

YPSat Thermal Analysis, Design, Integration & Testing

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European Space Thermal Engineering Workshop, ESTEC

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1 Project Overview

What is YPSat?

- Young Professionals Satellite
- Project entirely composed of – and managed by – ESA young professionals (YGTs, interns, contractors, staff)
- Team of 50+ people with range of backgrounds, across multiple ESA sites
- Inspired by the YES project: led by ~30 ESTEC YGTs and launched within 7 months on VA502 in December 1996
- Aiming to design, build, test, and deliver a payload for Ariane 6 maiden flight in < 18 months





ESTEC, ESOC, HQ, ECSAT



Timeline

2021

Oct 21
Announcement of opportunity & project kick-off

Dec 21
Selection of Ideas

2022

Jan 22
KISS Principle

Feb 22
Official Project Announcement

Mar 22
Meeting with H/TEC & H/ESA Education

Past 7 months..
Design & Procurement
Development & Manufacturing

2023

Jan 23
Final acceptance testing & spacecraft delivery



2 Mission Overview

Key Facts

Ariane 6 maiden launch from French Guiana, scheduled April 2023

Orbital altitude up to 600 km and inclination approx. 63°

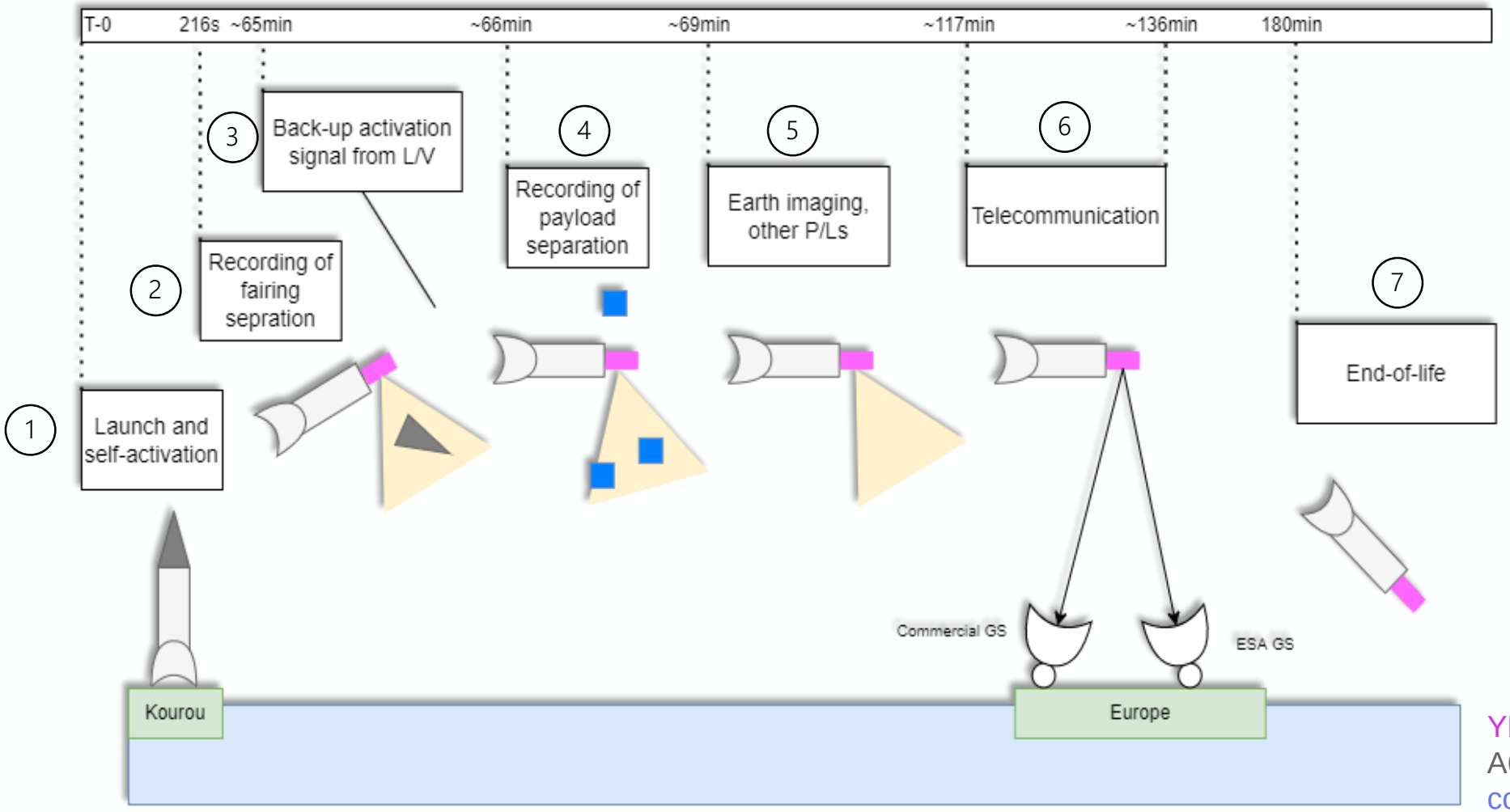
Deorbit together with upper stage after two orbits



Mission Objectives

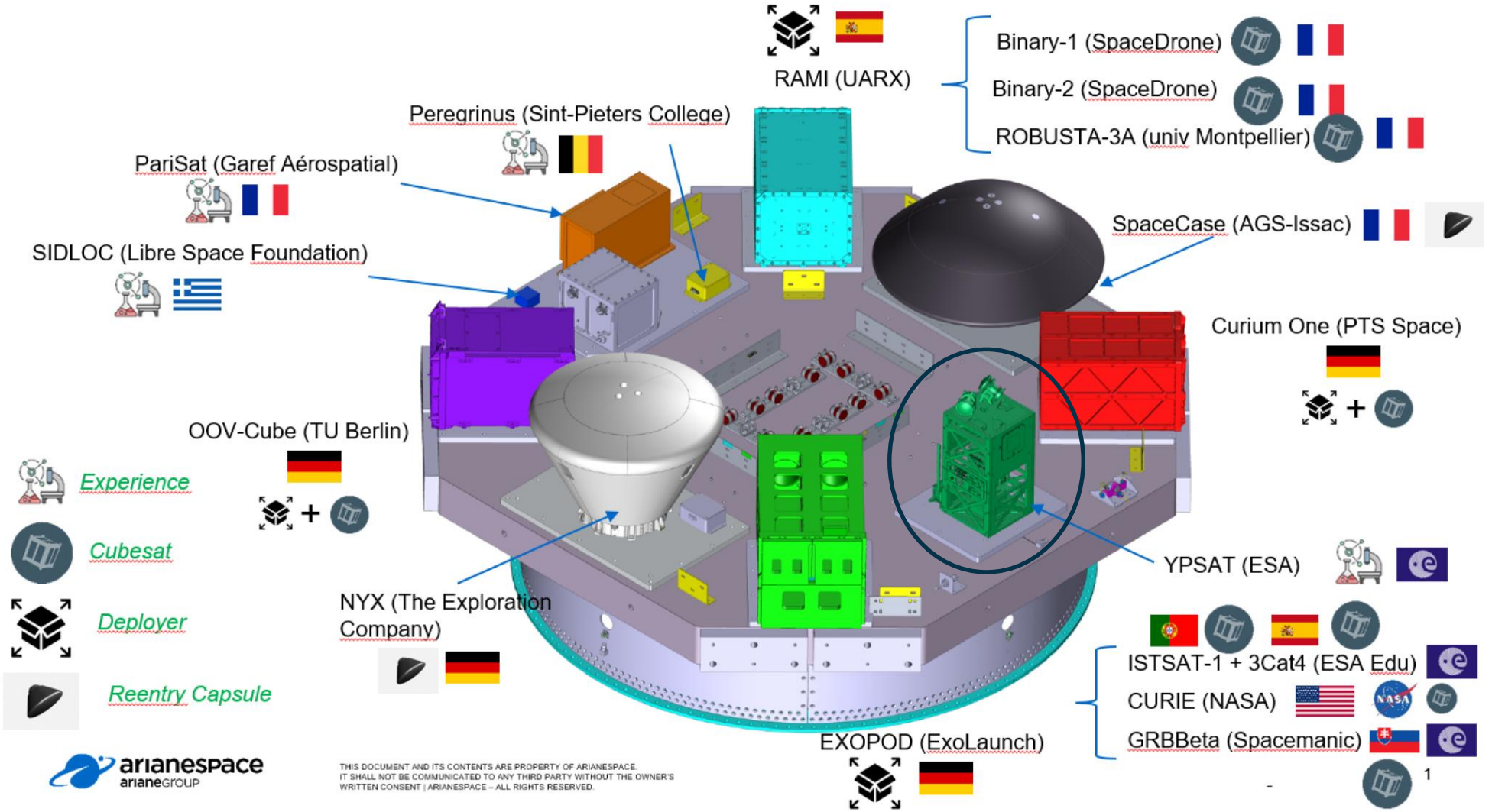
- Record fairing separation
- Record CubeSat deployment
- Acquire in-orbit images

