UC3M's ST3LLARsat1 Boira CubeSat: Thermal Control Subsystem evolution from concept to baseline design

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Layout

- CubeSat overview and goals
- Current team/config & Thermal design methodology
- BDR vs (current) FDR configurations
- BDR analyses
- BDR to FDR: identified issues
- Conclusions

CubeSat overview and goals

EDUCATIONAL

- **1st UC3M** CubeSat student programme.
- To provide students with **hands-on experience in a real space project.**

SCIENTIFIC

- Aim is to **design, build, and launch a 2U CubeSat to monitor climate change** by measuring local atmospheric moisture

TECHNOLOGICAL

- An in-house **state-of-art compact communication antenna**
- An in-house OBC software for **advanced AOCS/ADCS algorithms**

ST3LLARsat1 is integrated within **UC3M's Master in Space Engineering (MISE)**

***Sept'22**: Start of the 1st UC3M student CubeSat program with support of UC3M-SENER aerospace chair ST3LLAR*

***Sept'22-March'23:** Baseline Design Review (BDR) Phase*

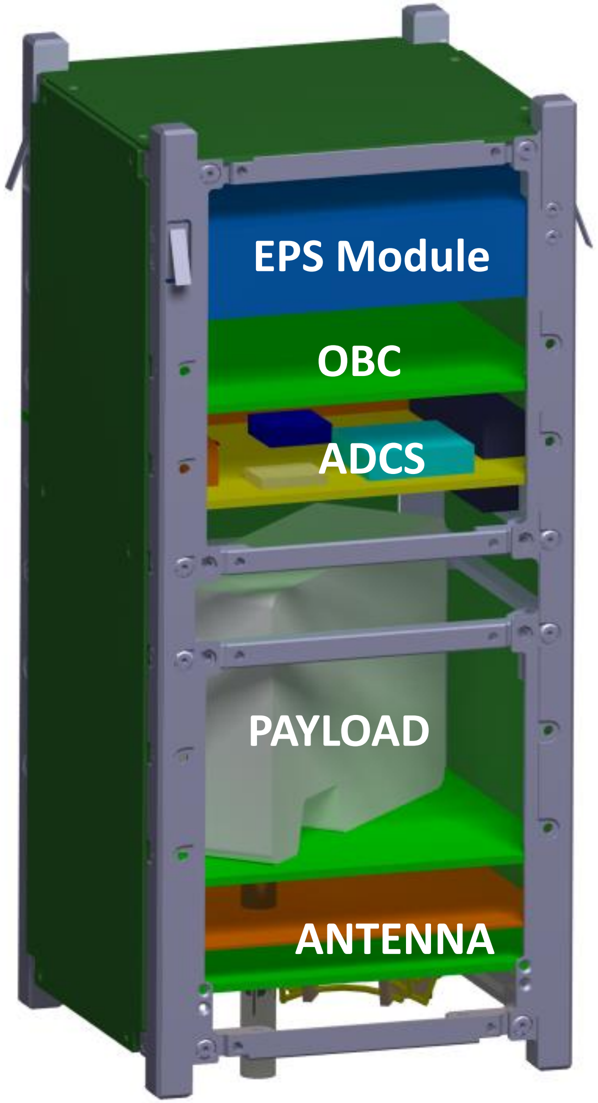
***April-August'23:** Consolidation of BDR design*

***Sept'23-Jun'24:** Final Design Review (FDR) Phase*

Dec'22: Selected by ESA for its first FYS-Design Booster program

FLY YOUR SATELLITE!

Current team/config & Thermal design methodology



Team: **3** professors + **1** research associate + **35** grad-students + **35** undergrad (**2** PhDs + **12** 2nd yr-MISE + **21** 1st yr-MISE volunteers)

Thermal team: **one** 2nd yr-MISE team lead + **three** 1st yr-MISE volunteers

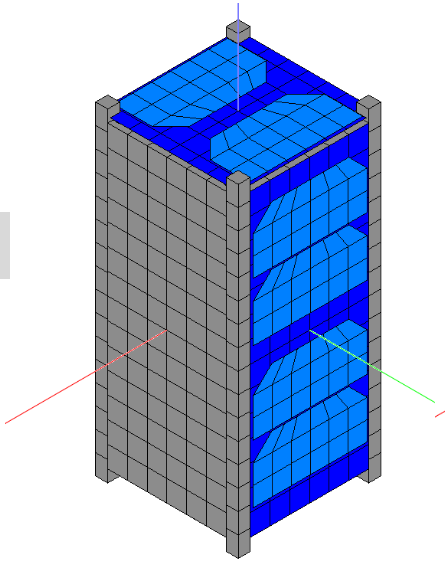
- **Thermal subsystem design methodology**
  - Identify components within the overall system
  - Perform thermal analyses:
    - Define inputs, outputs, and heat paths
    - Assume default values for unspecified characteristics
    - Obtain the geometrical and thermal mathematical model
    - Perform nominal and worst (hot/cold & extreme orbit) cases
  - Establish thermal subsystem design:
    - Define conceptual subsystem design
    - Check solution for consistency
    - Ensure integrity of design: identify abnormal behaviour, recommend control measures, validate predictions.

