TFAWS Active Thermal Paper Session

Numerical analysis of the Thermal Control System for the K'OTO nanosatellite

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Virtual Conference

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  - The Advanced Technology Unit
  - Satellite's Layout
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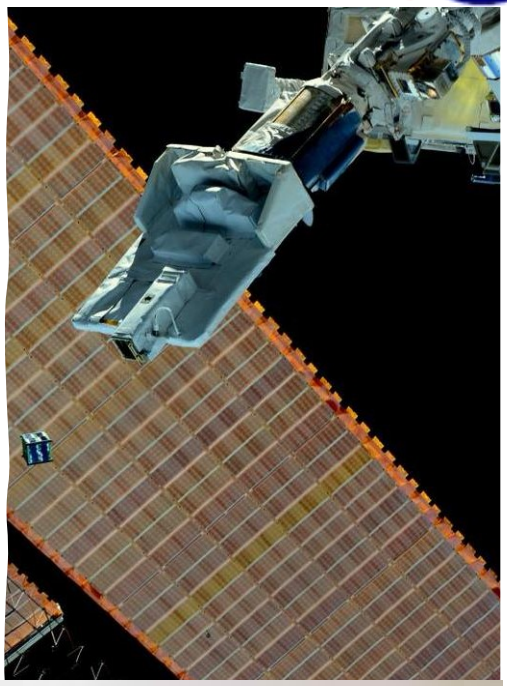
The K'OTO CubeSat

- **Mission:**

The K'OTO CubeSat has the mission of **take photographs of low-medium resolution over the Mexican territory and transfer it to the earth on the ham band**.

- **Aim:**

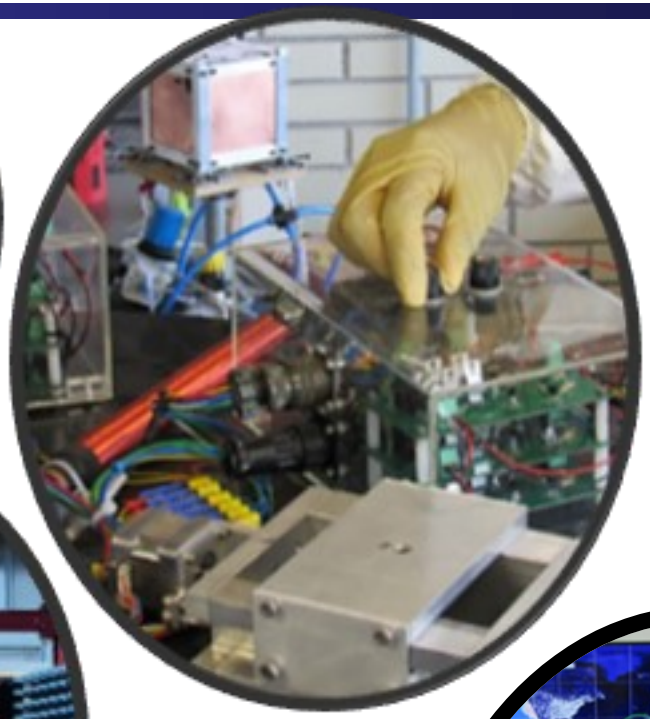
The aim of this research **is proposing a thermal control system for the K'OTO satellite and determine if is required the use an active thermal control system.**



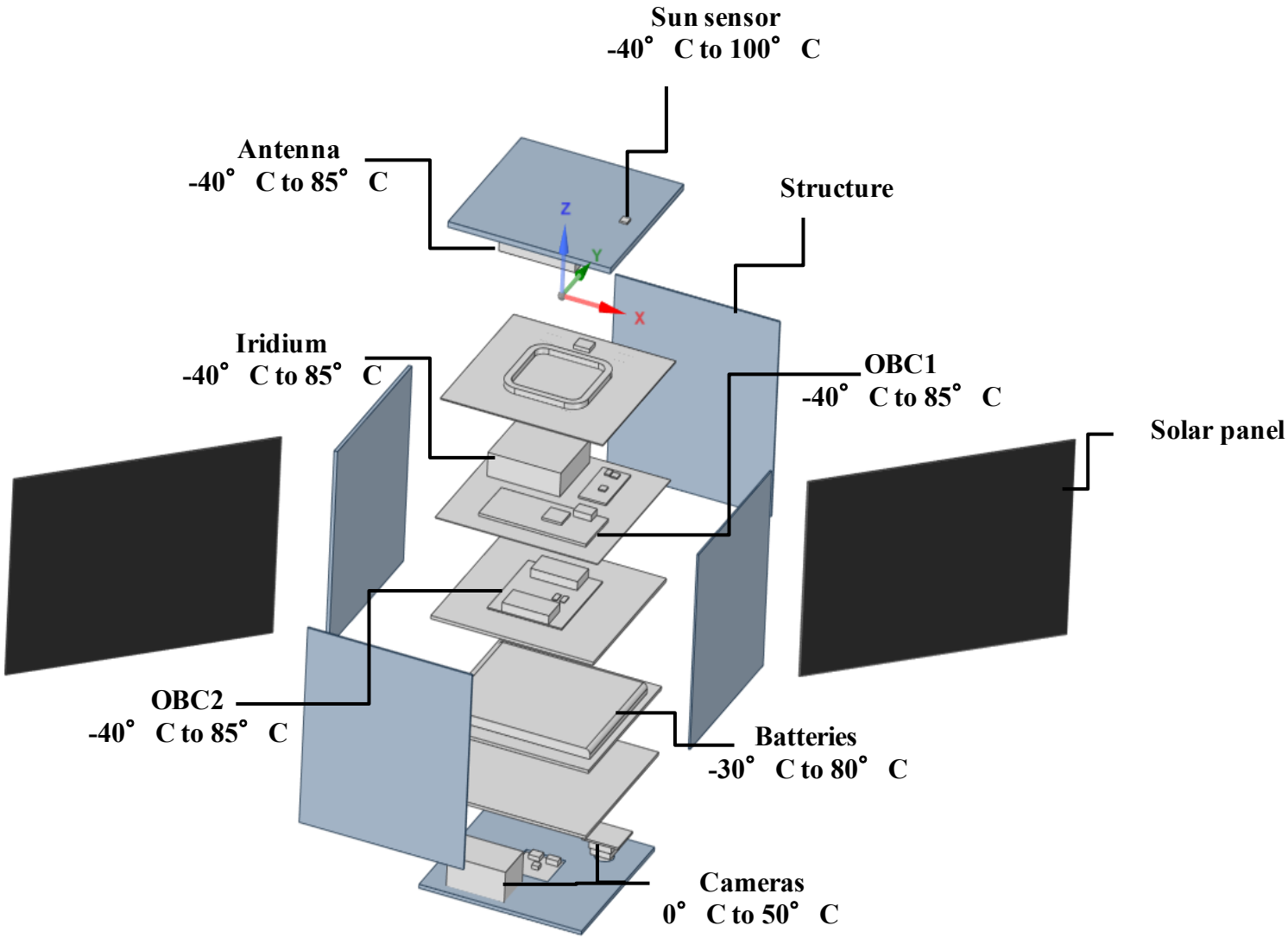
National Autonomous University of Mexico

