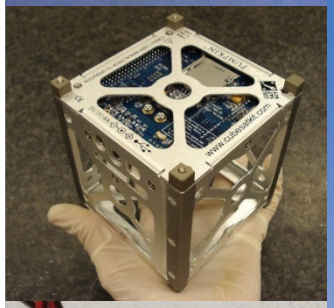
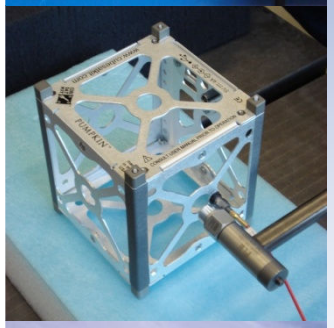




OUFTI - 1

Integration of batteries within OUFTI-1: Design, analysis, and validation

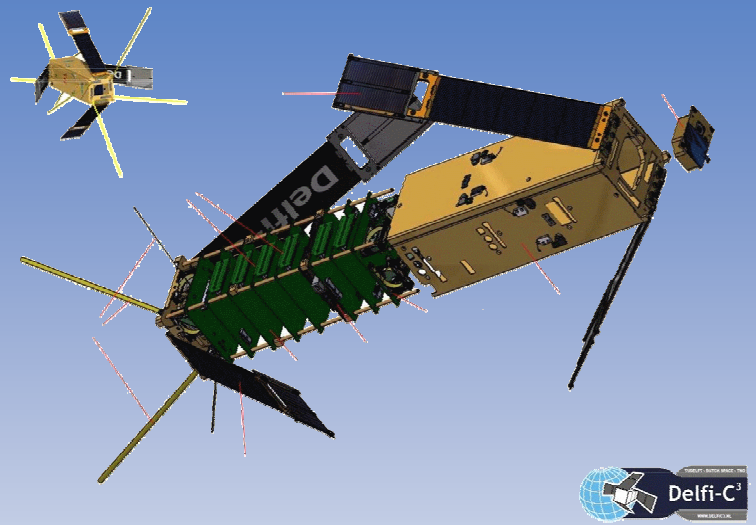
CalPoly, San Luis Obispo,
April 23, 2010

Noël Jean-Philippe

Université de Liège

Integration of batteries within a CubeSat

- Delfi-C3



- Integrate and “acclimate” COTS batteries

- Space environment issues : - temperature
  - vacuum

  CubeSat standard issues : - limited dimensions and mass

The thermal environment = 1st issue

- Batteries' temperature above 0° C

	Cut-off Voltage	2.7 V
Cycle Life		> 500 Cycles
Operating Temp.	Charge	0 ~ 40℃
	Discharge	-20 ~ 60 ℃
Dimension	Thickness (mm)	6.5 ± 0.2
	Width (mm)	37.5 ± 0.5

KOKAM SLP-603870H

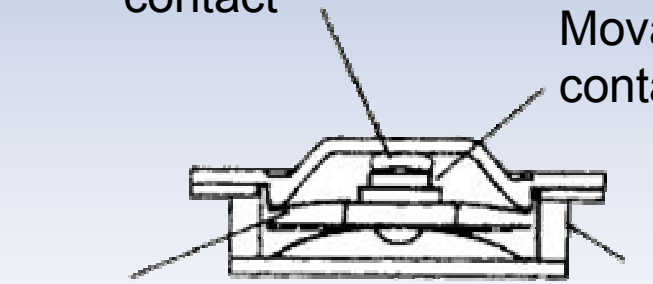
- Heat generation within the satellite
- Heaters controlled by mechanical thermostats

- Four questions : Which thermostats ?
  Which thermostats' arrangement ?
  Which heaters ?
  Which supply ?

Which thermostats ?

- **Klixon® 4BT Series:**
  - mass : 0.2 gram
  - dimensions : (mm) 6.7(radius) x 2(thickness)
  - space qualified
  - electrical contact realised thanks to a bi-metal
  - open-on-rise model
  - differential : 16.7°C
  - operational temperature : 23.9°C
  - cost : $ 350

Klixon® 4BT Series



Cross-section view

Klixon 4BT Series: Advantages

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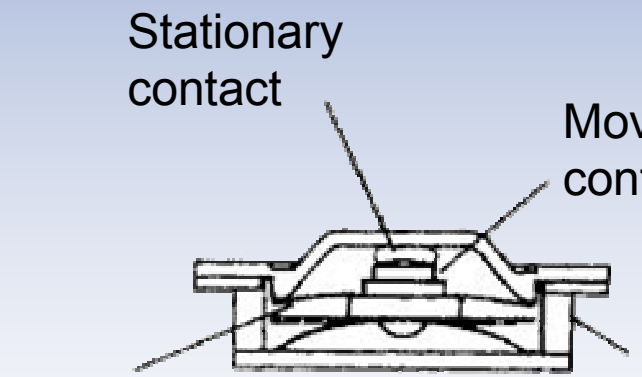
Klixon® 4BT Series



Cross-section view

Université de Liège

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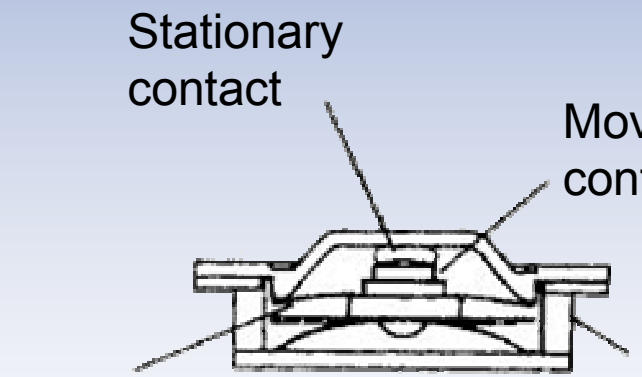

Cross-section view

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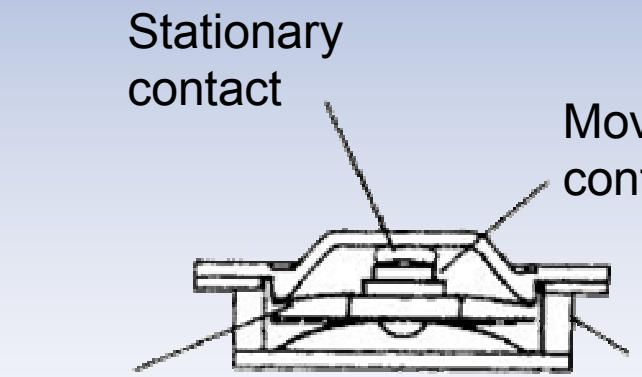


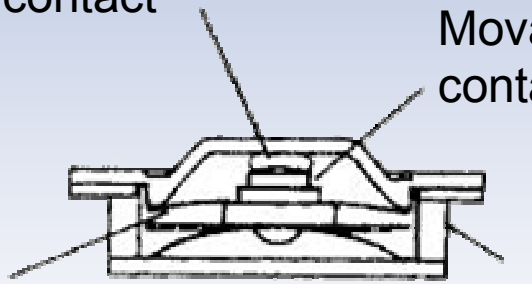
Cross-section view

Université de Liège

Klixon 4BT Series: Drawback

- **Klixon® 4BT Series:**
  - mass : 0.2 gram
  - dimensions : (mm) 6.7(radius) x 2(thickness)
  - space qualified
  - electrical contact realised thanks to a bi-metal
  - open-on-rise model
  - differential : 16.7°C
  - operational temperature : 23.9°C detrimental !
  - cost : $ 350