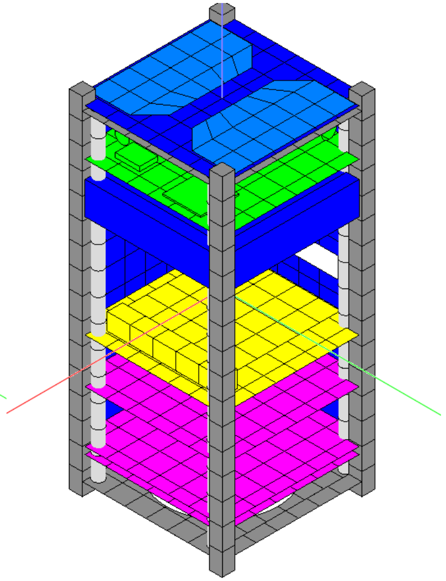
BDR vs (current) FDR configurations

External configuration

Inner configuration

BDR





- **Temperature ref. points:** only for **payload** and **battery**
- **Worst Case Orbits:**

  Cold Case: SSO – NM – 500 Hot Case: SSO – DD – 500
- **Heat paths**: preliminary analysis
- **Assumptions**: solar panels with white paint, black anodizing for aluminum structure, and black paint for external walls

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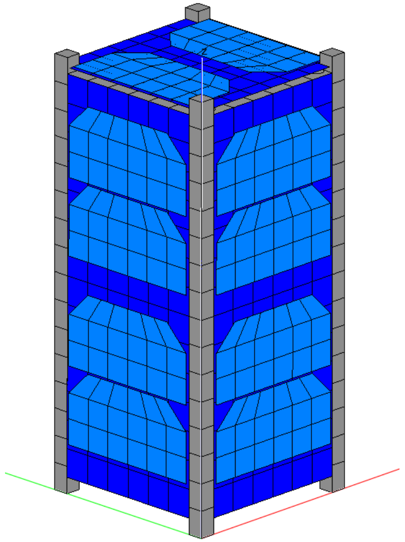
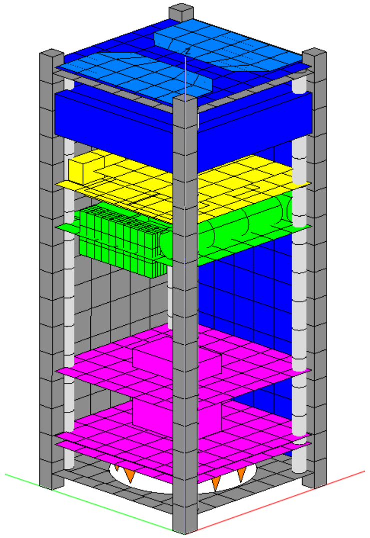
Pre-FDR





- **Temperature ref. points:** to add for **Solar panels**
- **Updated Worst Case Orbits:**

  Cold Case: SSO – NM – **400** Hot Case: SSO – DD – **525**
- **Heat paths**: detailed analysis. Path through antenna to payload
- New solar panels
- New subsystems distribution

BDR analyses

Battery is out of range in min. temperature and max- temperature
On Board Computer is out of range in max. temperature

MISSION SUMMARY							
Subsystem	Component	Min. Non Operative Temp.	Min. Operative	Min. Design Temp. [ºC]	Max. Design Temp. [ºC]	Max. Operative Temp. [ºC]	Max. Non Operative Temp. [ºC]
Power	Battery	-10	0	-7.87	49.01	40	60
AOCS	CPU_AOCS	-40	-40	12.12	76.36	85	85
OBC & Comms	CPU_OBC	-40	-40	30.68	88.54	85	85
AOCS	GPS Rx	-55	-40	-17.74	58.98	85	100
AOCS	Gyro	-40	-25	-14.52	61.27	85	105
AOCS	Magnetometer	-40	-40	-13.53	53.35	85	85
OBC & Comms	Memory1	-40	-40	3.59	65.17	85	85
OBC & Comms	Memory2	-40	-40	1.95	64.05	85	85
OBC & Comms	OBC_PCBs	-20	-20	-12.97	52.53	60	60
Structures	Structure	-40	-40	-32.44	48.17	60	60
Power	Solar Panel Z	-40	-40	-36.54	44.74	85	85
Power	Solar Panel mX	-40	-40	-35.39	55.14	85	85
Power	Solar Panel mY	-40	-40	3.59	65.17	85	85
OBC & Comms	Transceiver	-40	-40	-35.32	53.27	85	85
OBC & Comms	UHF Antenna	-20	-20	-14.33	52.89	60	60
Power	EPS I Casing	-40	-40	-18.15	41.83	150	150
Payload	Lens	-20	-20	-12.63	49.17	60	60
AOCS	Magnetorquers	-20	-20	-15.37	43.98	60	60
Payload	Ocean payload	-20	-20	-13.79	54.16	60	60