Mission Sequence



YPSat
A6
co-passengers

Ariane 6 Upper-stage Ballast



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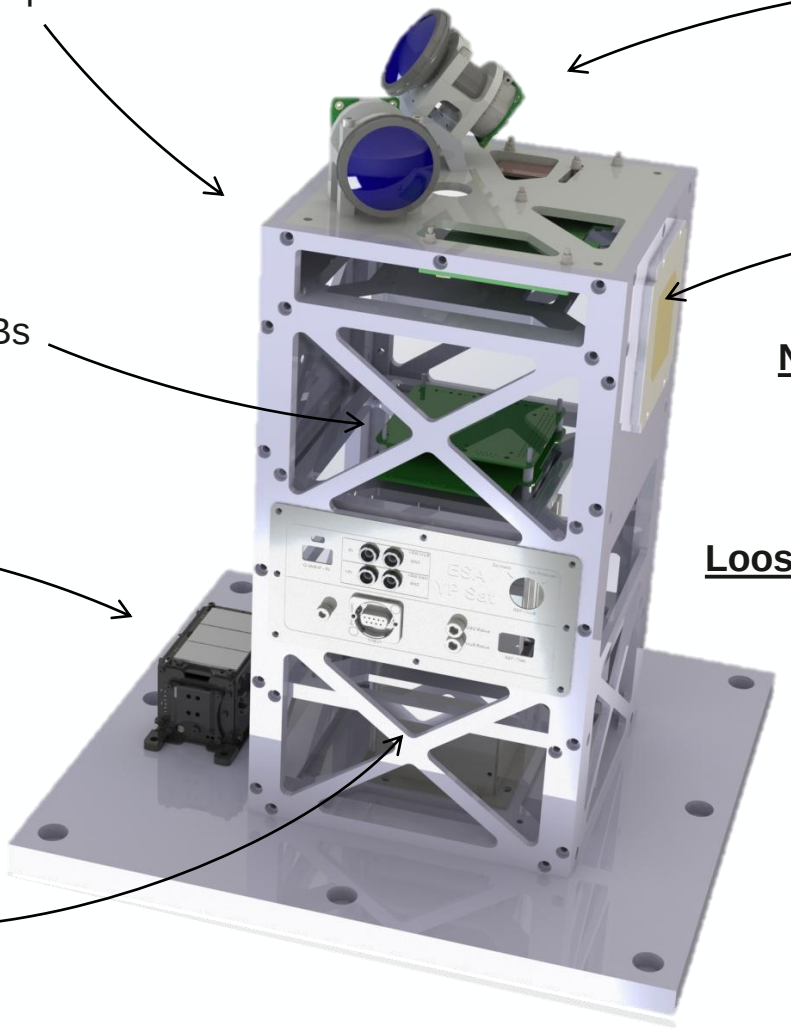
Spacecraft Overview

Exterior aluminium panels mounted to interface plate

Interior stack includes EPS, OBC, TX and PCBs

AMSAT PocketQube secondary payload

OSCAR magnetometer secondary payload



Scanway cameras primary payload

Patch antenna

No dedicated AOCS – at the mercy of the launcher

No solar arrays – battery power exclusively

Loose mass constraints – approx. 11.3 kg

Loose volume constraints – approx. 200x200x400 mm



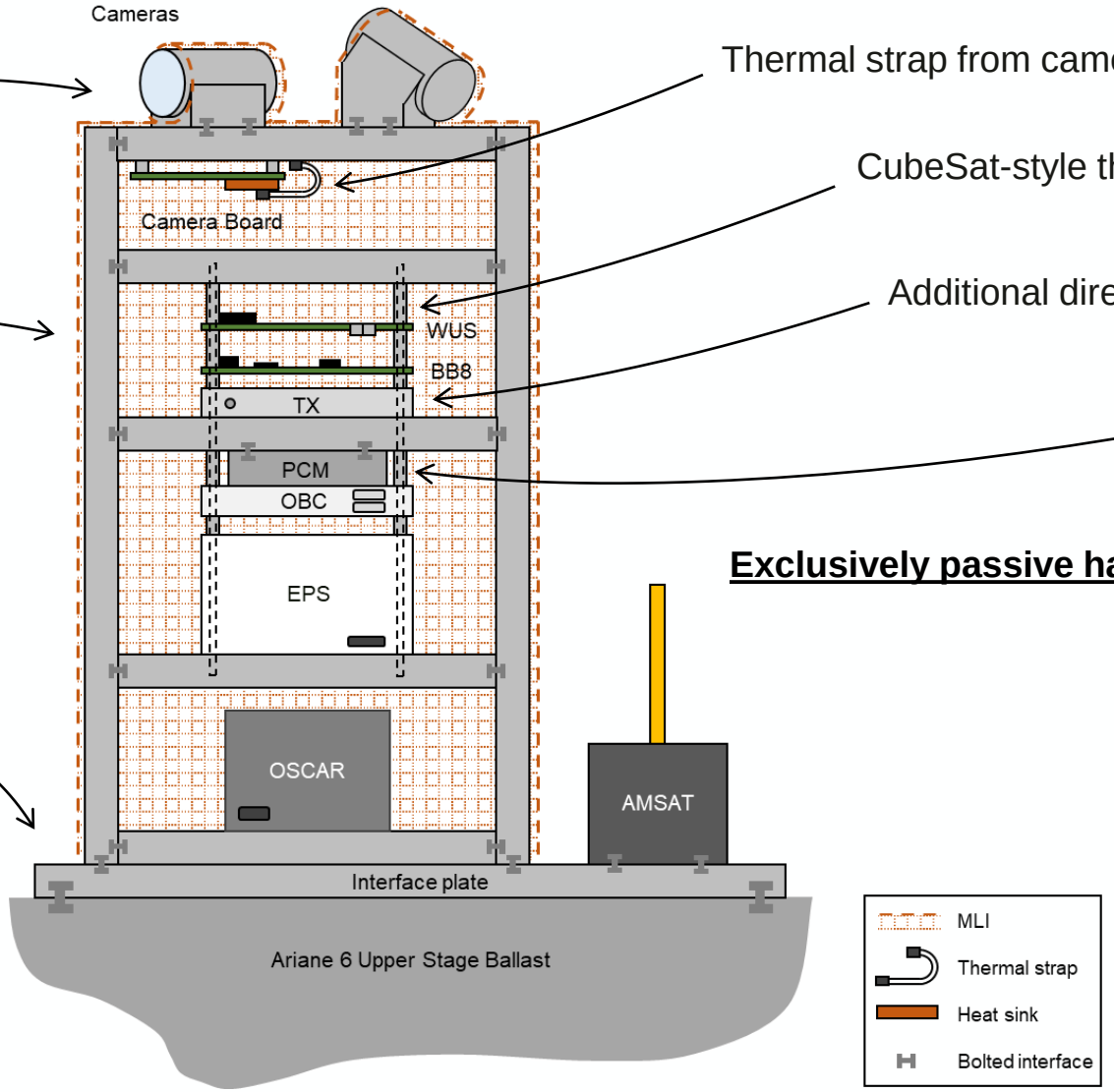
3 Thermal Overview

Thermal Architecture

Cameras covered by MLI, cut-out for lenses

Exterior panels covered by MLI, cut-outs for patch antenna & electrical interface plate. AMSAT not covered