The Advanced Technology Unit is in Queretaro State

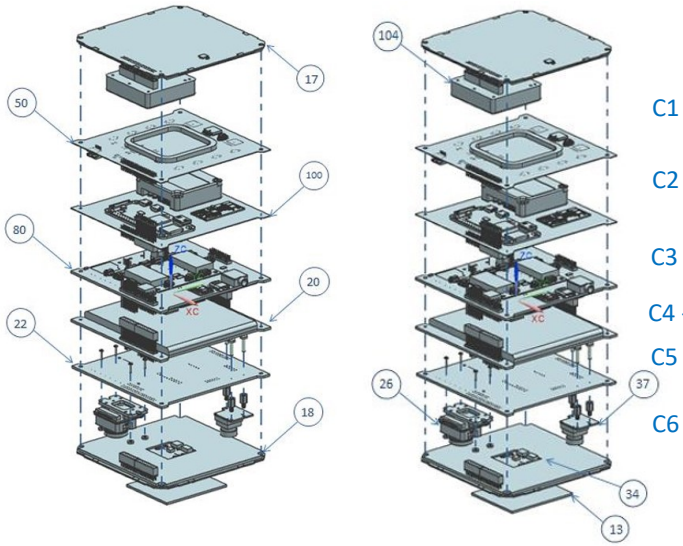
National Laboratory



Satellite Layout



Methodology



C1 - ADCS

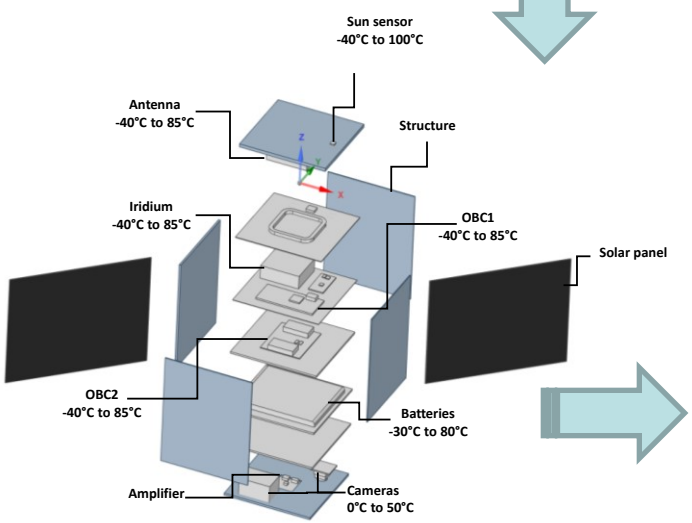
C2 - OBC2

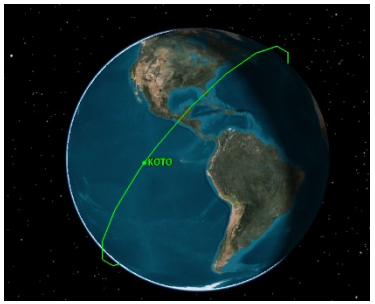
C3 - OBC1

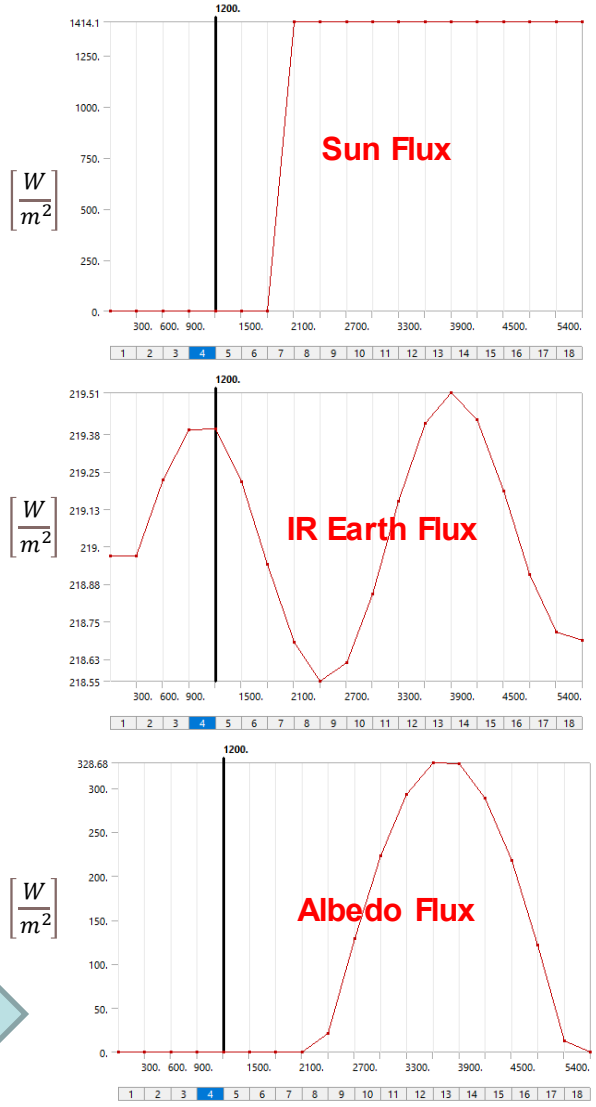
C4 - Batteries

C5 – Free board

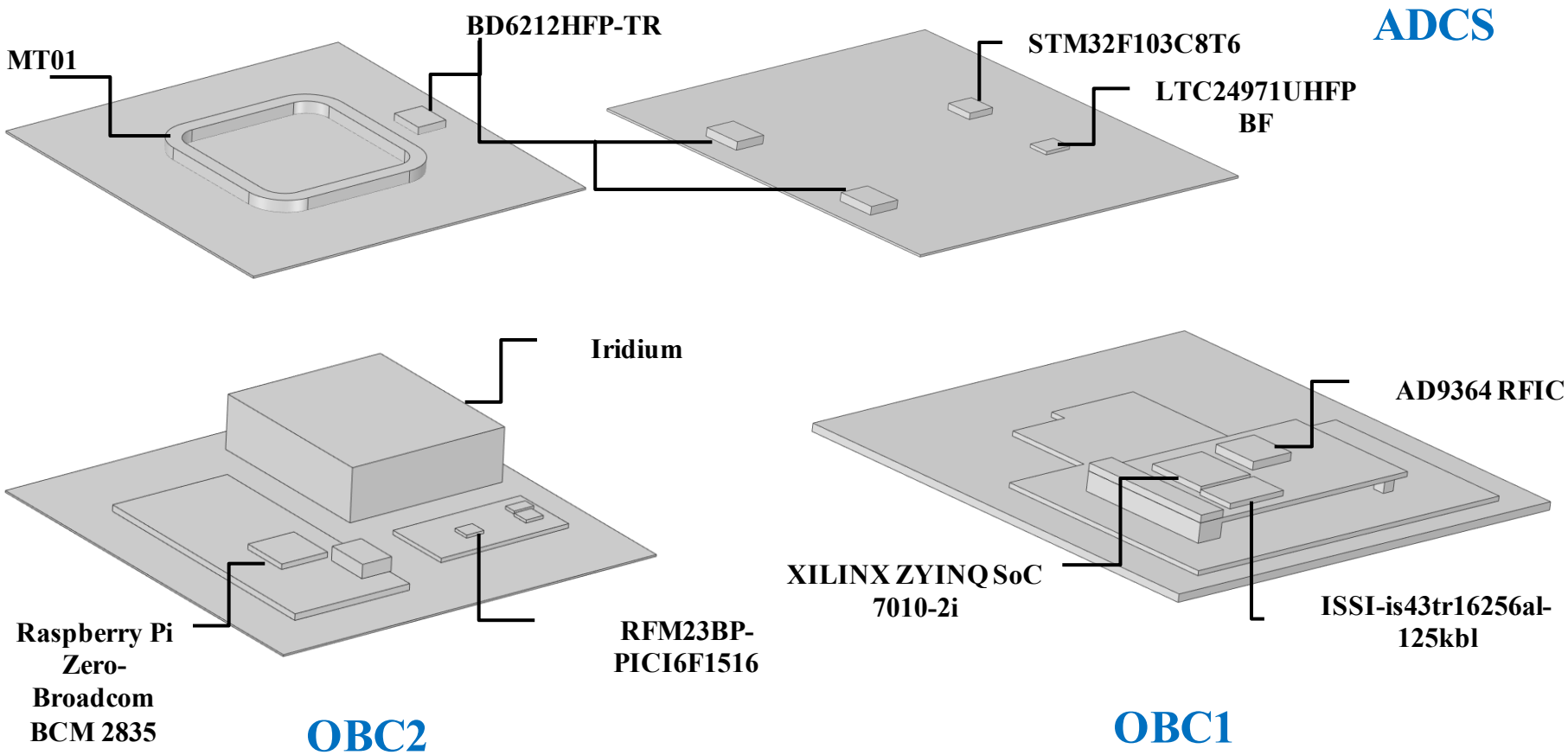
C6 - Cameras y amplifier



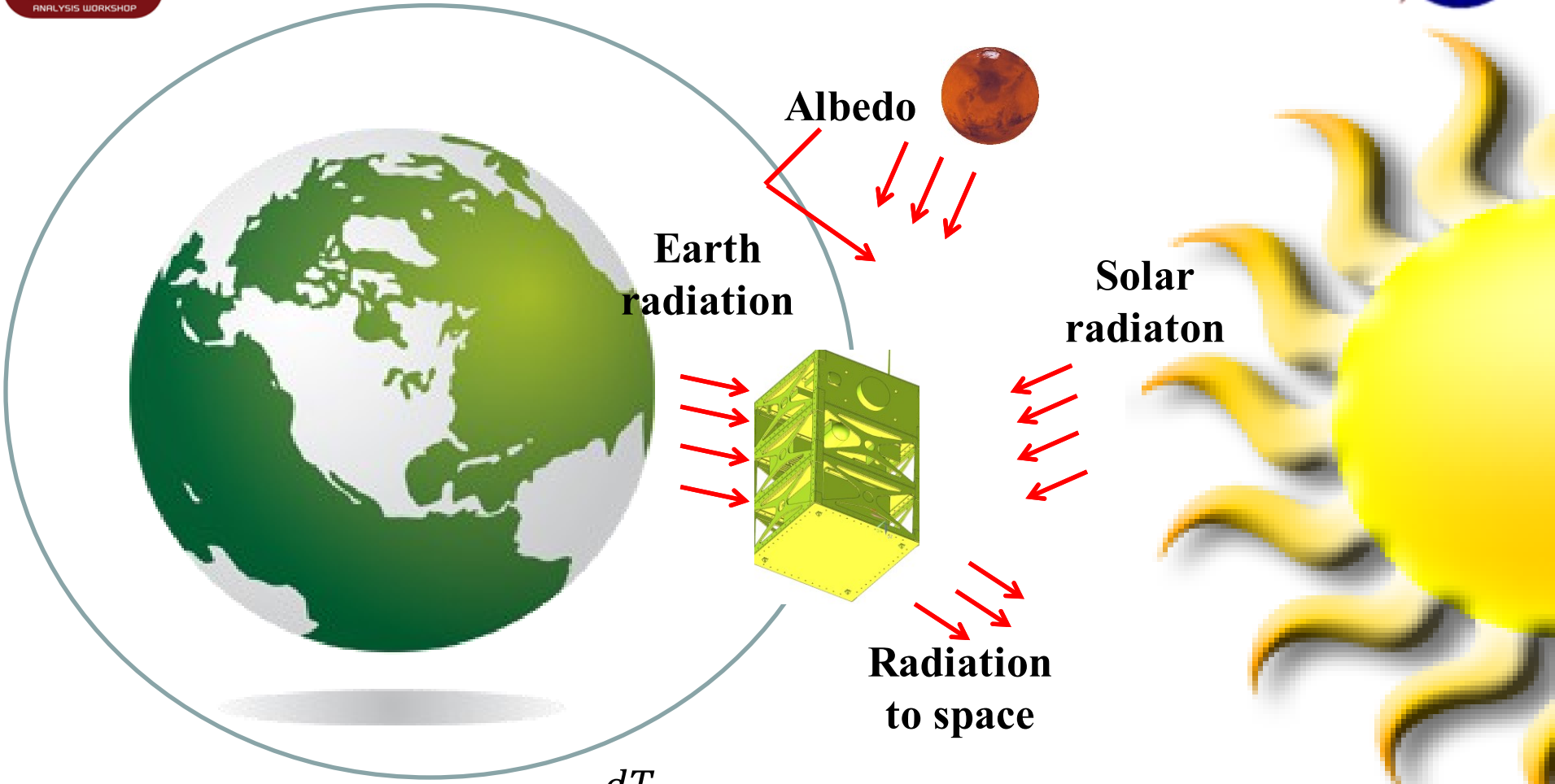




Methodology



Thermal Balance