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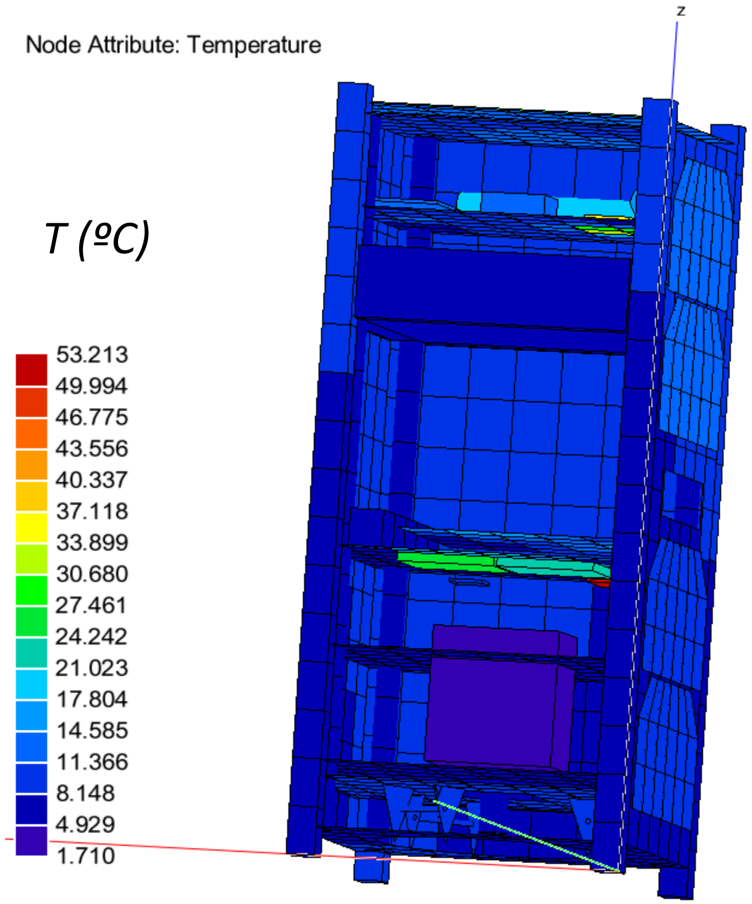
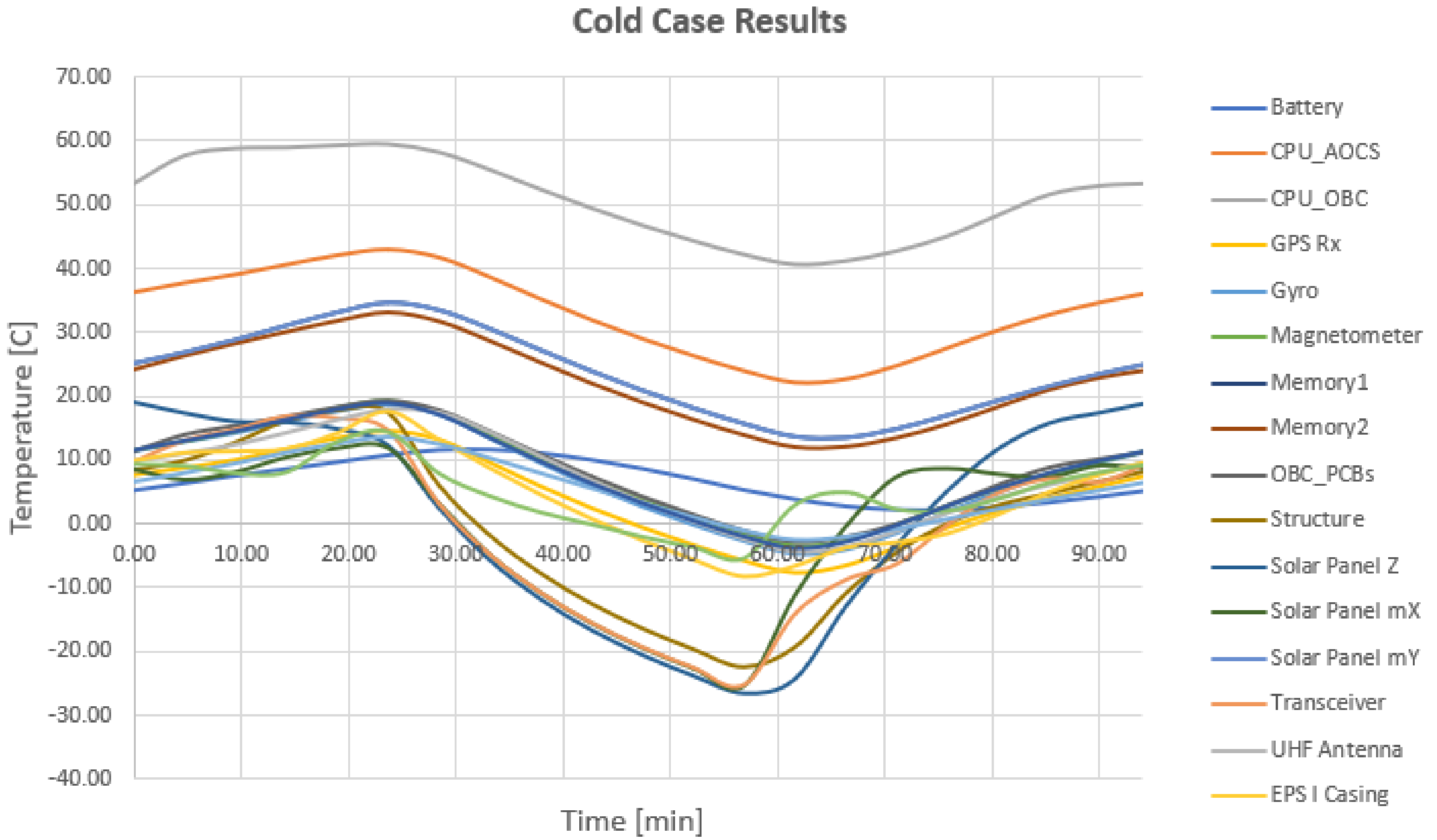
BDR analyses