Klixon® 4BT Series



Cross-section view

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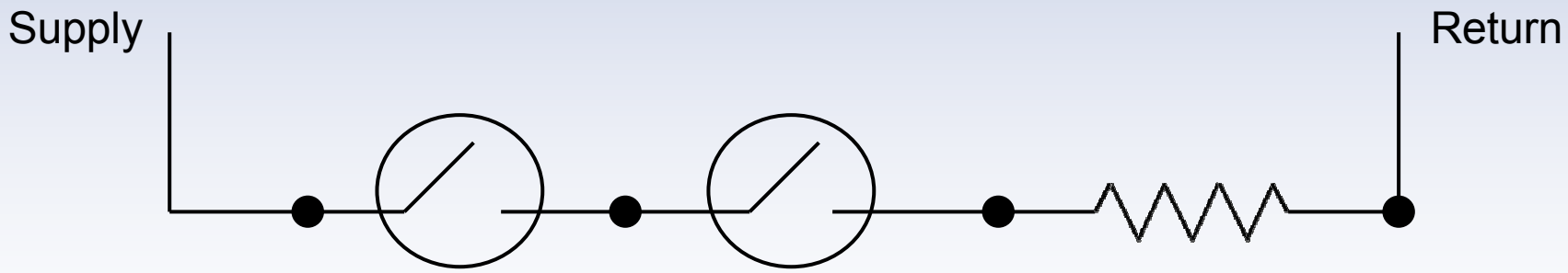
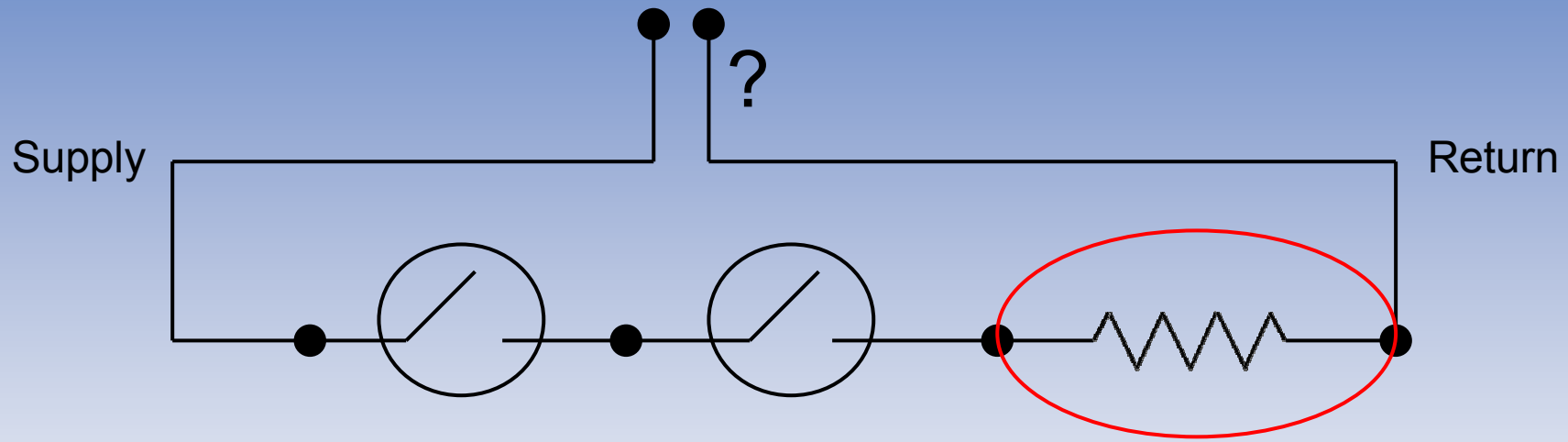
Which thermostats' arrangement ?

- Ideally, a "quad-redundant" arrangement
- Eventually, a two thermostats-configuration (price, available space, mass)
- Two batteries, two thermostats per battery

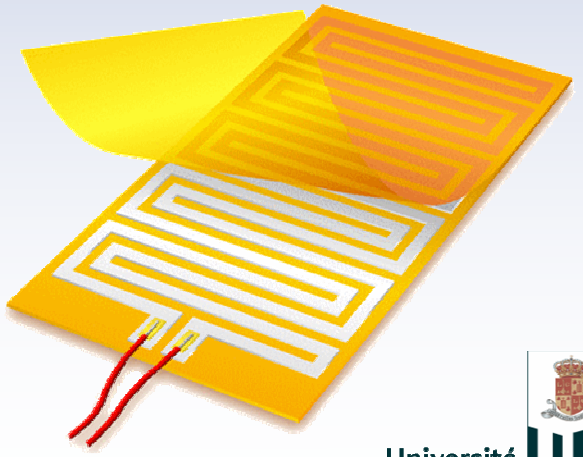


Which heaters ?

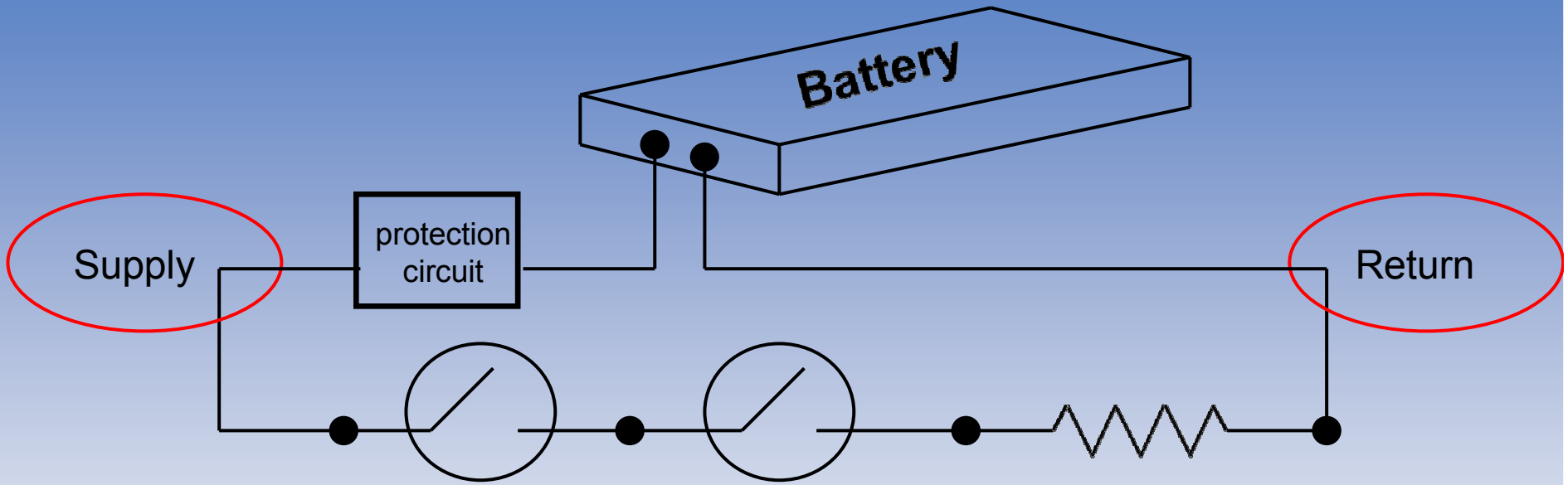


- Resistances (patch model) :