$$mCp\frac{dT}{dt} - \sigma A \epsilon F_{sat \to e} T^4 - \dot{Q}_c = \dot{Q}_S + \dot{Q}_a + \dot{Q}_{IR}$$

Space Environment

- The K'OTO satellite will be launched early 2022 from the KIBO module. Therefore, the analysis considers the Keplerian elements of the ISS
- The space environment data was extracted accounting the satellite vectors were taken from its position with respect to Sun, Earth, and the satellite height. Then this data was postprocessed according to the following equations.

Space Environment

- Solar Flux

$$F = \frac{(1\ AU)^2}{(r_{sun})^2} \qquad \dot{Q}_{sun} = FI_{sun}\left(1367\,\frac{W}{m^2}\right)$$

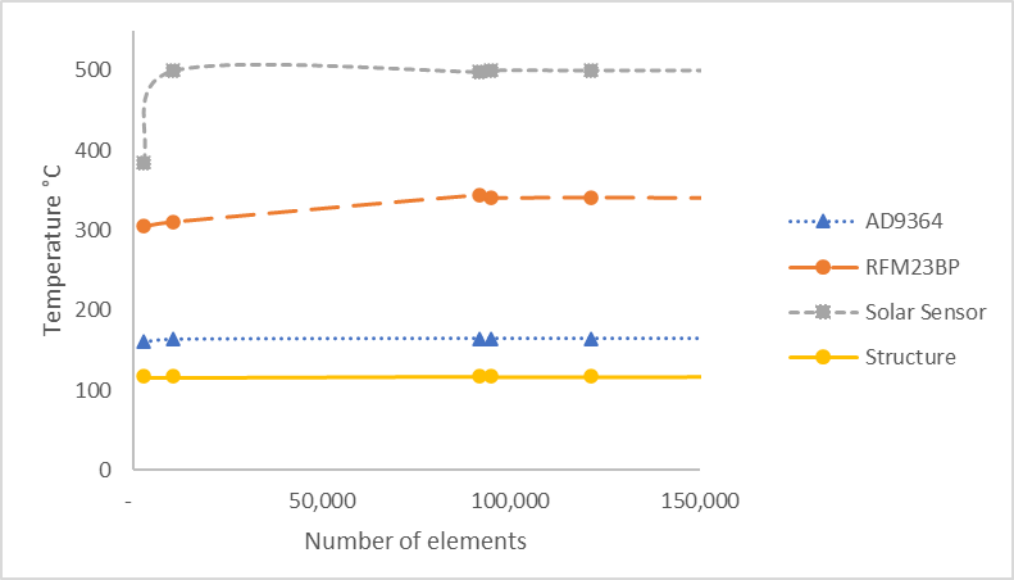
- IR Earth Flux

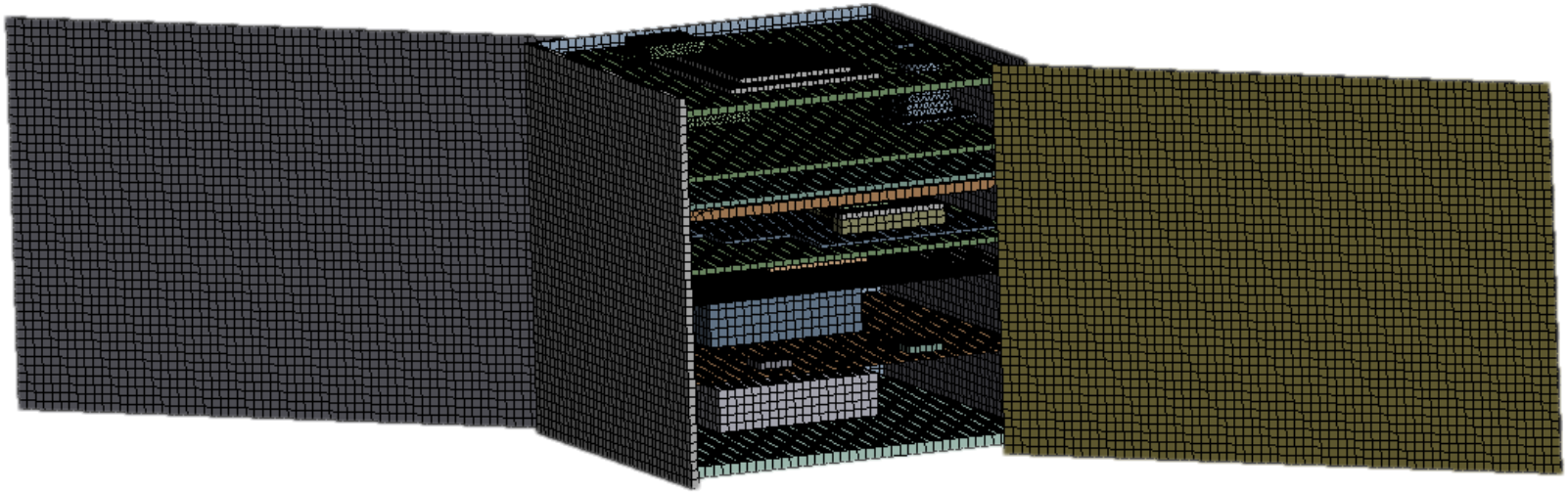
$$F_G = cos\left(\frac{R_p}{R_p + h}\right)^2 \qquad \dot{Q}_{earth} = FF_G\left(241\,\frac{W}{m^2}\right)$$

- Albedo Flux

$$\theta = cos^{-1}\left(\frac{\vec{r}_{sun} \cdot \vec{r}_{earth}}{\|\vec{r}_{sun}\|\,\|\vec{r}_{earth}\|}\right) \qquad \dot{Q}_{albedo} = \left(410.1\,\frac{W}{m^2}\right) FF_G cos\theta$$