COLD CASE

➢ **Assumptions**:

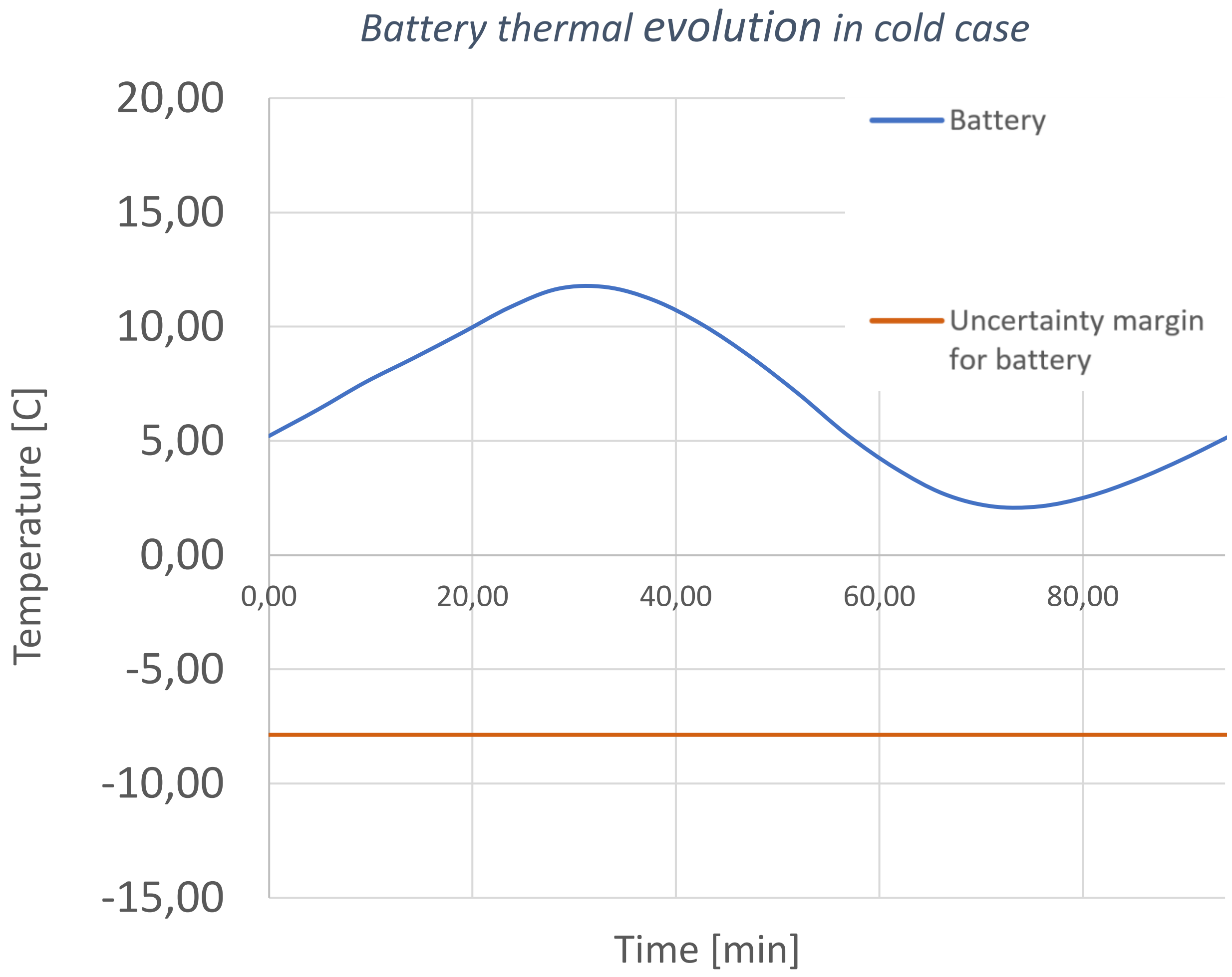
- Only the **capacitances** for the **EPS** and the **payload** are included
- Most electronic equipment **do not have a thickness ➔ no thermal inertia**
- Thermal contacts are **simplified**