  0.5 W thanks to Joule's effect



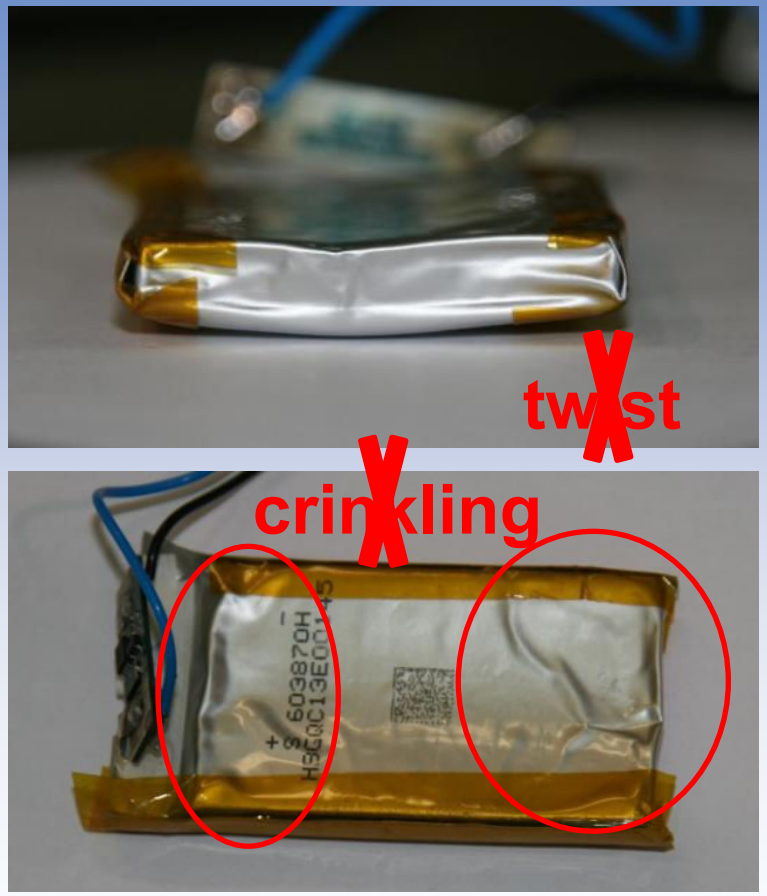
Which supply ?



- Direct supply from the battery to be reheated itself
- Empty and cold battery ?

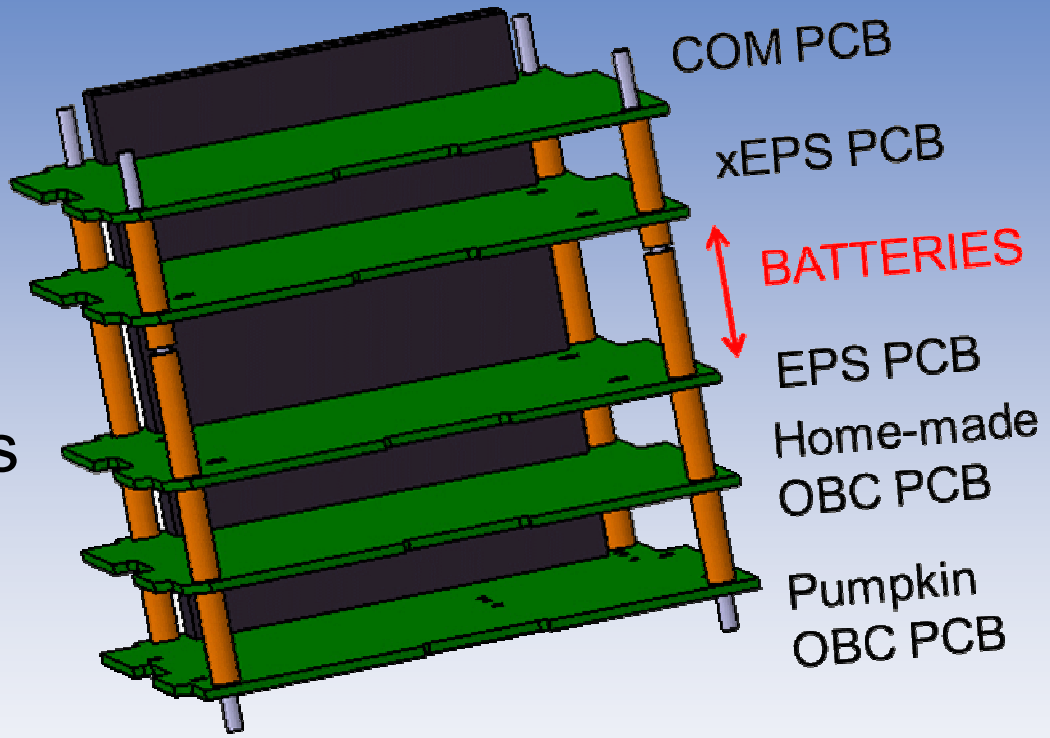
Battery support: imposed constraints

1. **Under vacuum-deformations = 2nd issue**
2. Space
3. Integration of heaters and thermostats