Standard bolted interface to ballast via intermediate plate



Thermal strap from camera PCB specified by Scanway

CubeSat-style threaded rod & spacers for low-dissipation units

Additional direct contact to structure for high-dissipating units

PCM between TX and OBC

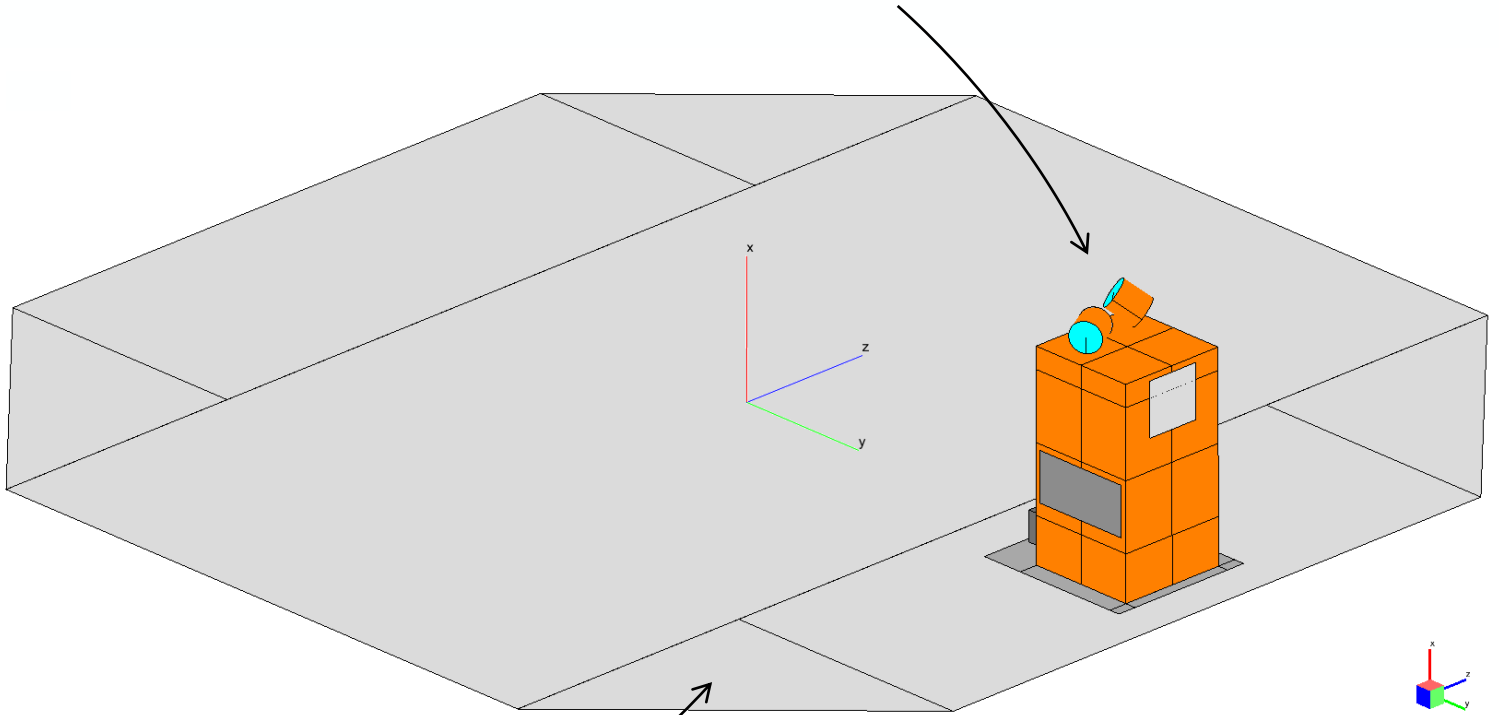
<u>Exclusively passive hardware, mostly flight-proven</u>

4 Thermal Analysis & Design

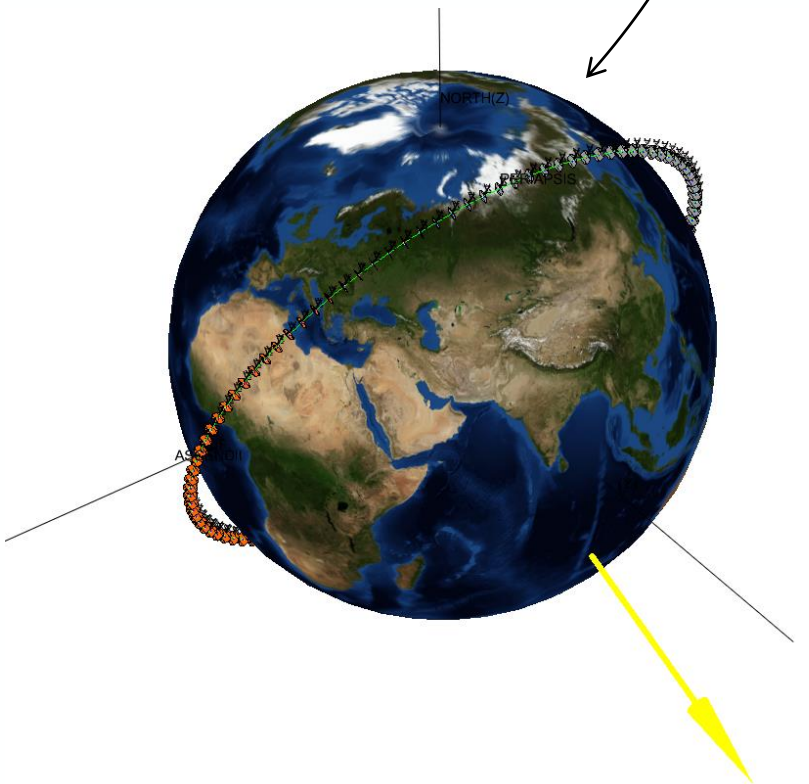
Model Overview

Standard thermal design. Limited information available. Design decisions needed quickly → **keep model as simple as possible**

Minimal number of nodes –
most units are single nodes with lumped parameters

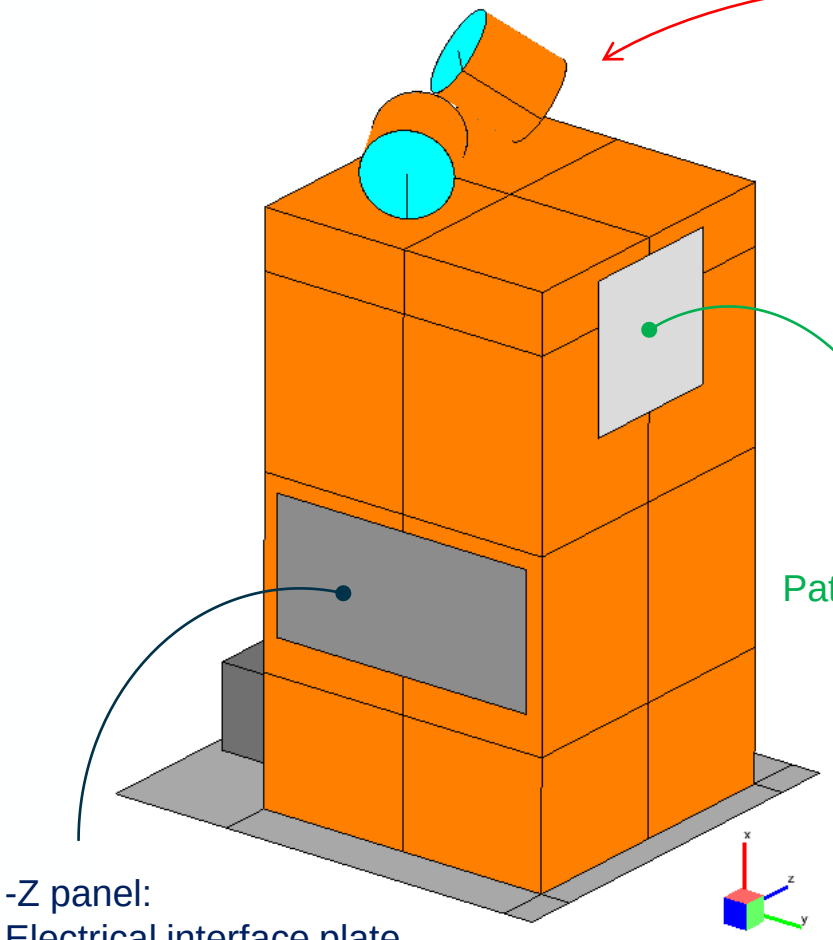


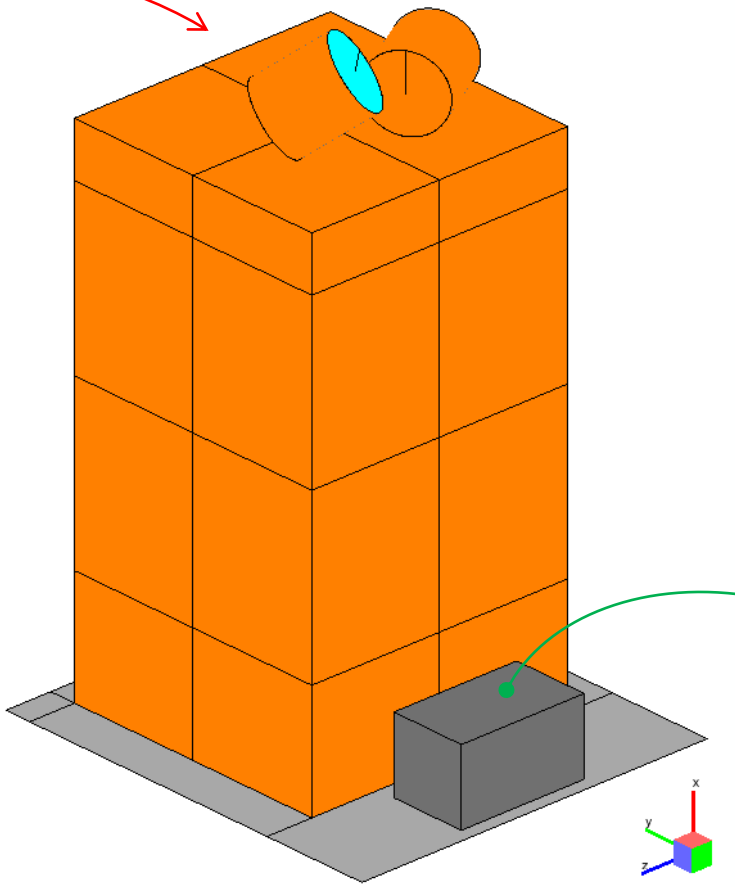
Minimal number of cases –
make design robust to extreme scenarios