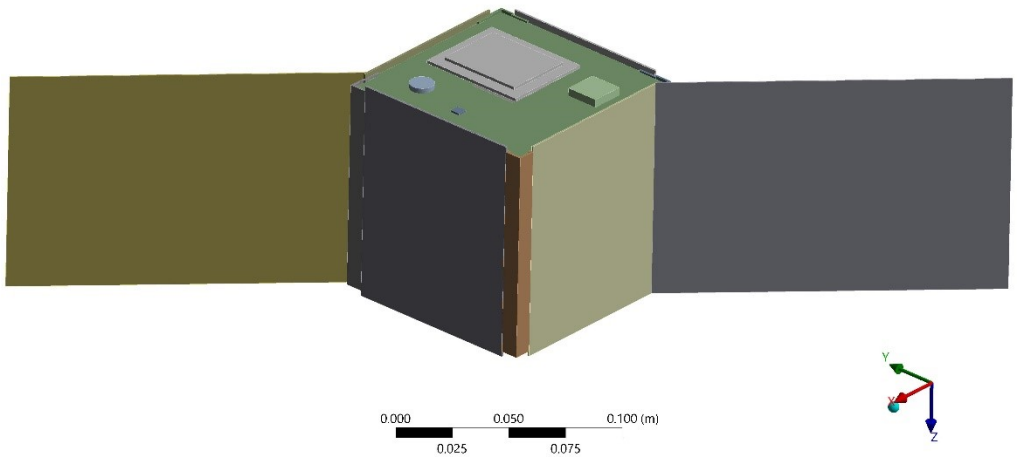
Mesh


500
400
300
200
100
0
Temperature °C
-
50,000
100,000
150,000
Number of elements
AD9364
RFM23BP
Solar Sensor
Structure

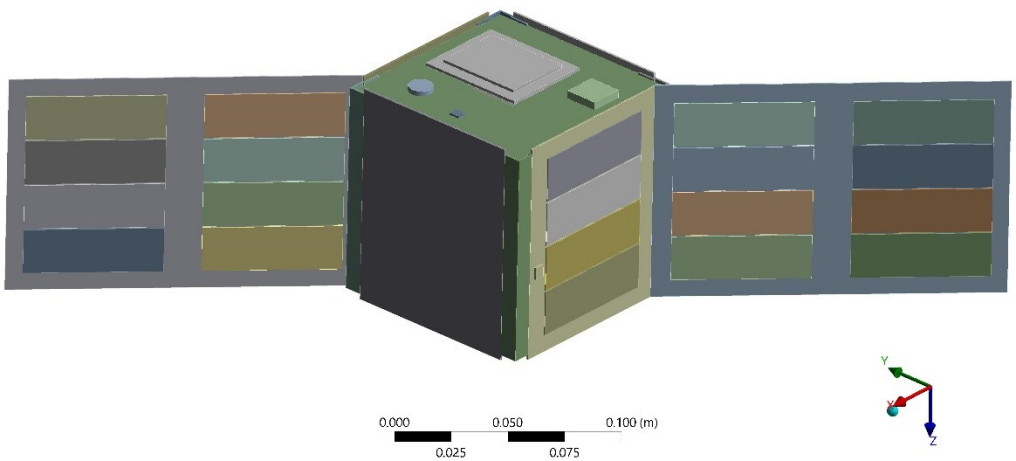


Cases Modeled

- Case 1. Without TCS



- Case 2. With TCS



- **White paint**
- **MLI**
- **Solar Cells**

Model Setup

Thermophysical properties

Material	Conductivity [W/mK]	Specific Heat [J/kg K]	Density [kg/m^3]
Aluminium 6061	167.9	1256	2770
Aluminium LM24	100	880	2790
Fr4 2oz Copper	17.7	600	1910
Silicon Solar Cell	25	712	2330

Optical properties

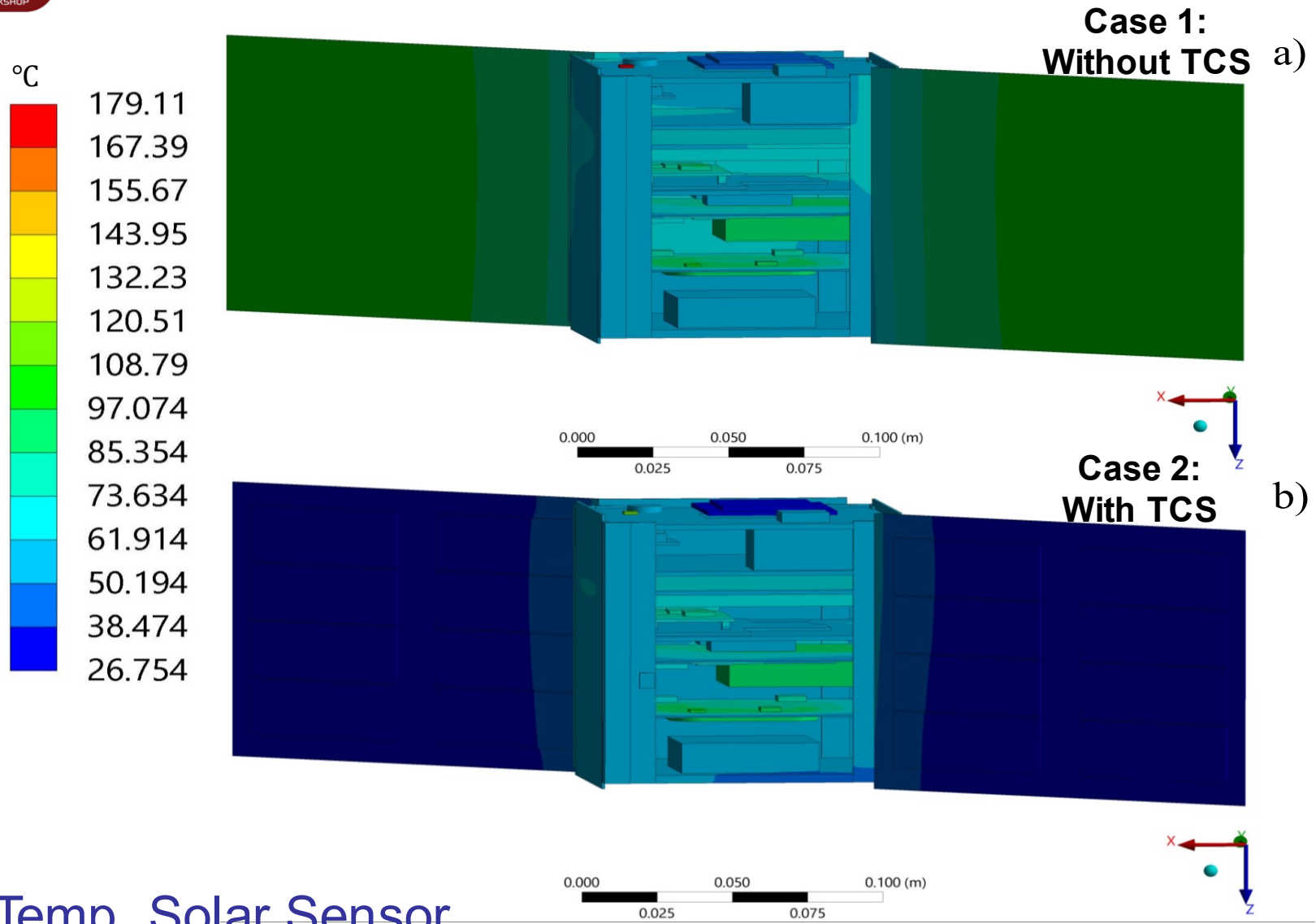
Material	Absorptivity	Emissivity
MLI	0.2	0.8
Solar Cells	0.85	0.85
Zerlauts Z-93 White Paint	0.17	0.92