Battery support: imposed constraints

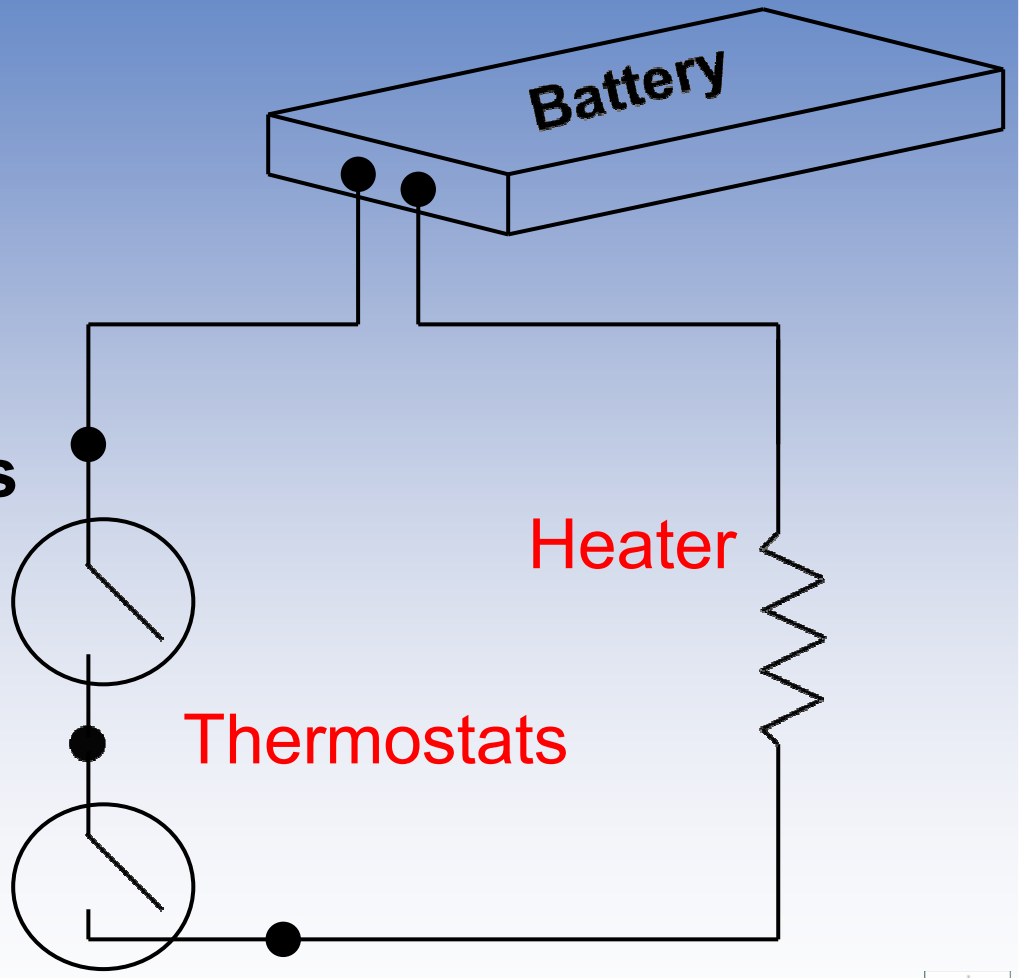
1. Under vacuum-deformations
2. **Space = 3rd issue**
3. Integration of heaters and thermostats