No dynamic modelling of launcher –
ballast modelled as shell with constant
temperature at 10 °C (cold) or 45 °C (hot)

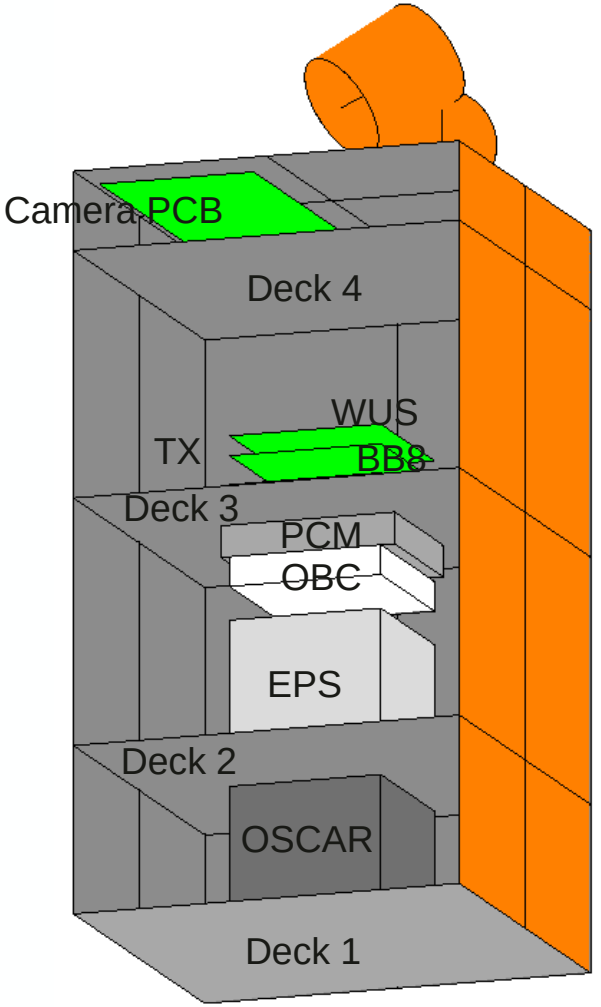
Geometry: Spacecraft-level

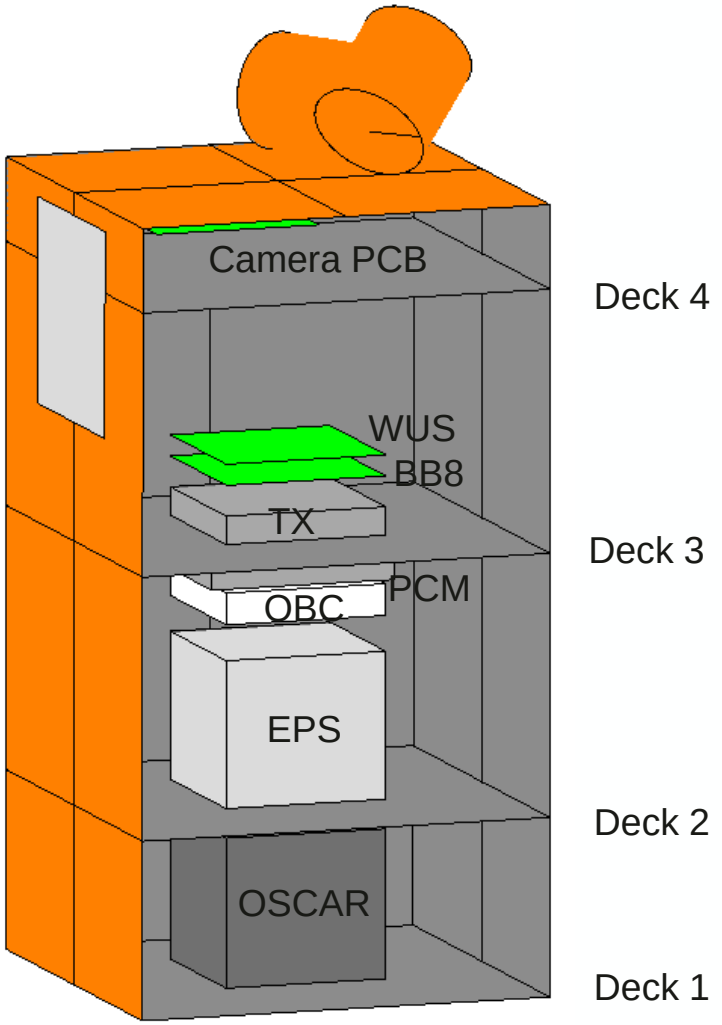




Note: Panels & camera surfaces with kapton MLI. Assumed $\alpha = 0.4$, $\varepsilon = 0.63$

Geometry: Unit-level

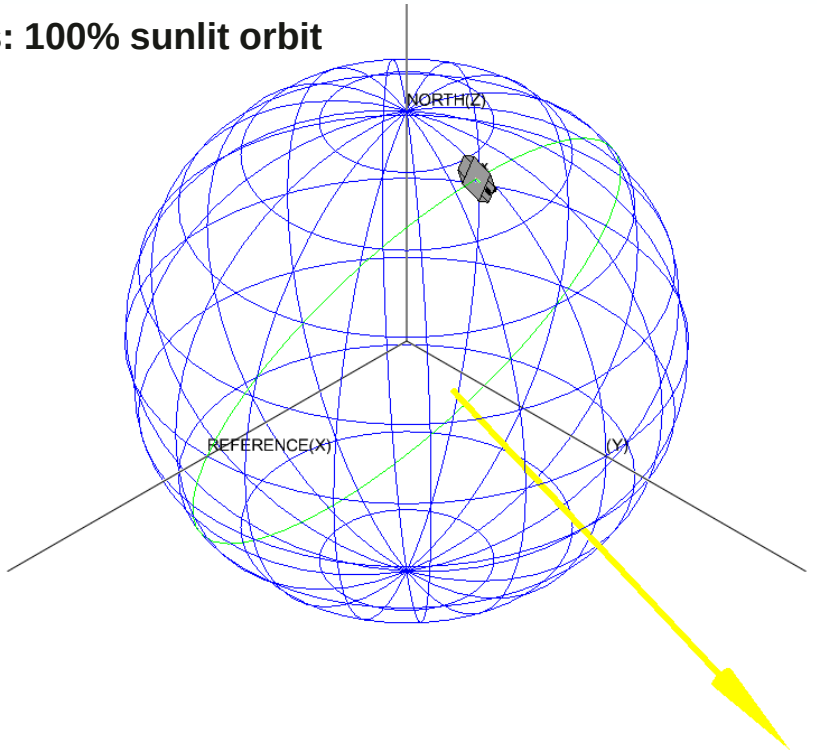




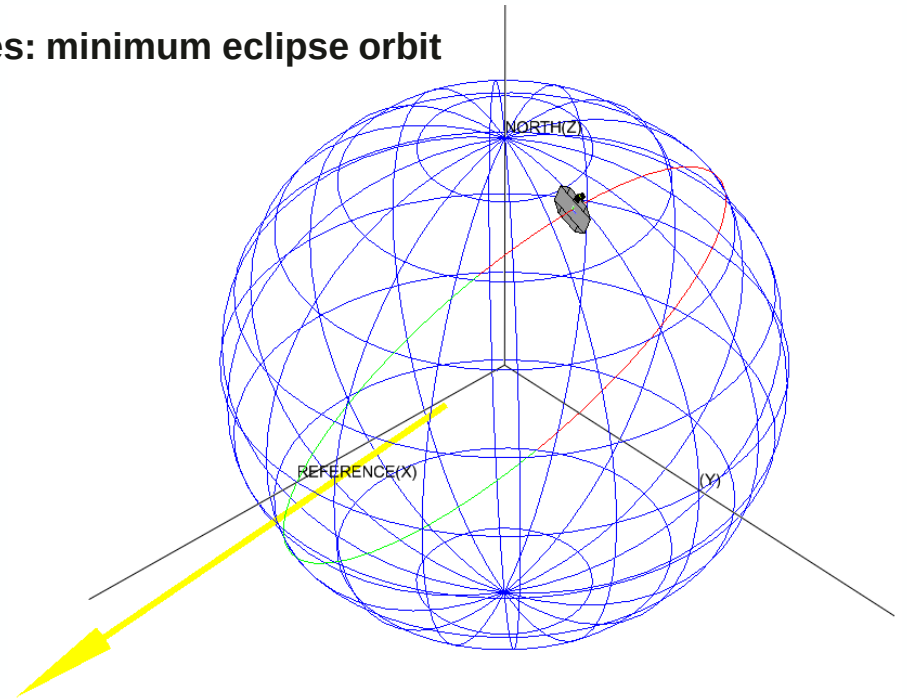
Radiative Cases

- Depending on launch day/time trajectory can have long eclipse or no eclipse at all
- For example, summer-time launch has potential for no eclipse during entire two orbits
- Thermal design must be robust to any launch scenario → **radiative cases with most extreme orbits**