Internal power dissipation ~25 [W]

Power dissipation of internal components

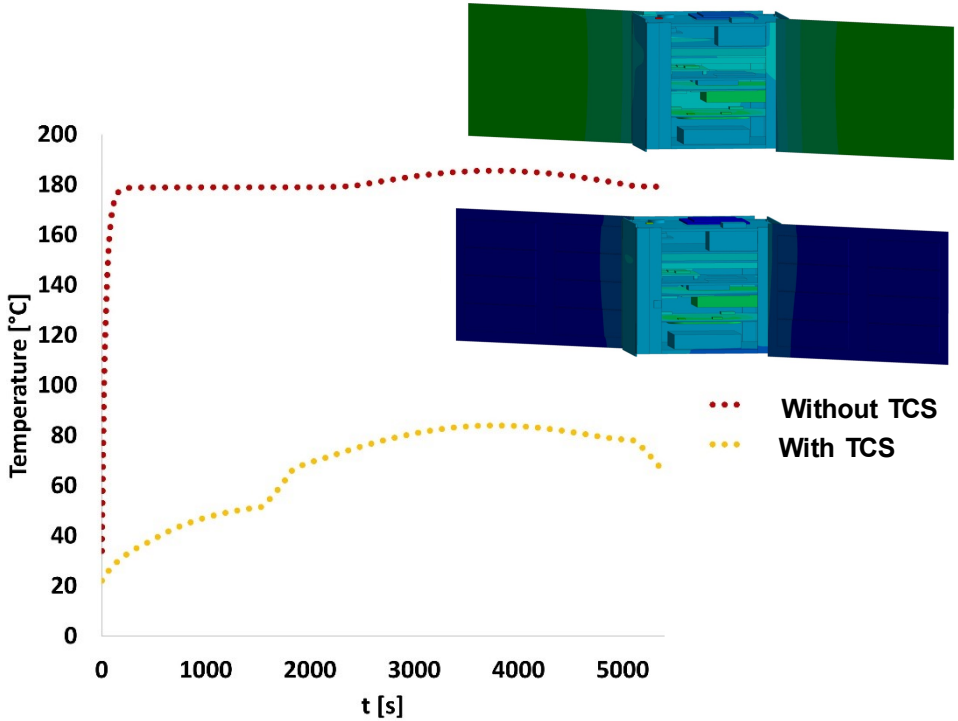
Board	Component	Power dissipation [W]	Operational Temperature
ADCS	STM32F103C8T6	0.363	-40 to 85
	LTC24971UHFPBF	1.76	-40 to 85
	BD6212HFP-TR	0.832	-40 to 85
	MT01	2.66	-55 to 85
Top cover/Bottom cover	Solar Sensor	0.98	-40 to 100
OBC2	Iridium	3.75	-40 to 85
	Raspberry	0.875	-40 to 85
	RFM23BP	0.911	-40 to 125
OBC1	AD9364 RFIC	0.774	-40 to 85
	XILINX ZYINQ SoC 7010-2i	0.8	-40 to 100
	ISSI-is43tr16256al-125kbl	0.33	-40 to 95
Batteries	14 EXA Pegasus Class Battery	11.1	-30 to 80
		Total 25.135	