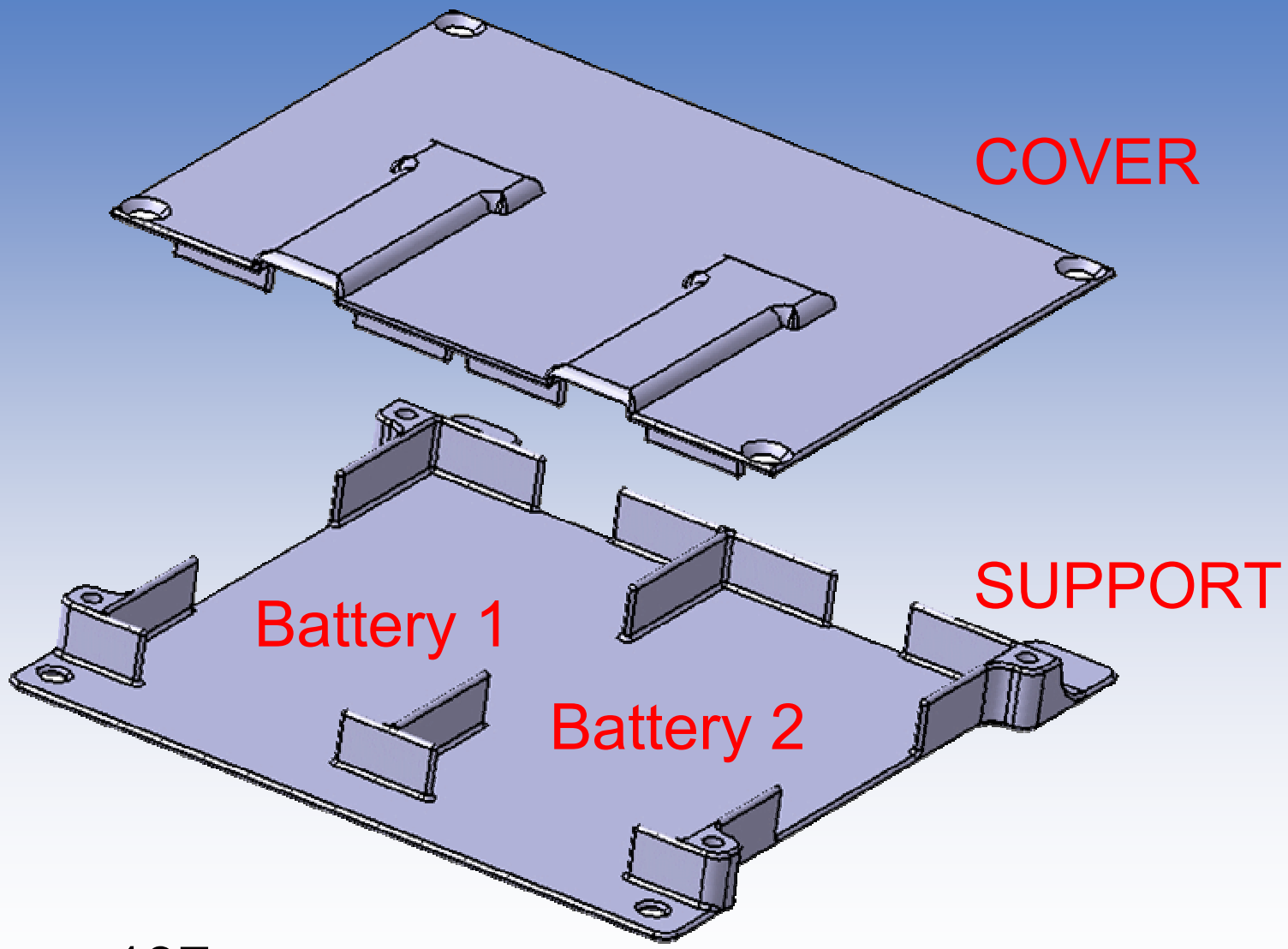
Internal configuration of OUFTI-1

Battery support: imposed constraints

1. Under vacuum-deformations
2. Space
3. **Integration of heaters and thermostats**



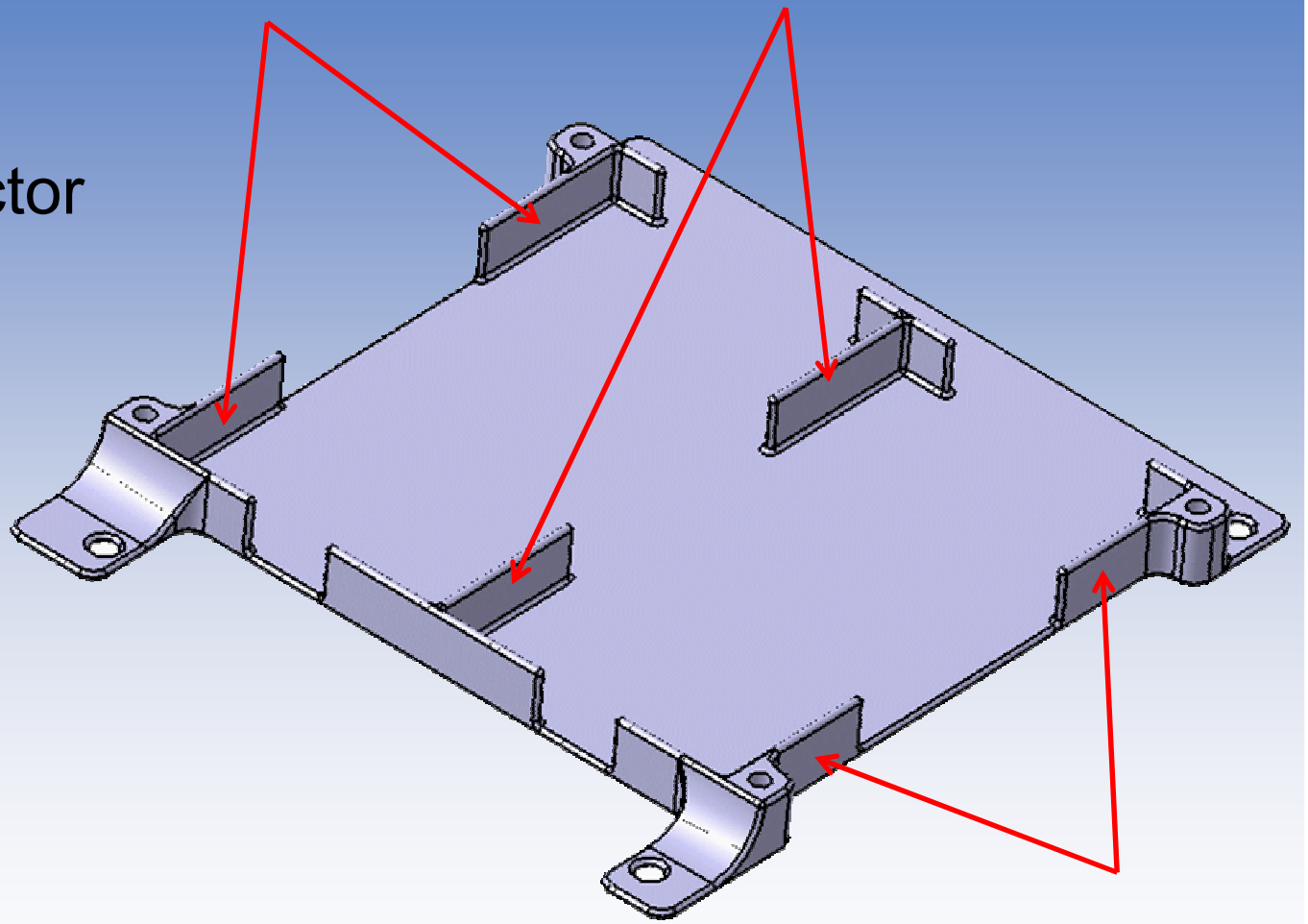
Resulting design



Total mass = 197 grams

Design features

- Reinforcers
- PC/104 connector
- Cover
- Integration
- Aluminium



Design features

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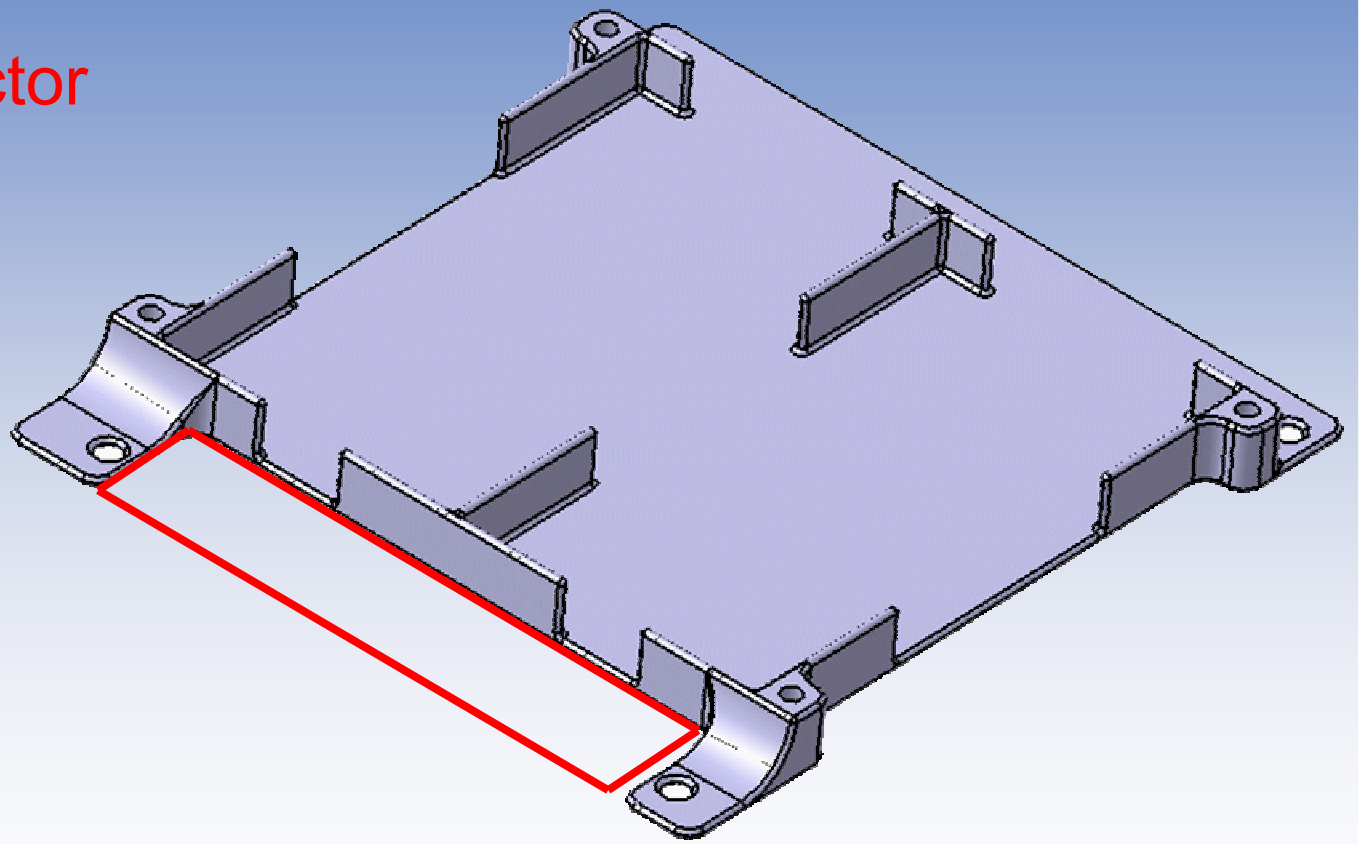