Hot cases: 100% sunlit orbit



Cold cases: minimum eclipse orbit



Note: assumed attitude pointing in velocity direction → minimum eclipse orbit is a hot case for cameras due to high solar flux at eclipse exit

Case Definition Overview

Hot Cases

Case	Orbit	Roll?	Ballast Temp (°C)
HC01	100% sunlit	Yes, constant 1°/sec	45
HC02a	100% sunlit	No roll, sun on +Y	45
HC02b		No roll, sun on -Y	
HC02c		No roll, sun on +Z	
HC02d		No roll, sun on -Z	
HC02e		No roll, sun on +X	
HC03	Min. eclipse	Yes, constant 1°/sec	45

Camera hot case

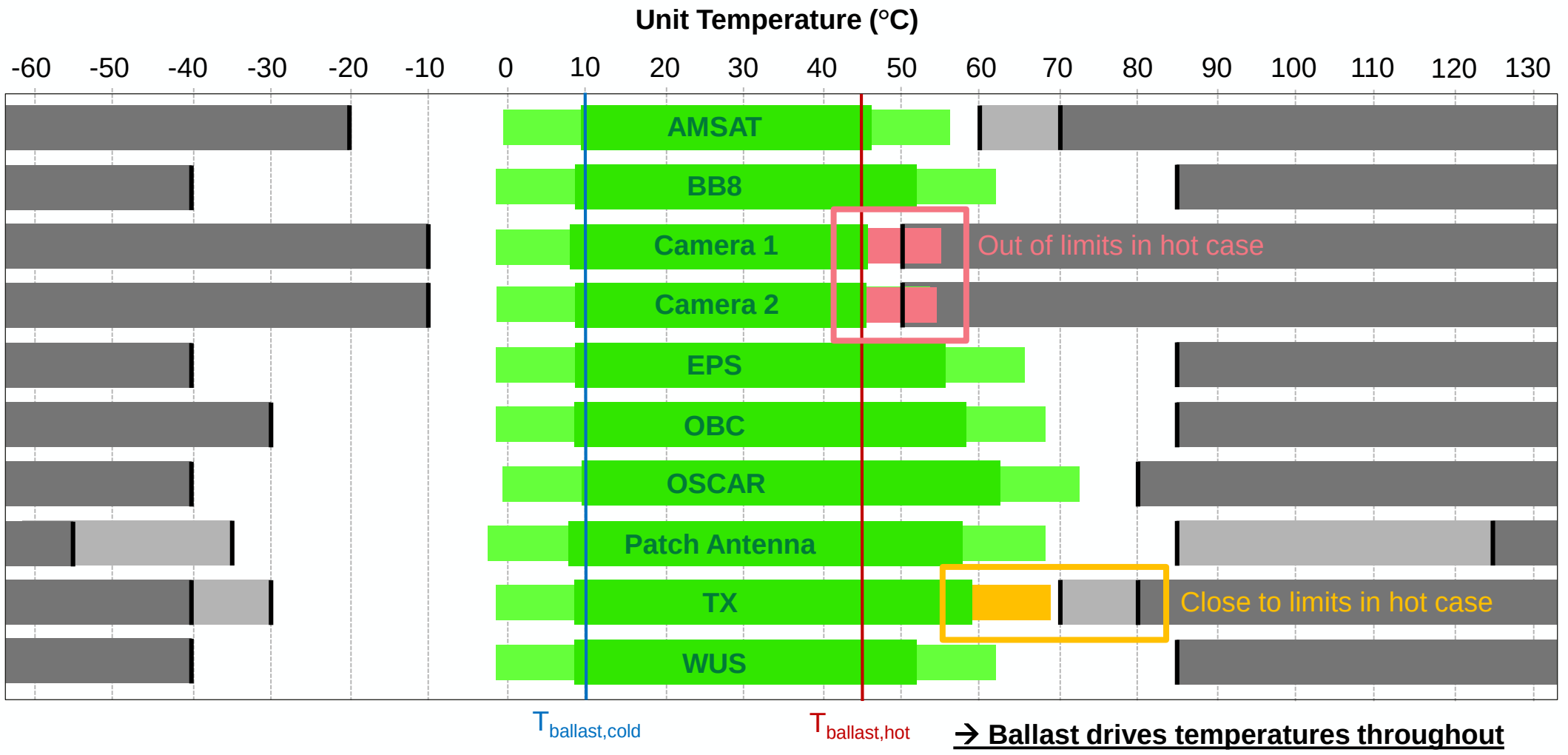
Cold Cases

Case	Orbit	Roll?	Ballast Temp (°C)
CC01	Min. eclipse	Yes, constant 1°/sec	10
CC02	100% sunlit	Yes, constant 1°/sec	10

Camera cold case

- Total of five main cases (3 hot, 2 cold)
- Ballast at +45°C for hot, +10°C for cold

Results Overview



→ **Ballast drives temperatures throughout**

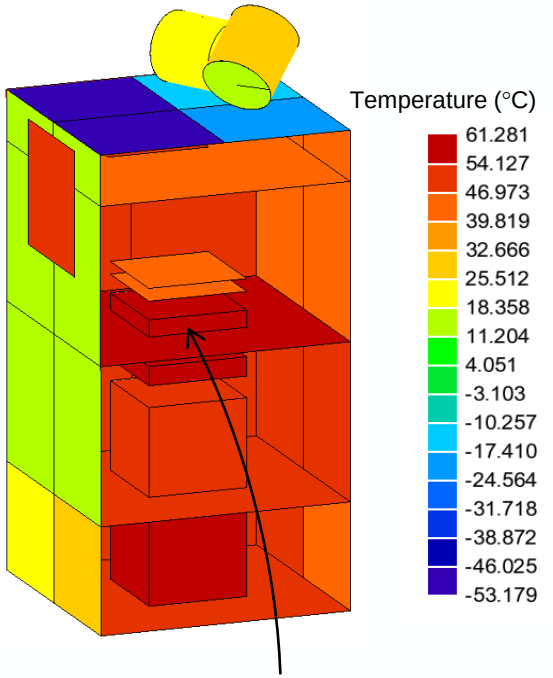
Transmitter

Problem

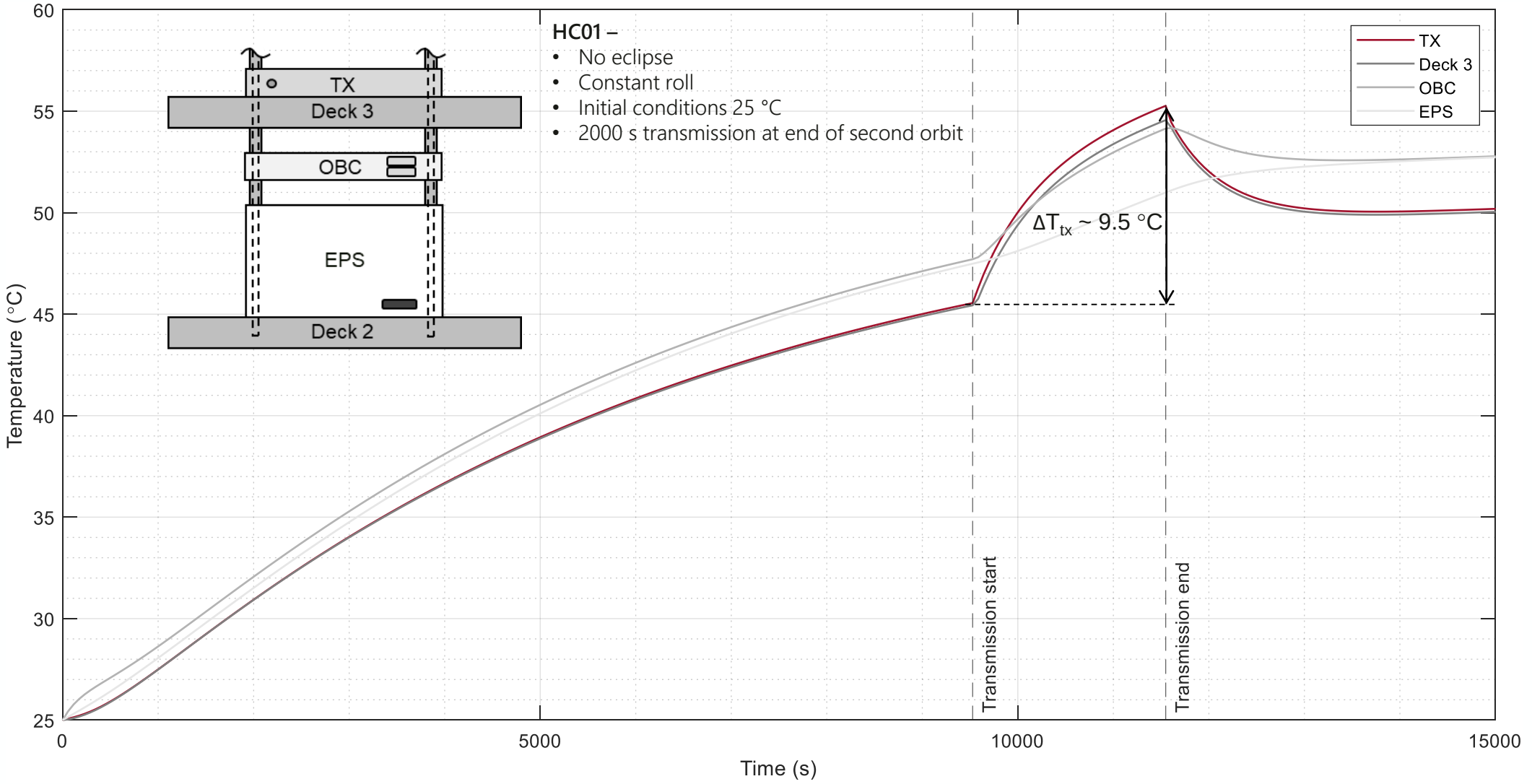
- Only one opportunity to downlink before re-entry
- This transmission window can be up to 2000s long
- To maximise downlink, transmitter will run at full power (dissipation ~ 7 W)
- Transmitter switches to idle at 70°C → mission failure
- 2-3°C margin in hot case… more margin desired