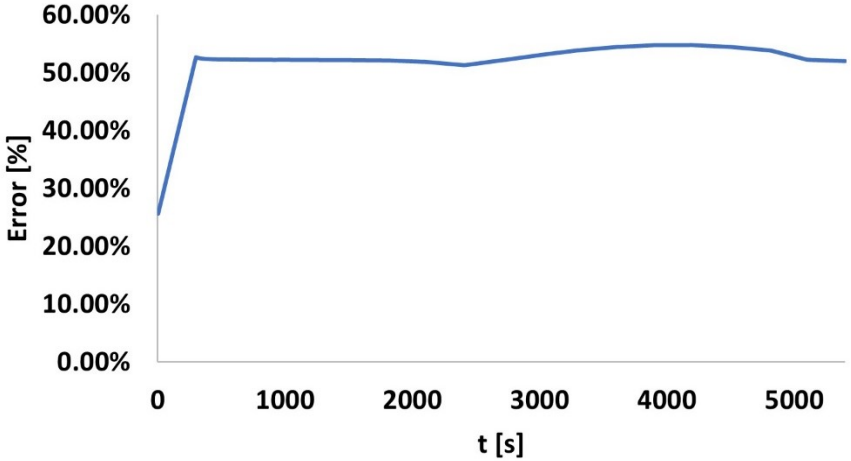
Results



Op. Temp. Solar Sensor
-40 °C to 85 °C

Results





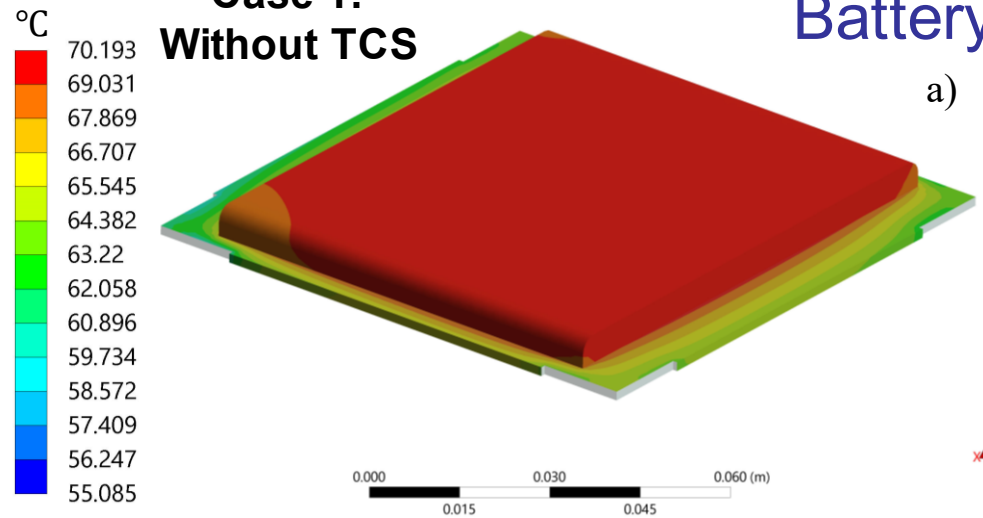
Op. Temp. Solar Sensor
-40 °C to 85 °C

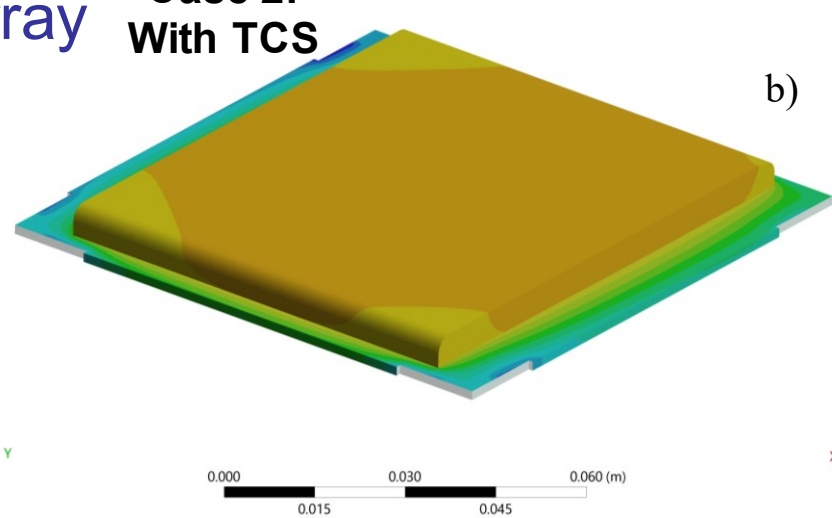
Results

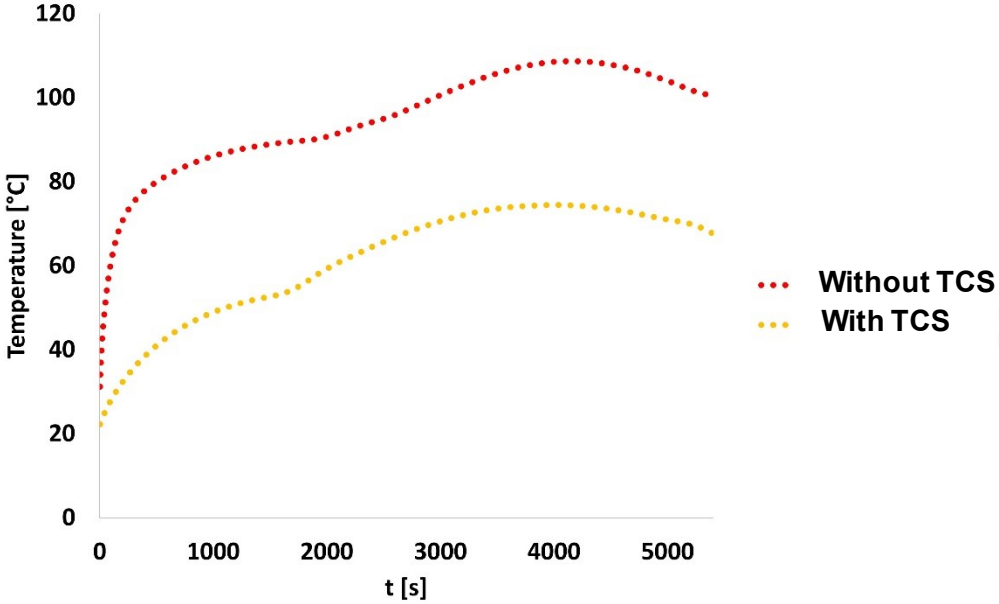
Battery Array