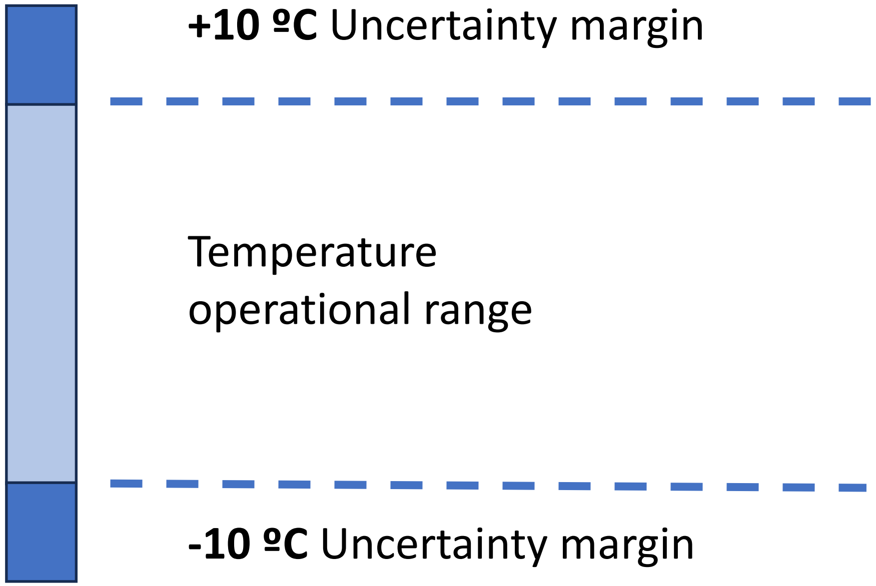




BDR to FDR: identified issues & proposed solutions

Battery behaviour





Proposed solutions:

- **Thermostatic control definition** could be changed:
  - Heaters ON temp. set at 15 ºC (instead of 5 ºC)
- **Change of modelling uncertainty** :
  - If battery heater's duty cycle shown to be <70%, then we can lower batt. model uncertainty to 5 ºC

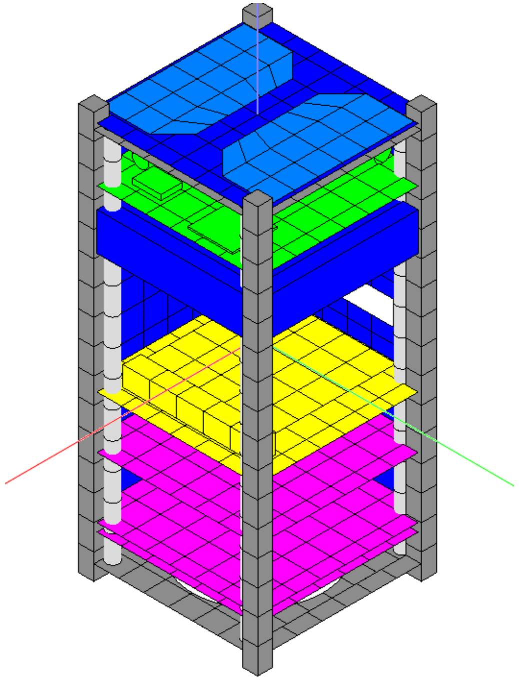
BDR to FDR: identified issues & proposed solutions