Design features

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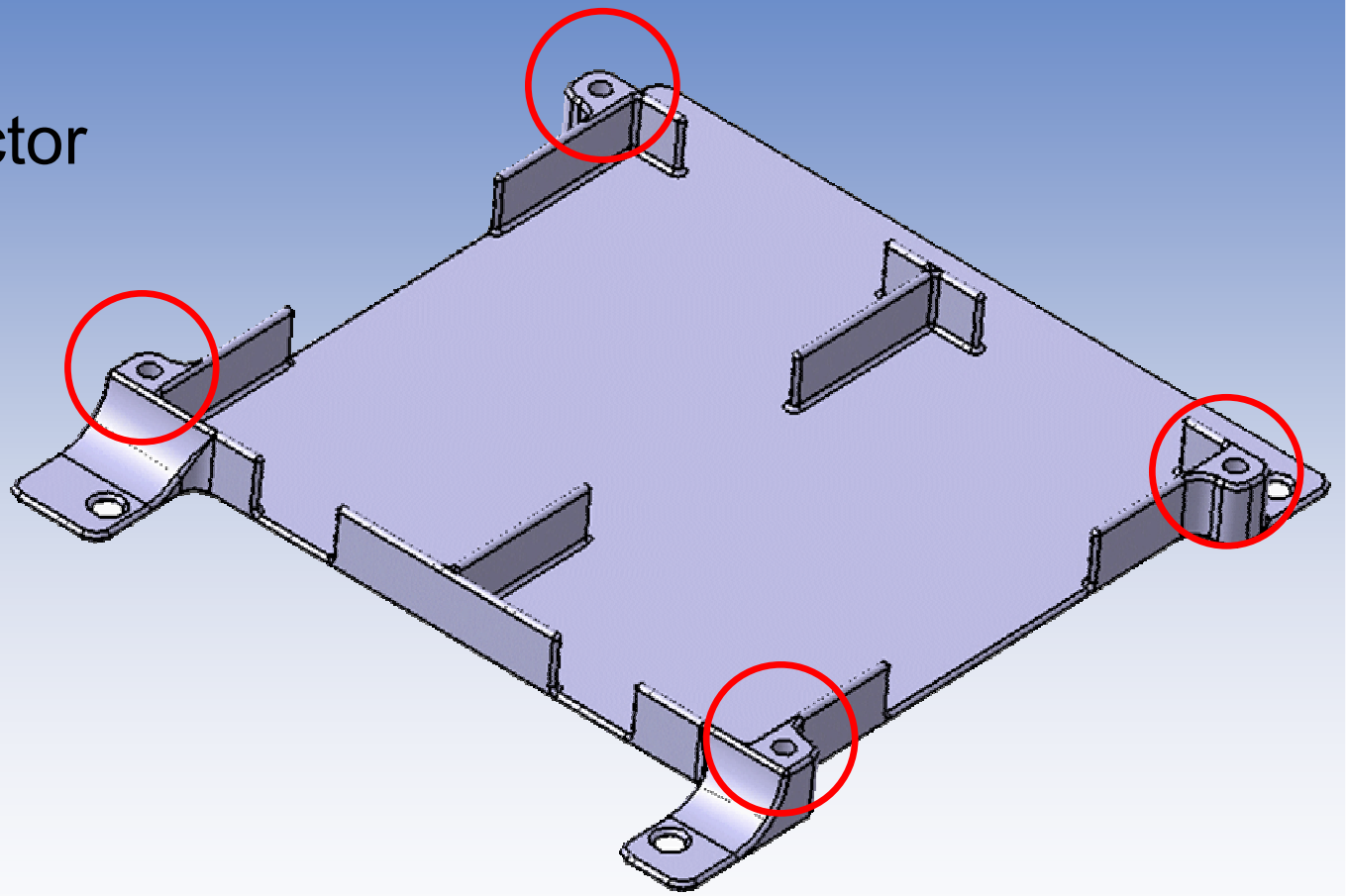