Solution

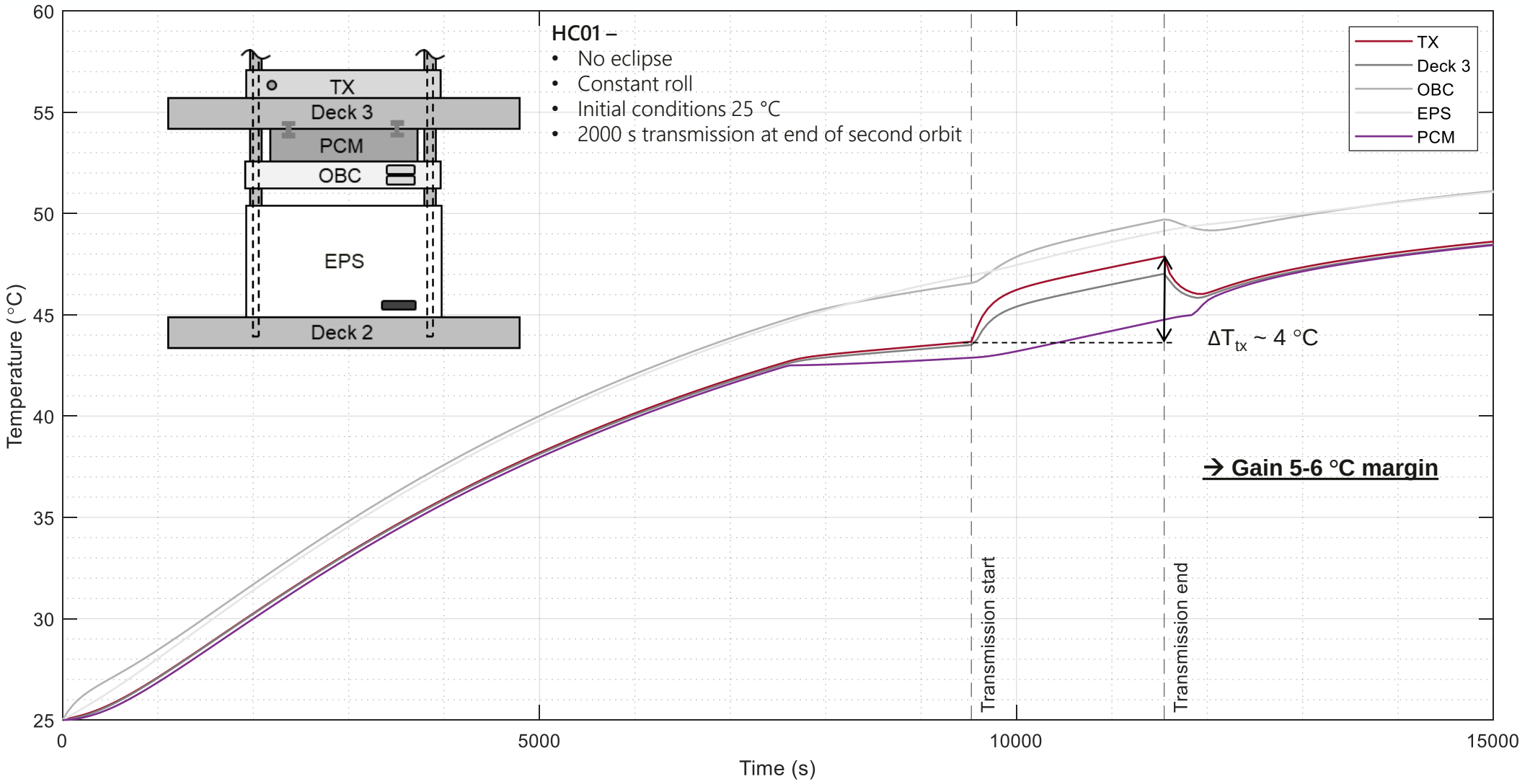
- Increase thermal capacitance to dampen temperature spike
- PCM heat capacitor unit from Belgian supplier
- Docosane ($C_{22}H_{46}$) with melting temperature 42.5°C
- Not mass-constrained + flexibility in stack configuration = straightforward integration



Transmission Example – without PCM



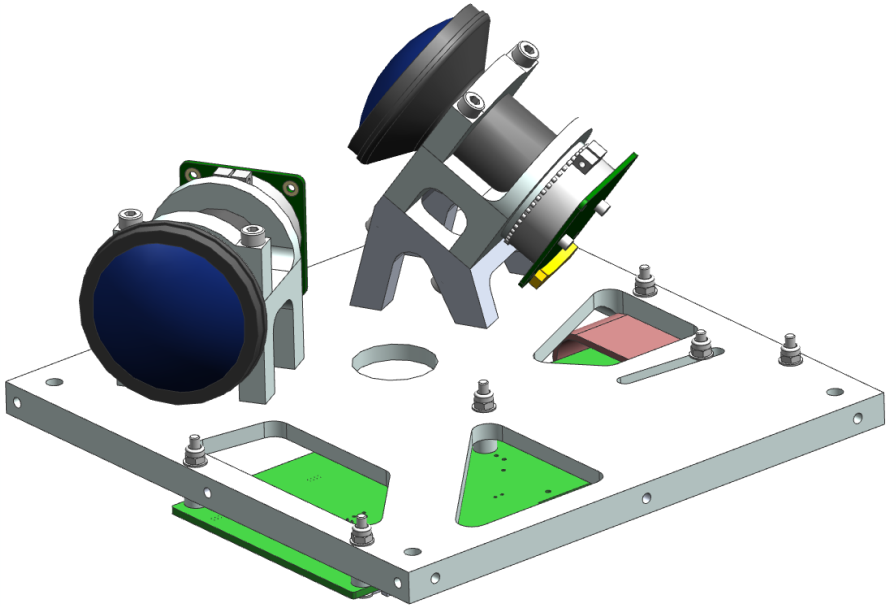
Transmission Example – with PCM



Cameras

Problem

- Camera operating limits are -10 to +50 °C
- Camera body is exceeding upper limit in all hot cases due to ballast
- Primary payload → Mission critical



Potential Solutions

- Increase coupling to structure?
  - Assuming ballast at 45 °C , +X panel will be close → not effective
- Small radiator on +X, e.g. SSM tape?
  - Minimal radiating area available due to cut-outs in panels

Ideal Solution…

- The problem disappears
  - Unit-level TVAC thermal balance of full camera assembly to correlate GLs
  - More refined modelling of camera housing, lens, and bracket
  - Revisit ballast temperature assumption