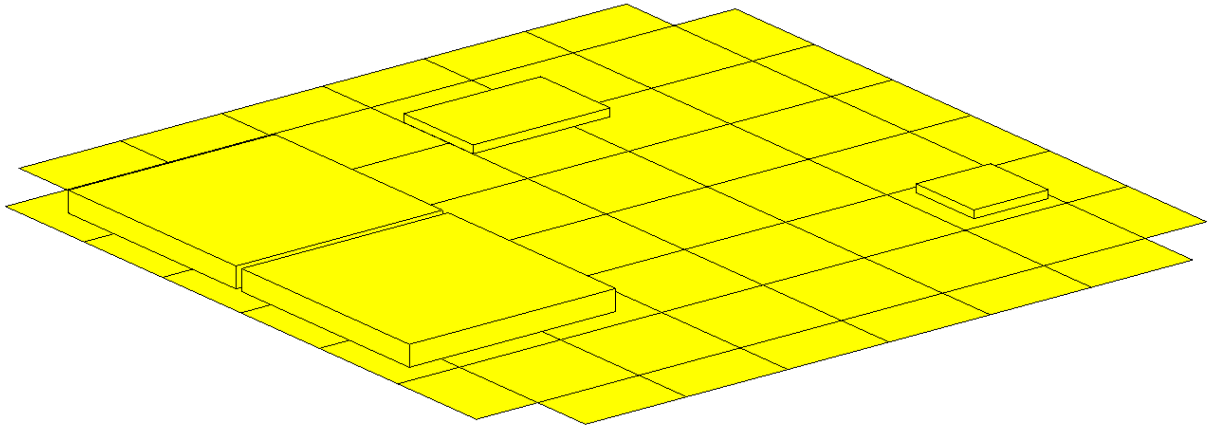
On Board Computer MCU behaviour

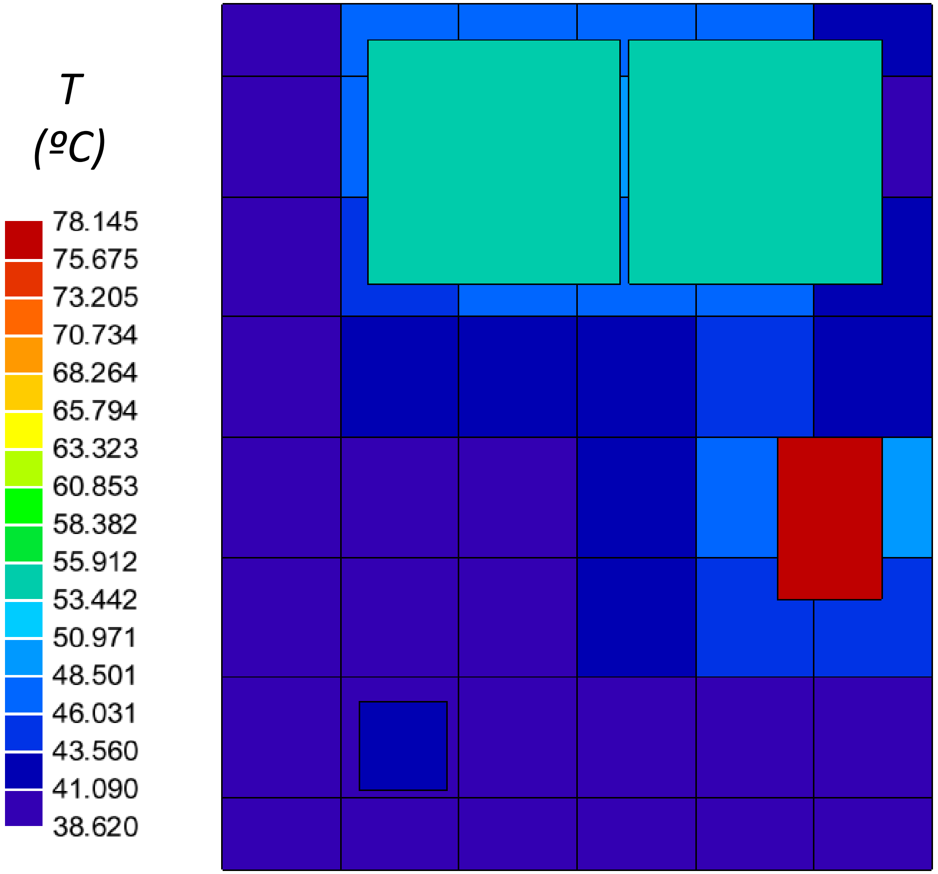
Issue:

- **Exceedance on OBC** (just a few degrees)
- **Contact conductance** is 20 W/m2K

Not critical but need to keep an eye and check it for final model/design







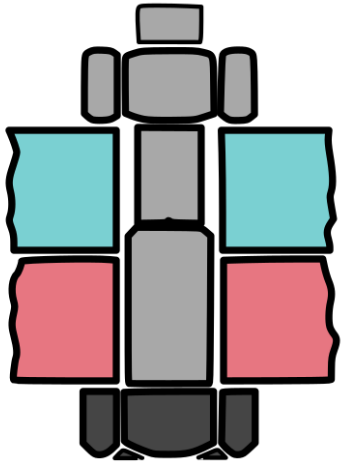
CPU of the OBC hot results with PCB

BDR to FDR: identified issues & proposed solutions

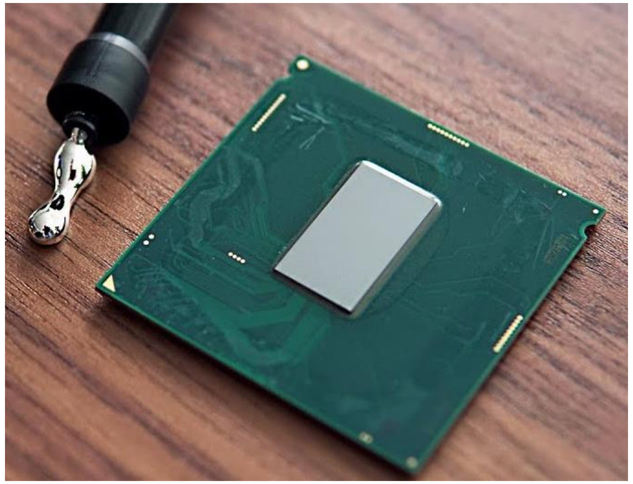
On Board Computer MCU behaviour

- **Contact conductance** assumption known to be low, can be improved by looking at MCU integration:
  - By considering the MCU mounting method: bolted, soldered, pinned
- **Thermal fillers** have been proposed to increase conductivity between CPU and PCB

Bolted

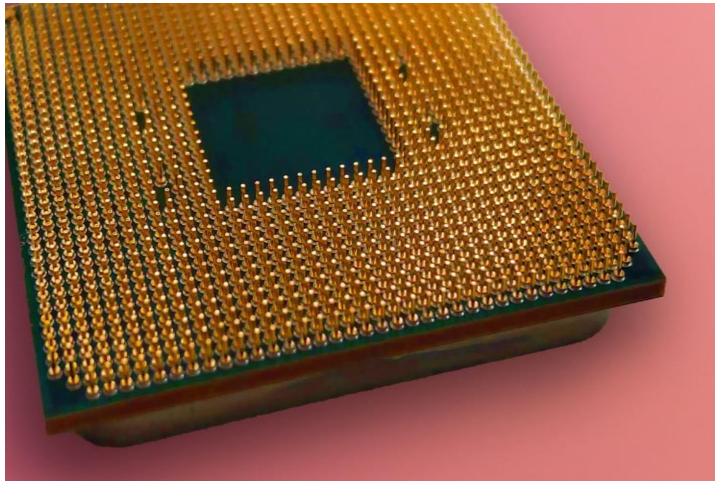


Soldered



https://www.pcgamer.com/bent-cpu-pins-may-become-a-thing-of-the-past-as-amd-eyes-major-socket-change/

Pinned



https://videocardz.com/newz/golem-intel-core-i9-9900k-will-be-soldered

Conclusions

Technical:

- Recommended to be more conservative for HOT case by assuming that 100% of power delivered to components is dissipated as heat.
- Consider calculated versus predicted temperatures from beginning of design phase as they can change based on chosen duty cycles.