Design features

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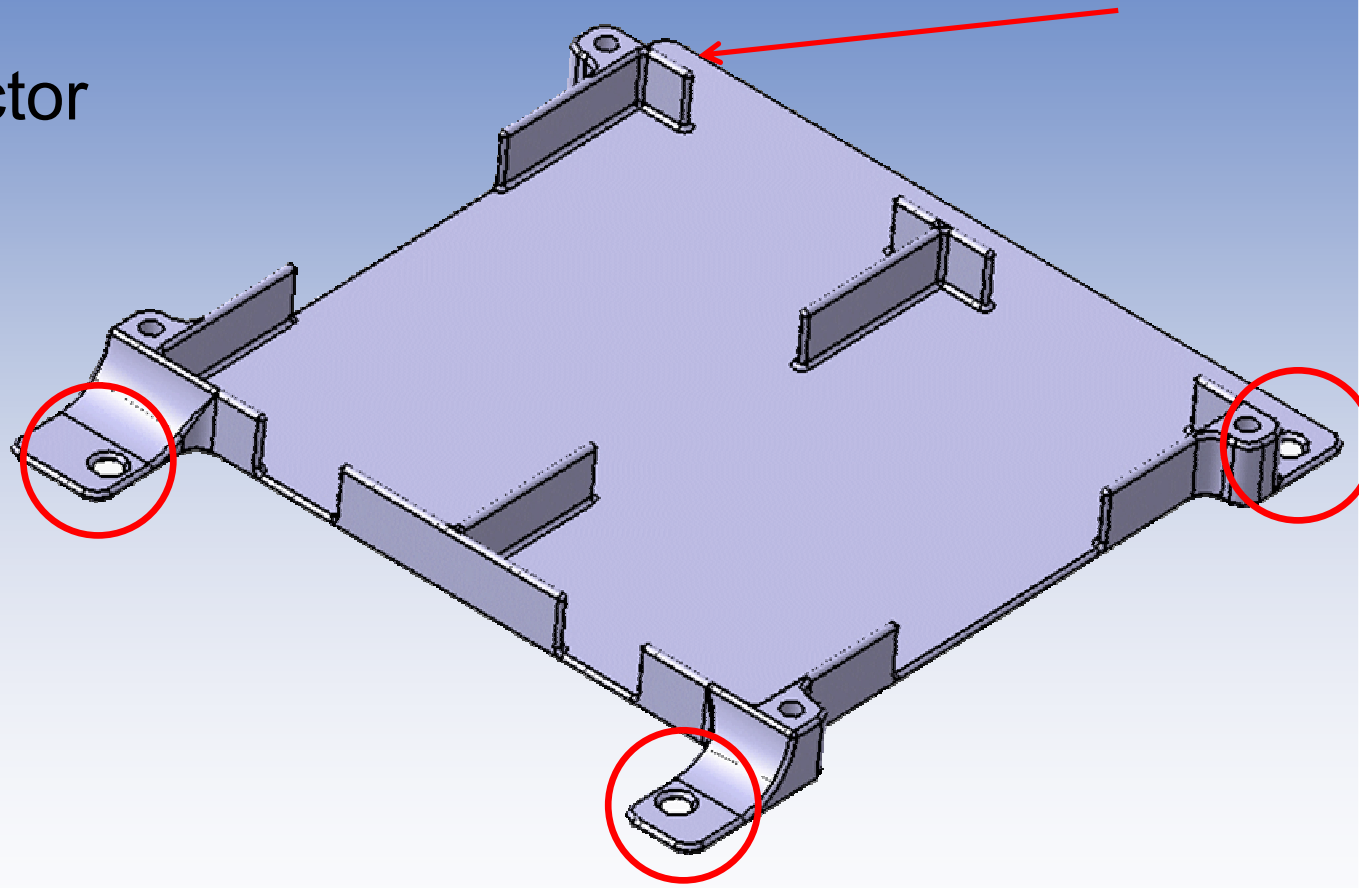
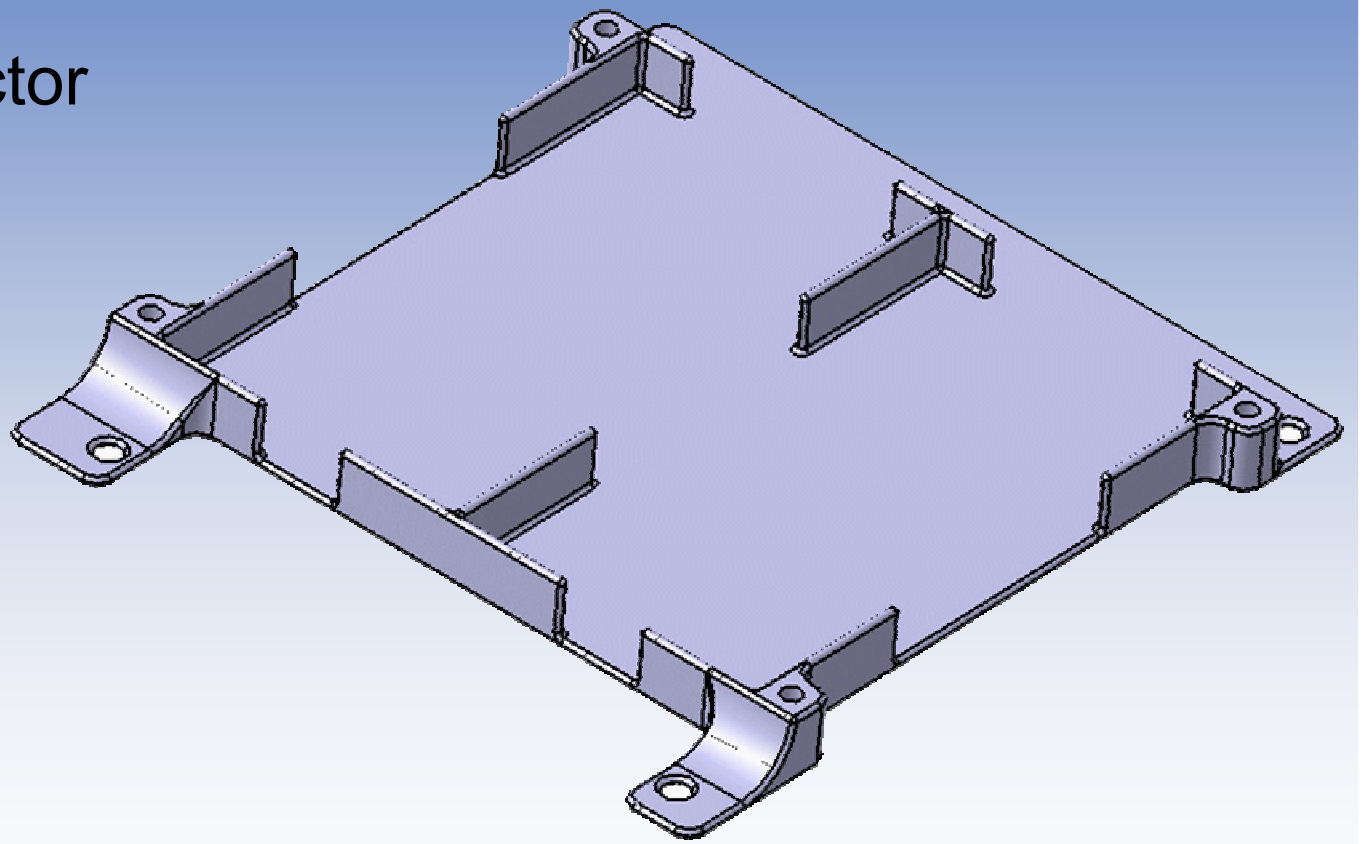
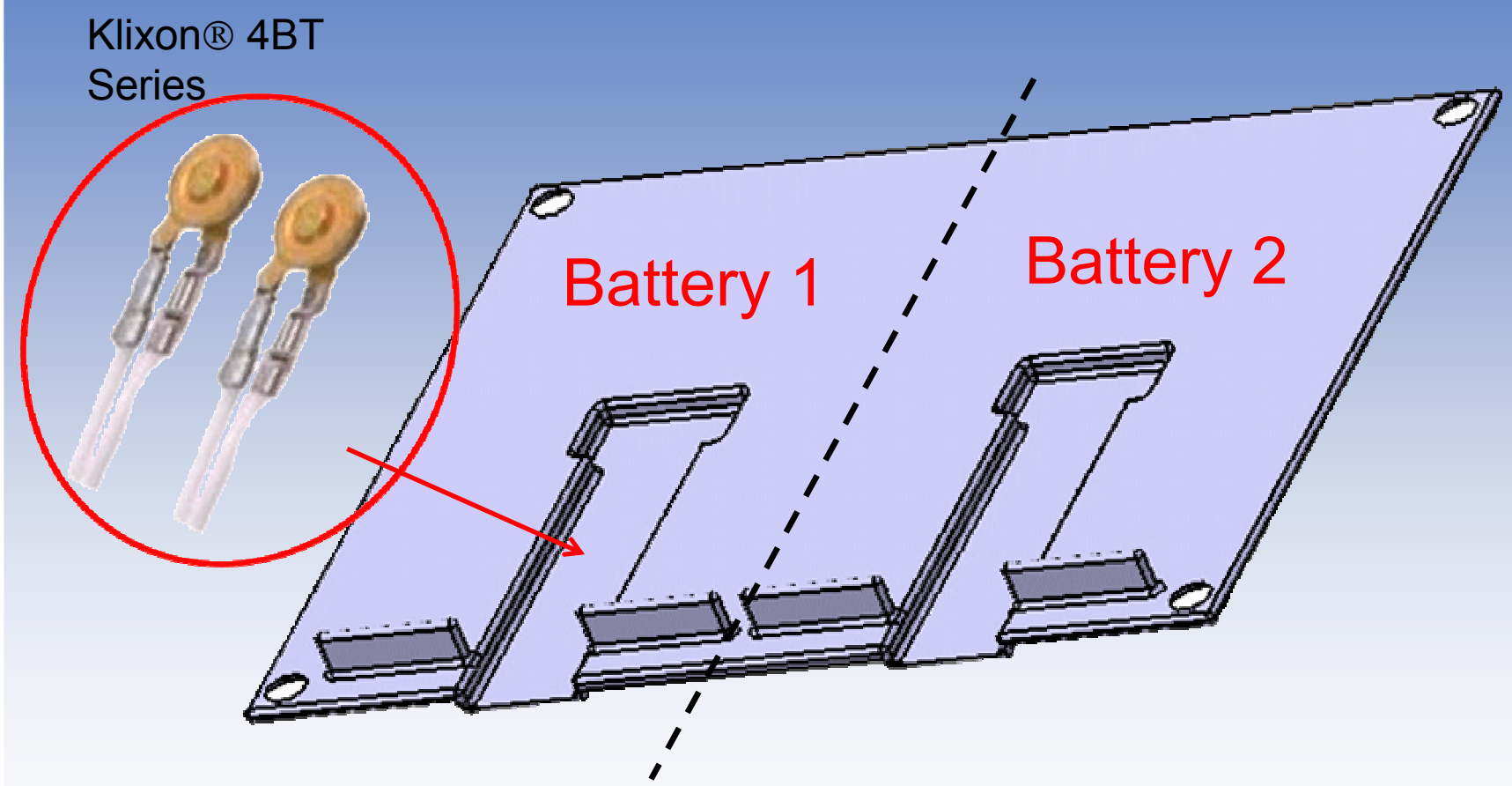