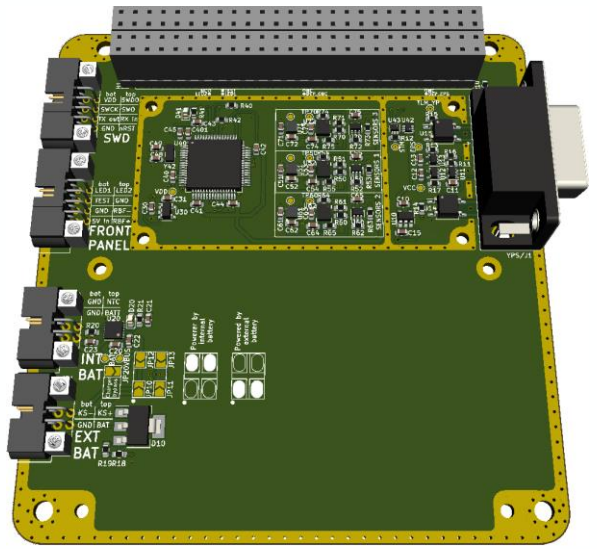
→ Remains an open issue

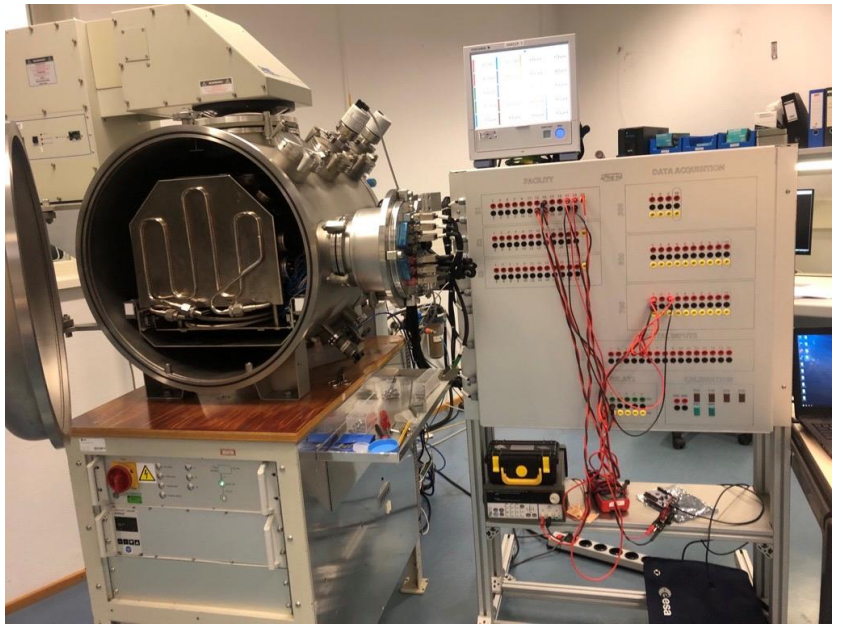

esa
5
Thermal
Testing &
Integration

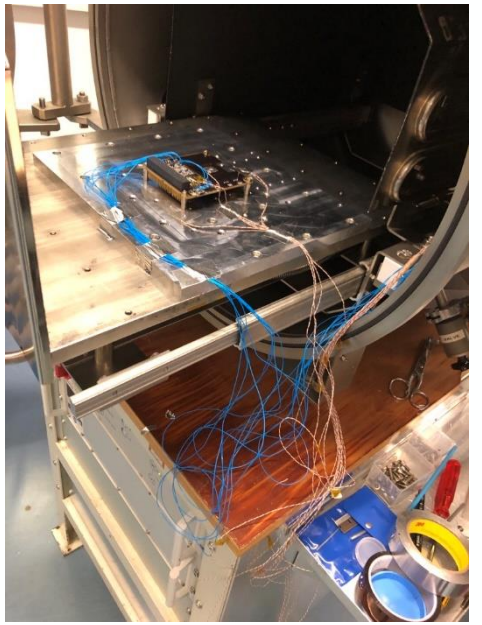
WUS Prototype TVAC

Wake-up System (WUS) Board

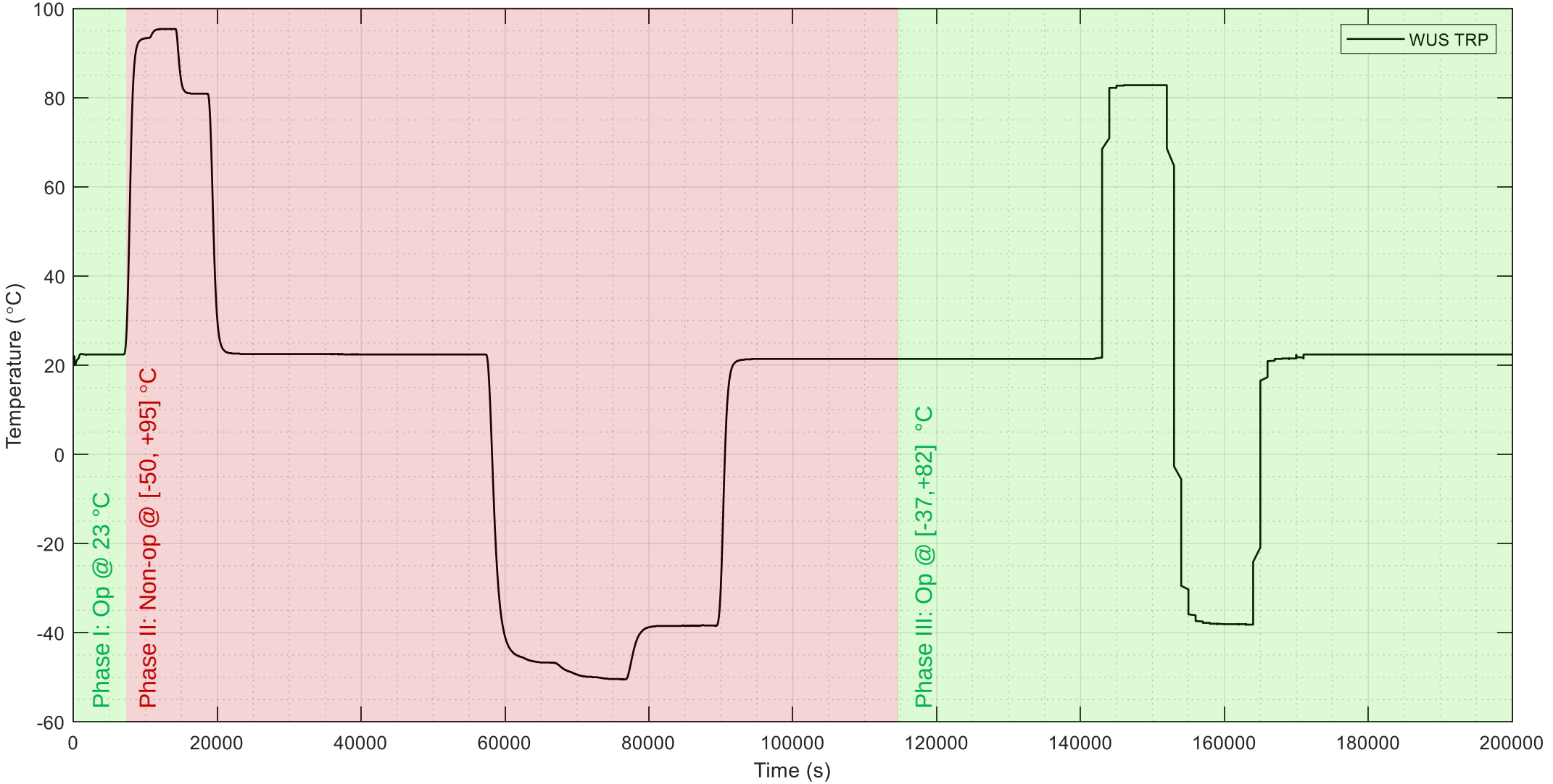
- Custom-built to enable self-detection of launch
- Allows spacecraft to conserve power and remain in hibernation between final battery charging slot and launch
- Detects launch with accelerometer, gyroscope & barometric pressure sensor → wakes up the spacecraft
- Mission critical → Functional testing in vacuum required