Team Management:

- Critical subsystems must be led by ‘experienced’ student (i.e. previous year volunteer)
- Choices, assumptions, and solutions MUST be documented

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The ***UC3M-SENER aerospace chair****, for funding and expert support*

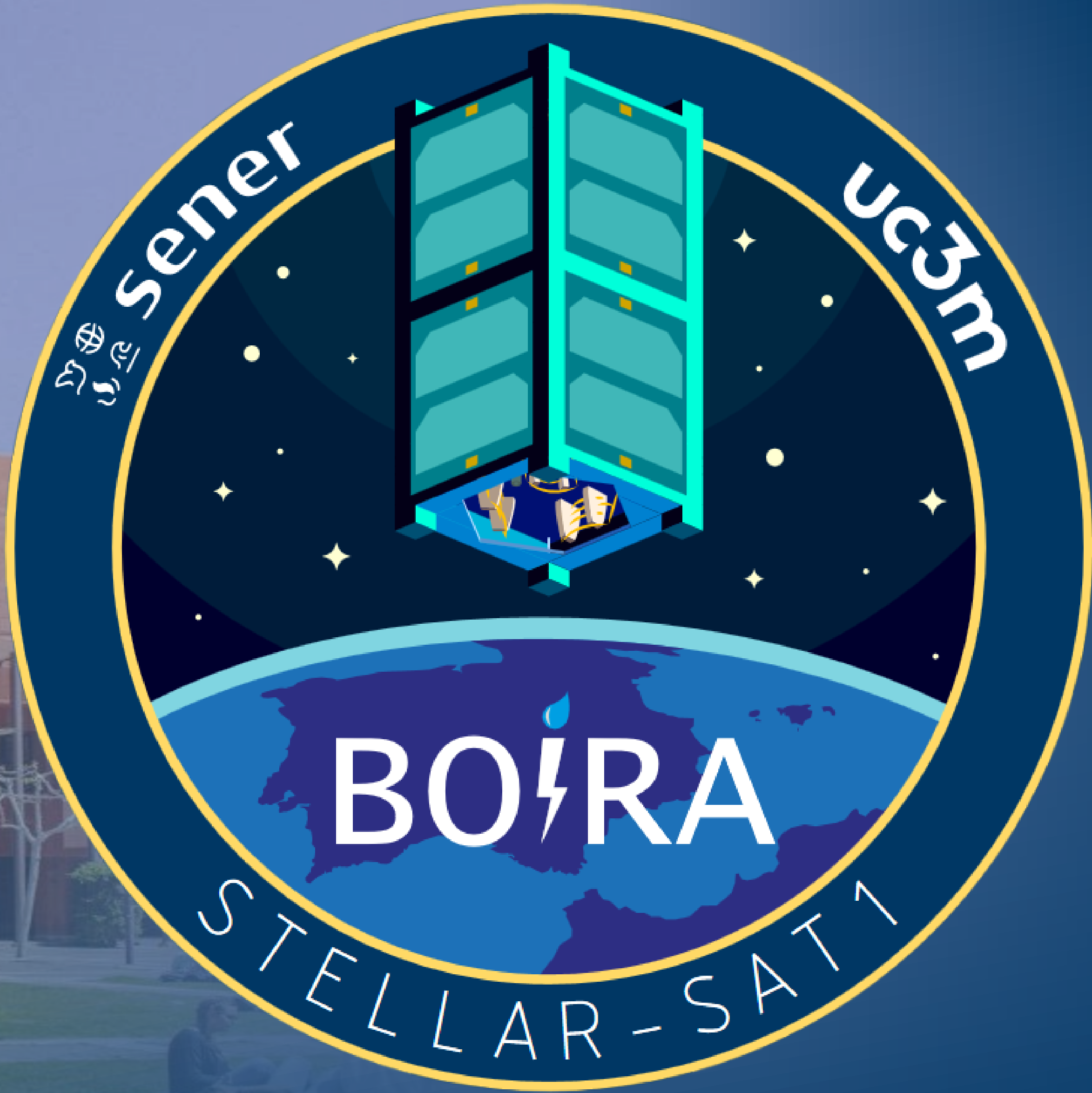
For expert support, training and providing access to their AIV facilities within their ***FYS Booster Design programme***

UC3M's Aeroelastic and Structural Design Lab for their knowledge and support

The E.T.PACK-F H2020 project for integrating us in their ***GCS development activity***

For providing their ***thermal modeling software***

Thank you!



