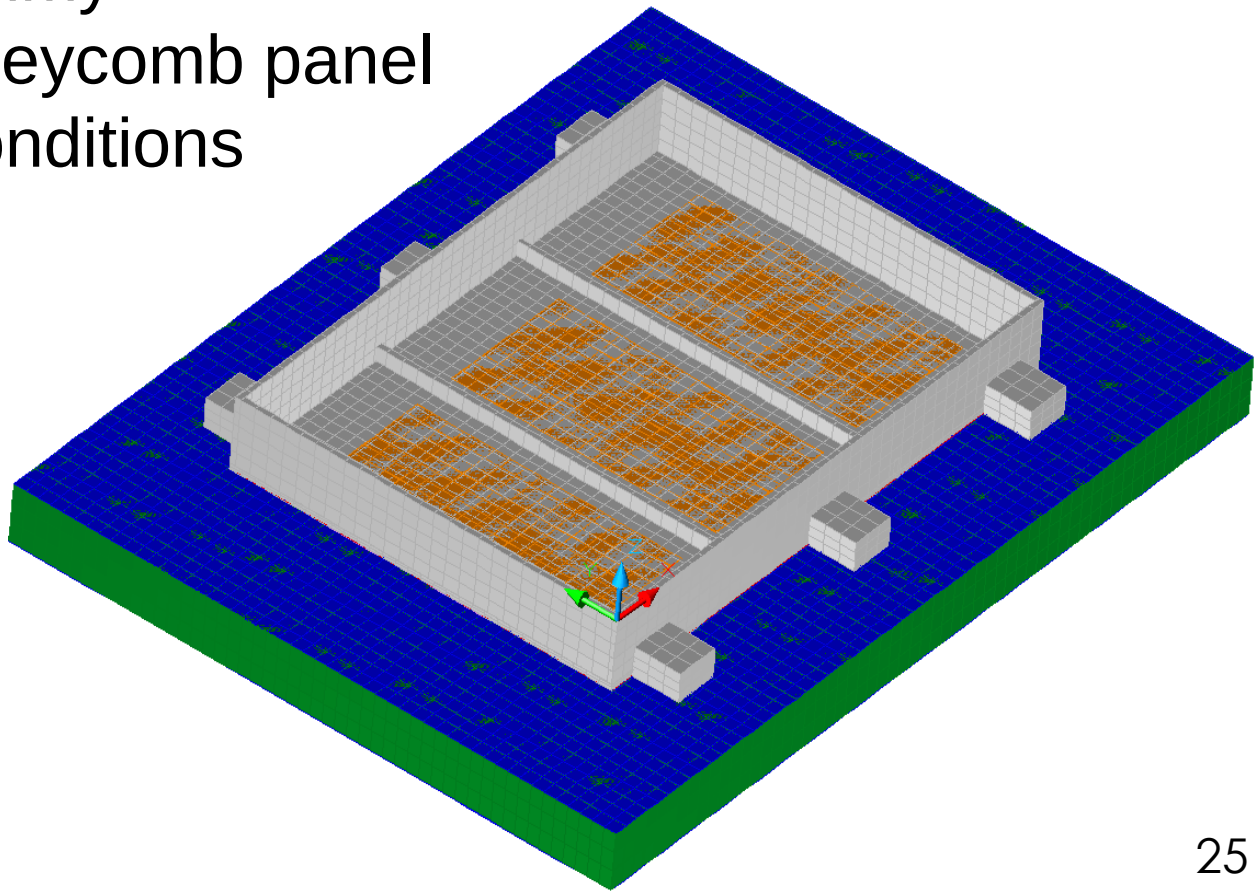
Based on the observation of the test temperatures, it can be indicated the following order of thermal performance:

1. Thermal grease
2. RTV 566
3. Indium foil
4. eGraf
5. Bare



Future work – detailed TMM

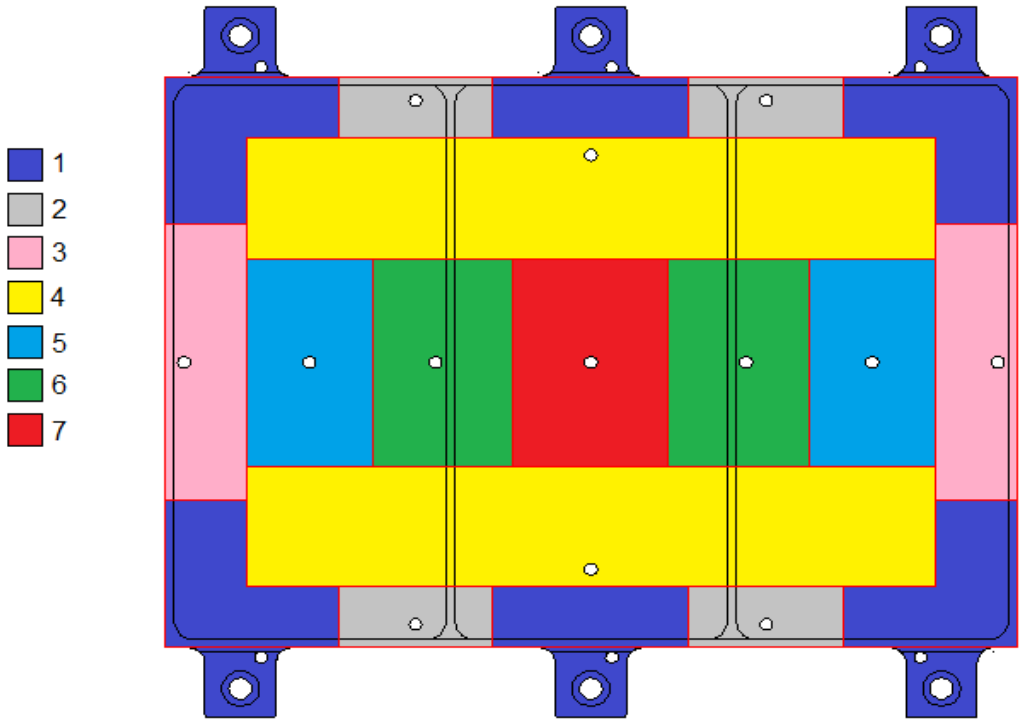
- Use the Thermal Desktop® SINDA/FLUINT detailed TMM
  - detailed dummy
  - detailed honeycomb panel
  - boundary conditions



Future work – detailed TMM

- Baseplate divided into 7 regions
- Each reagion has a couple of corresponded temperature sensors
- Identification of effective thermal conductance for each reagion – different contact pressure