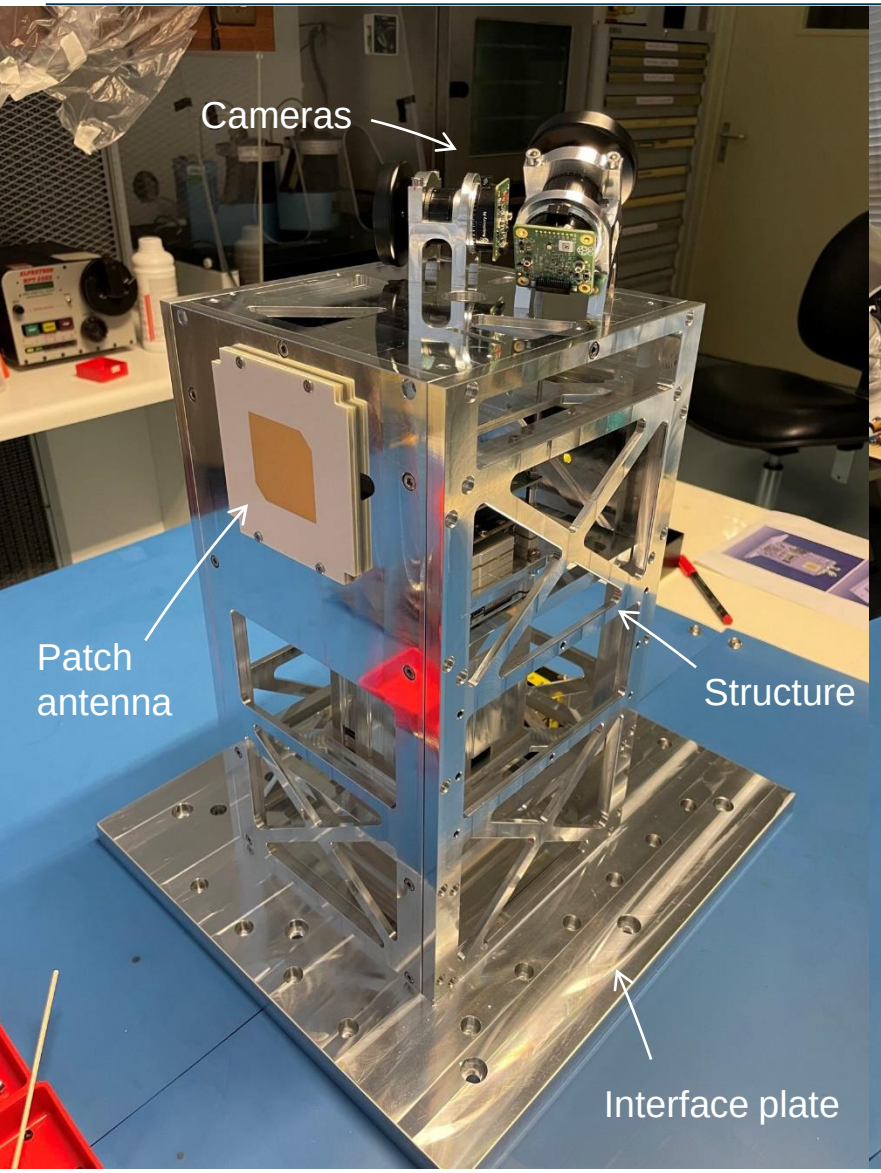


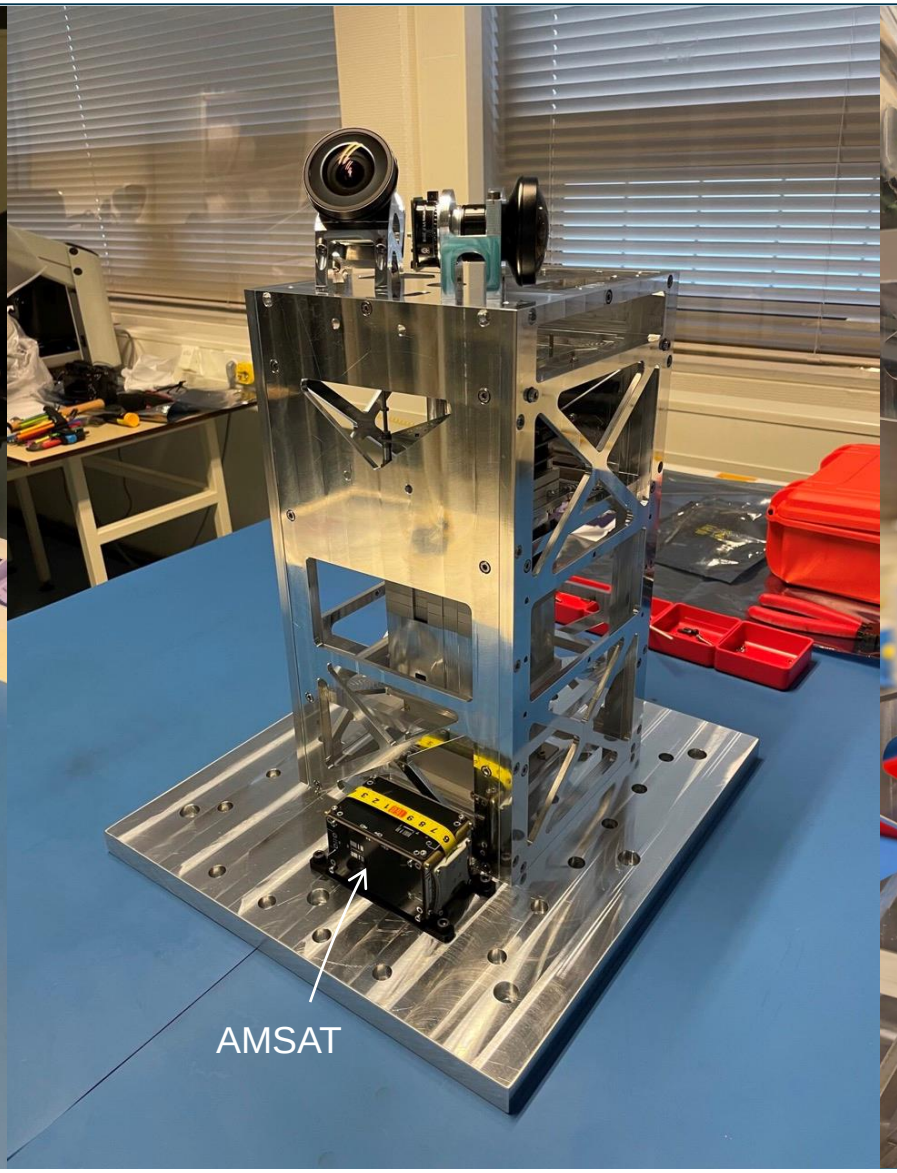
WUS Prototype TVAC

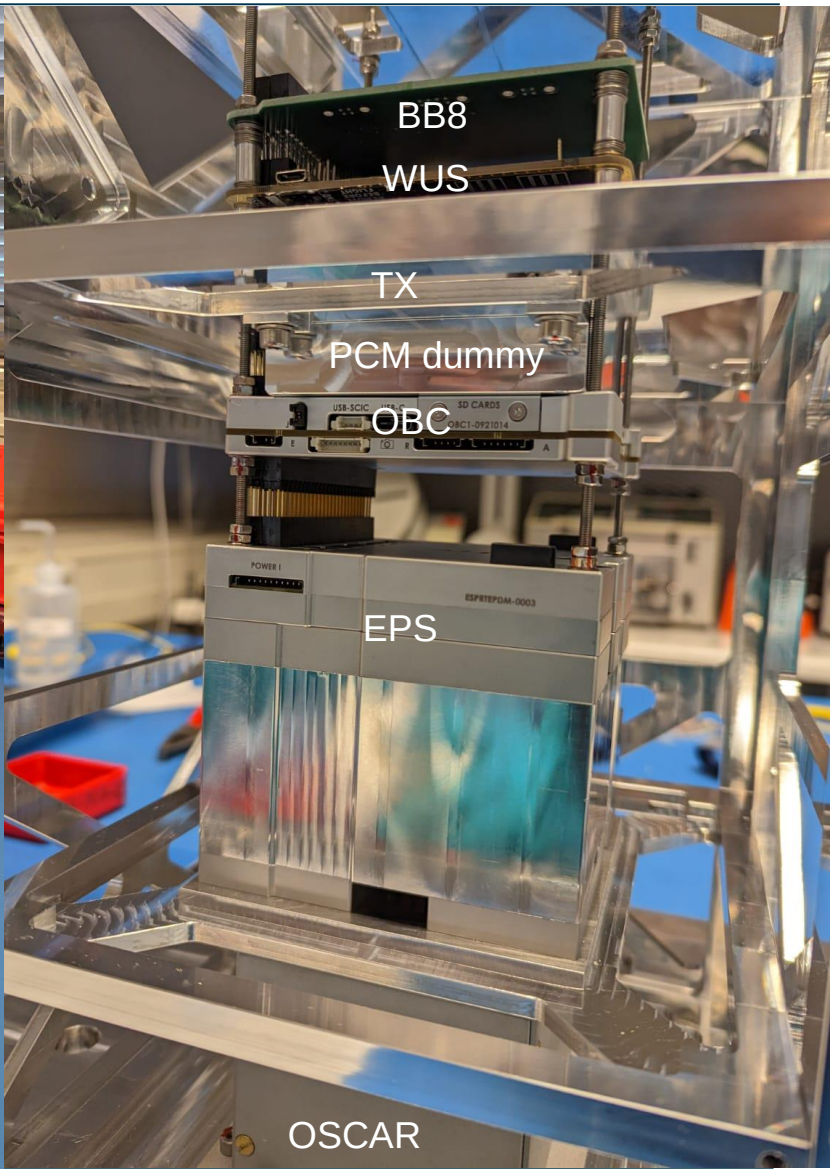


→ **Performed successfully in vacuum, well-beyond flight predicted temperatures**

State of Hardware







6 Conclusions

Future Work

Analysis & Design

- Correlation of test data for cameras and PCM. Verification of camera temperatures
- Aerothermal flux effects during fairing separation (up to 540 W/m^2)
- Heating effects inside fairing before launch

Integration & Testing

- Unit-level derisking & qualification TVAC campaign in MSL
- Manufacture & integration of FM MLI blankets at ESTEC
- Spacecraft-level acceptance TVAC campaign in MSL

Conclusions

- Analysis based on very conservative assumptions for robustness of thermal design
- Passive thermal hardware only
    - MLI blankets made at ESTEC
    - First ever flight of a European-built PCM
- Cameras are primary concern
- Long time since a spacecraft being built at ESTEC
- Incredible learning experience!

Acknowledgements

- **YPSat team**
- **TEC-MT**
    - Stephane Lapensee
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- **ESTEC Workshop**


Thank you for your attention
Any questions?