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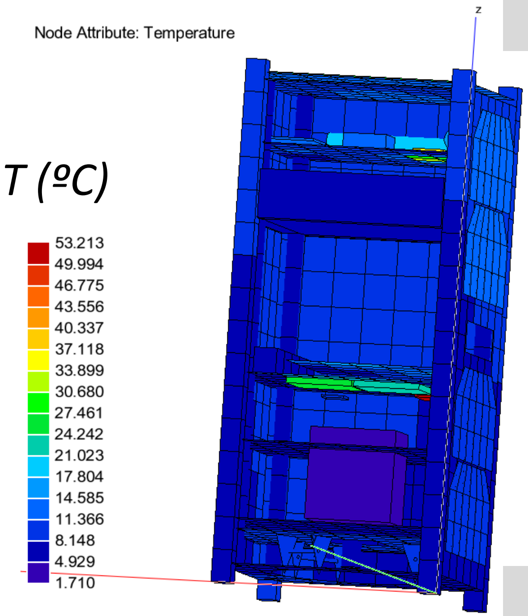
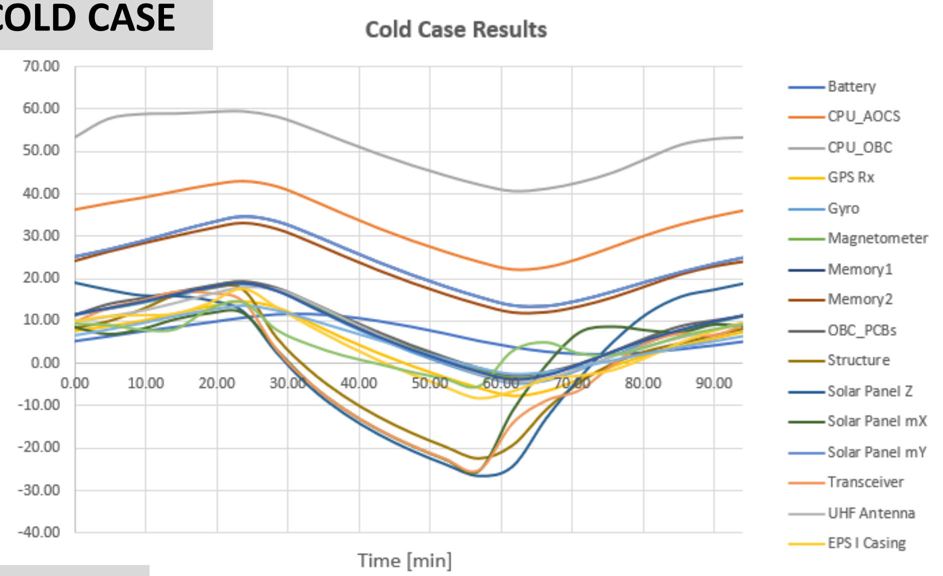
Back-up slides

Analysis on BDR Configuration

COLD CASE

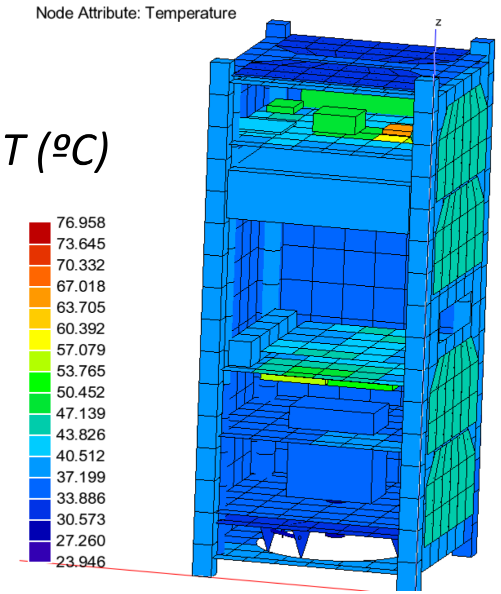
T (ºC)

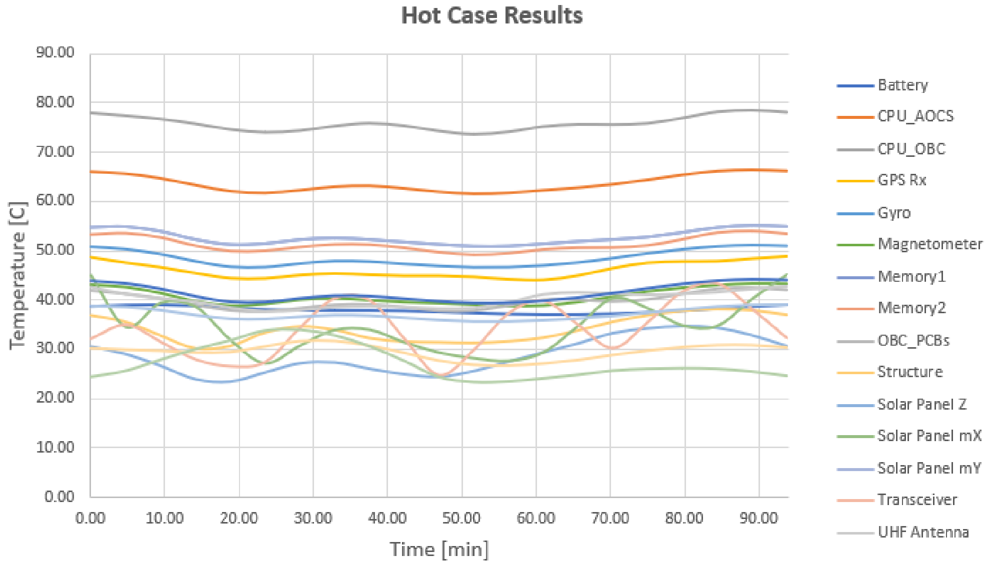




HOT CASE

T (ºC)





- Only the **capacitance** for the **EPS** and the **payload** are included.
- Most of electronic equipment **do not have a thickness** associated, **no thermal inertia**.

The thermal contacts are **not representative enough**.

- Example: Second lowest plate is thermally decoupled from its surroundings.