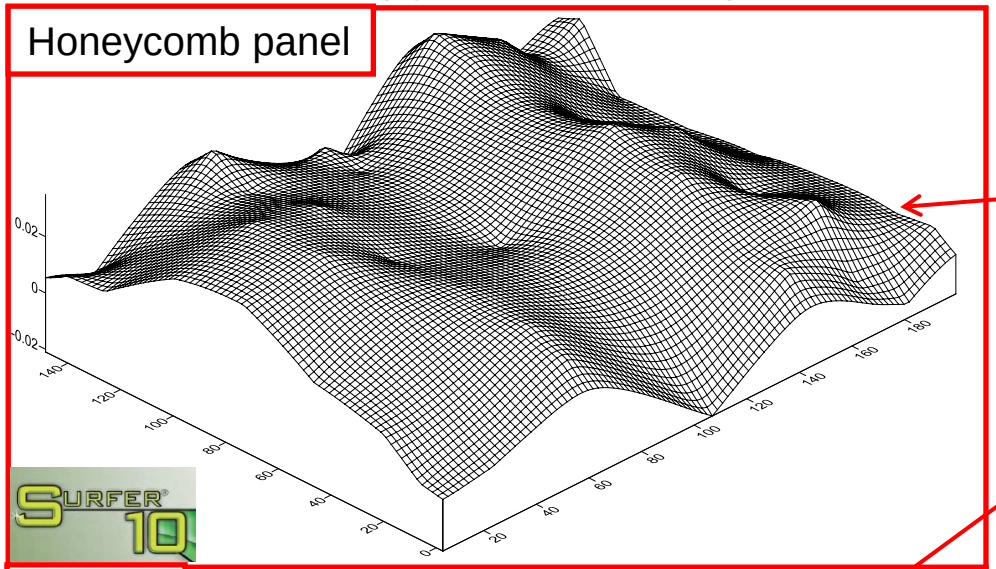
Proposed regions



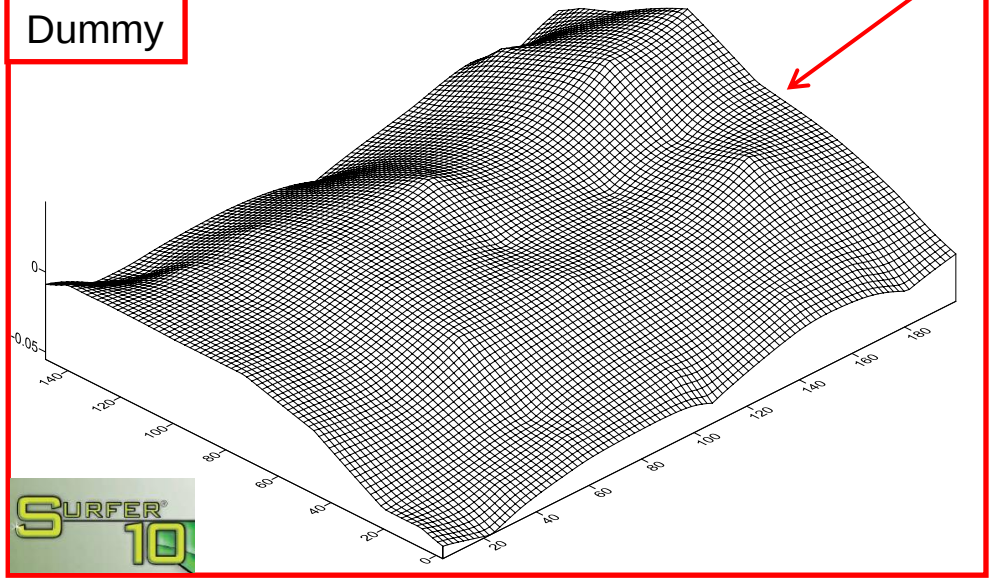
Influence of flatness/roughness

- All surfaces comply with flatness requirements

Honeycomb panel



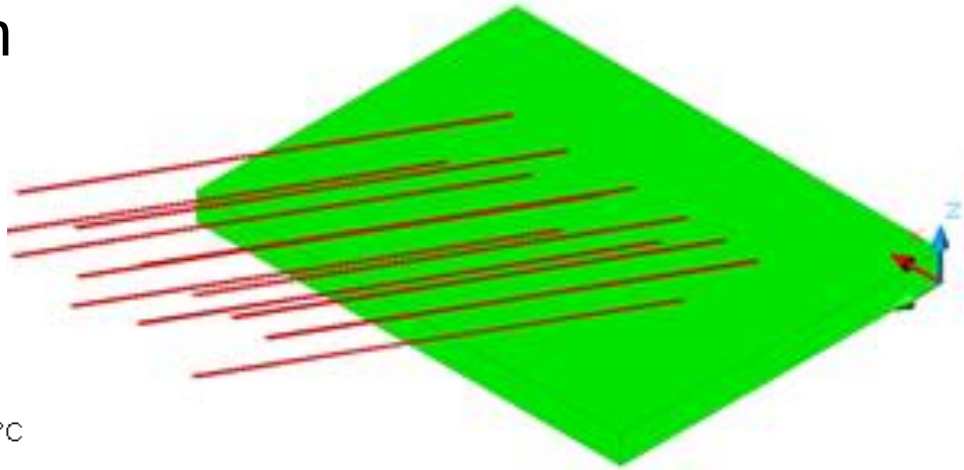
Dummy

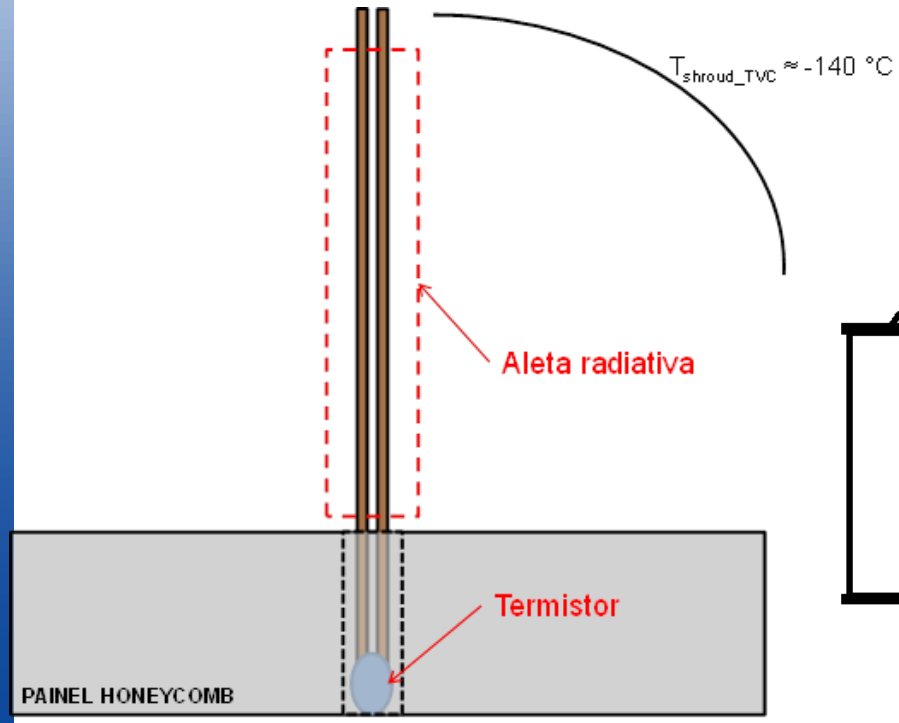


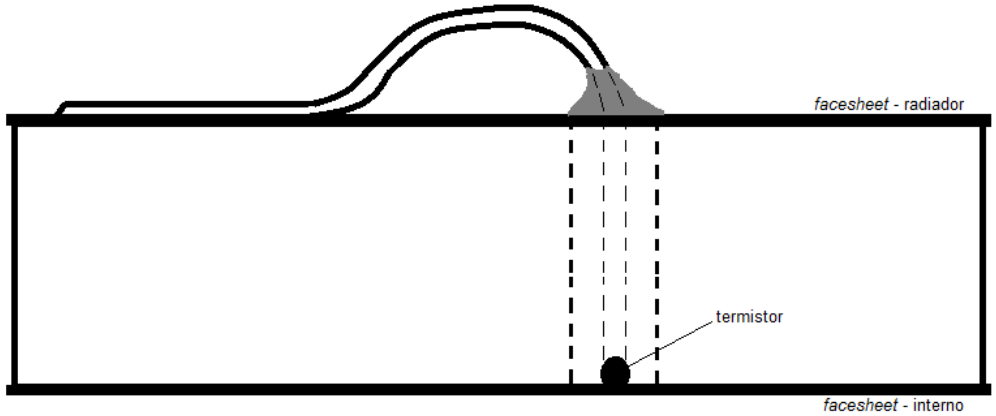
Surface roughness

Study about thermistor wires influence

- Wires act like radiation fin
- Radiator blockage (~5%)







Conclusions

- A **unique test setup** has been developed to simulate the interface between satellite electronic equipments and honeycomb panels;
- The test demonstrated that any of the tested materials has a better performance than the bare interface;
- As a preliminary conclusion, the **thermal grease** performed better than the others;
- There are a lot of data to be analysed from the first test;
- It is planned to use the apparatus to test **different instalation methods** for thermal grease and RTV 566 and other materials.