Design features

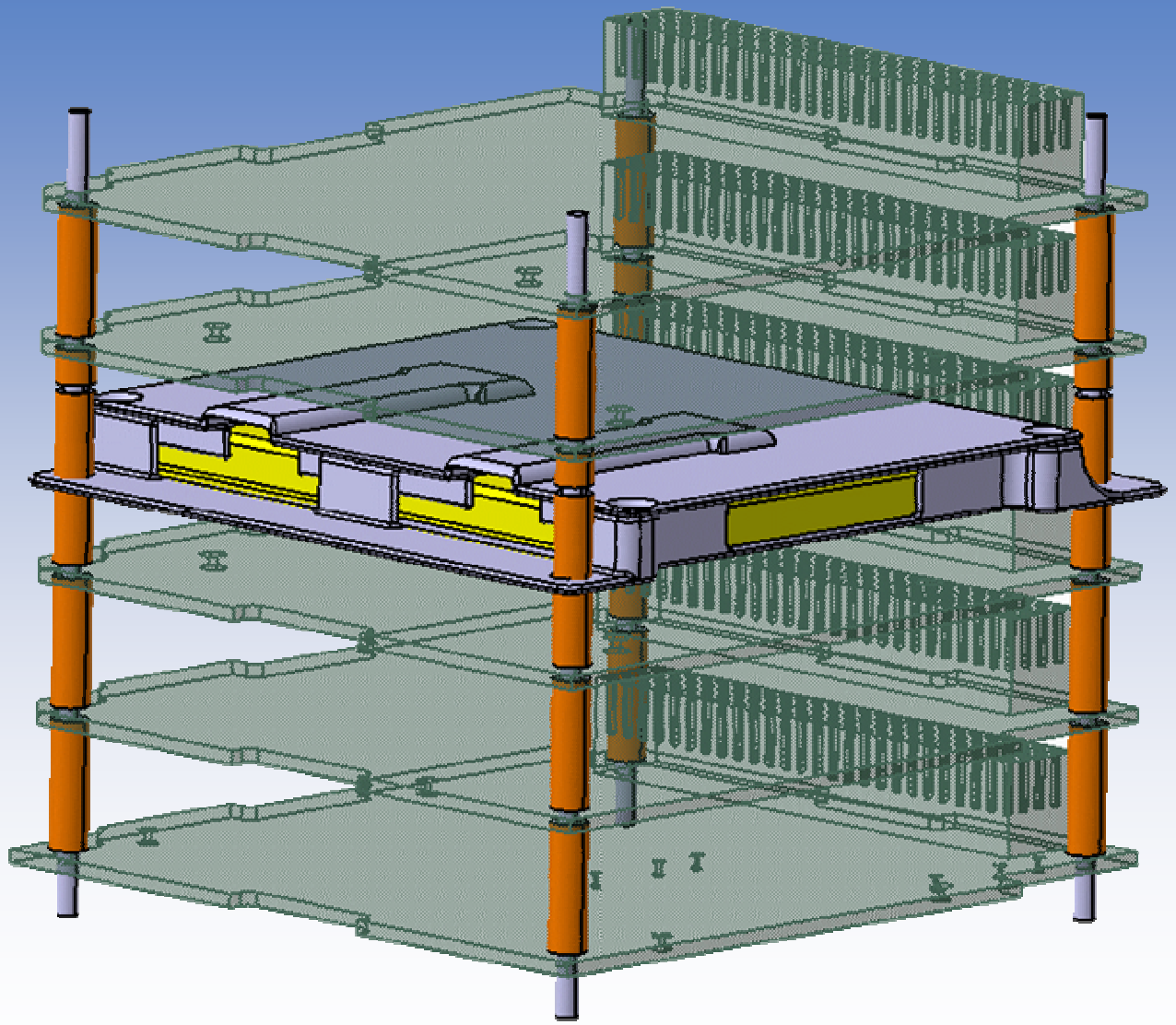
- Reinforcers
- PC/104 connector
- Cover
- Integration
- Aluminium



The cover welcomes the thermostats



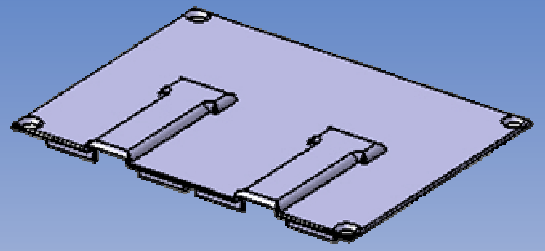
Design integrated within OUFTI-1

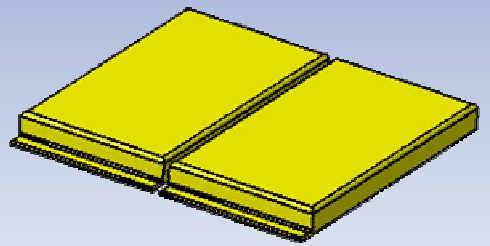


In summary

Issues:

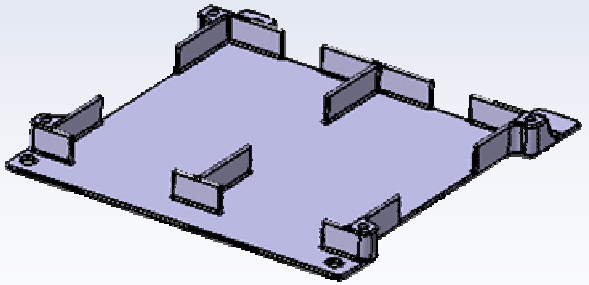
- Thermal environment
- Under vacuum-deformations
- Available space and mass





Solutions:

- Heaters
- Mechanical thermostats (redundancy)
- Appropriate design



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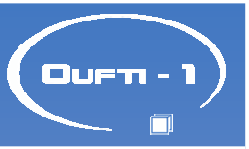

Thank you for your attention !