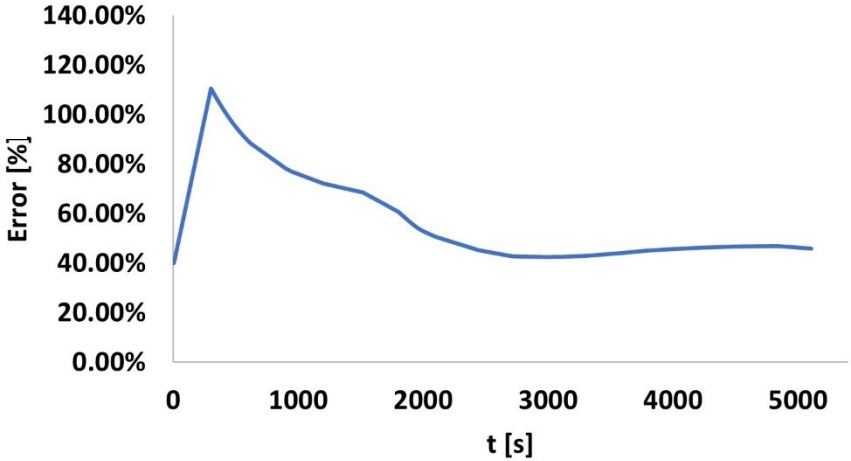
Case 1: Without TCS

Case 2: With TCS





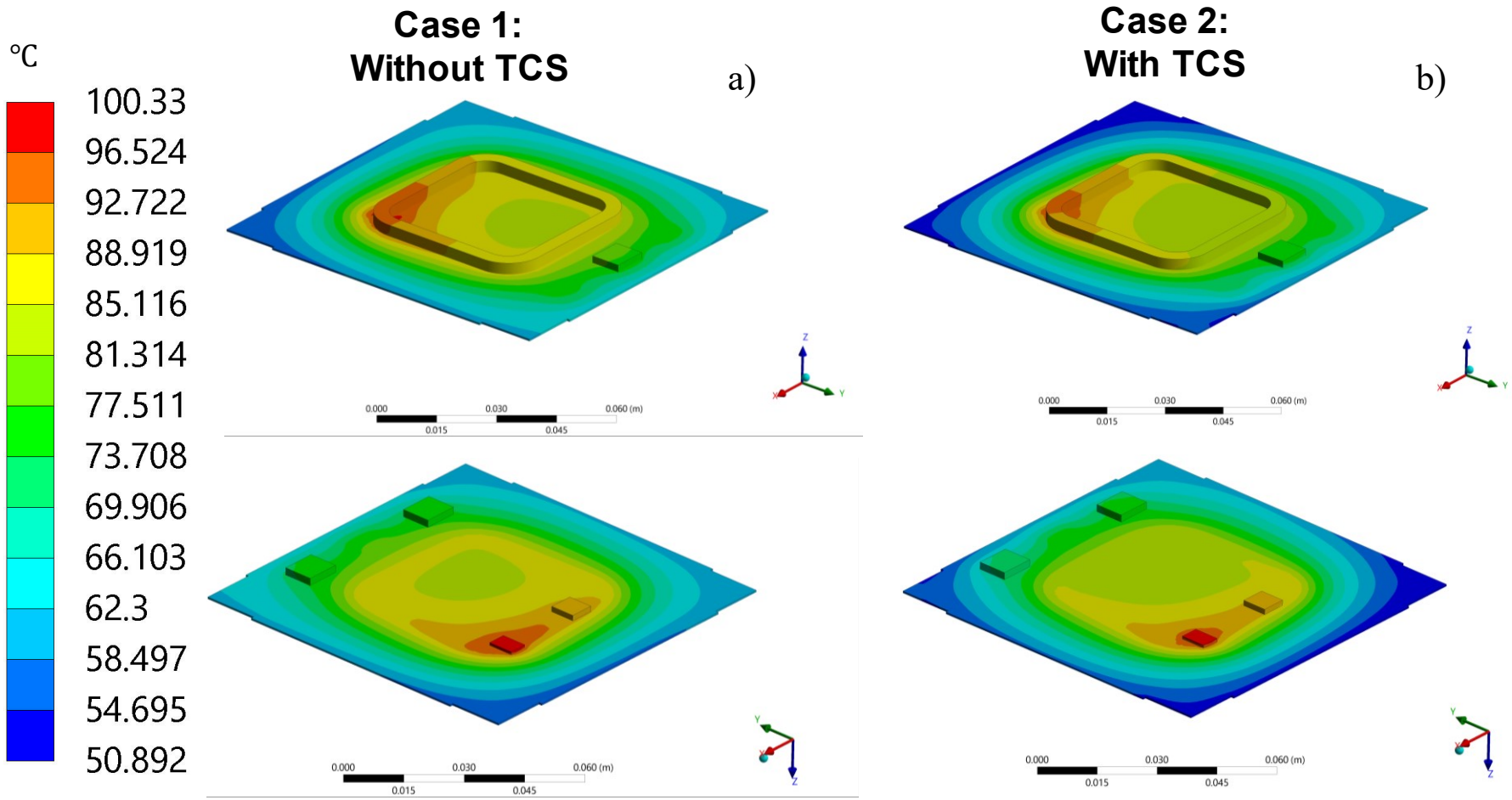




Op. Temp -30 °C to 80 °C

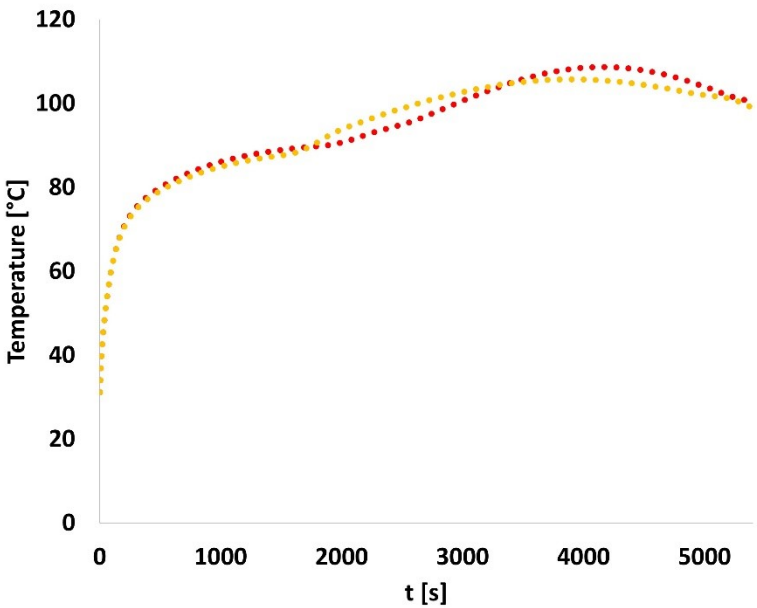
Results

ADCS

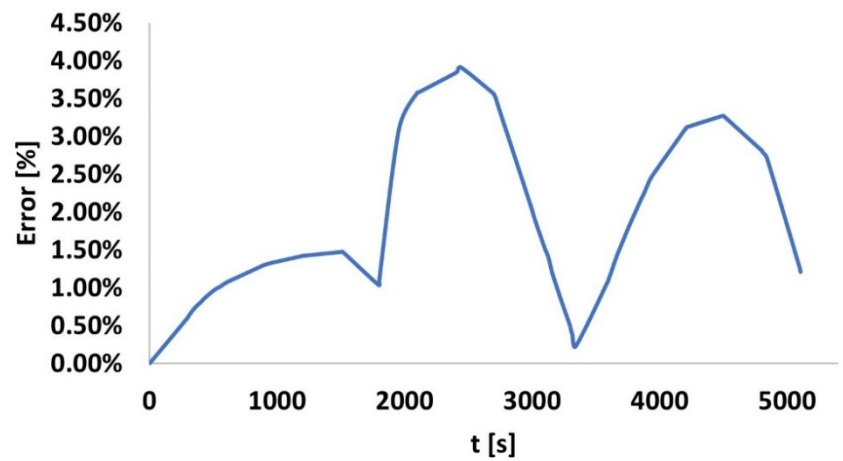


Op. Temp -40 °C to 85 °C

Results

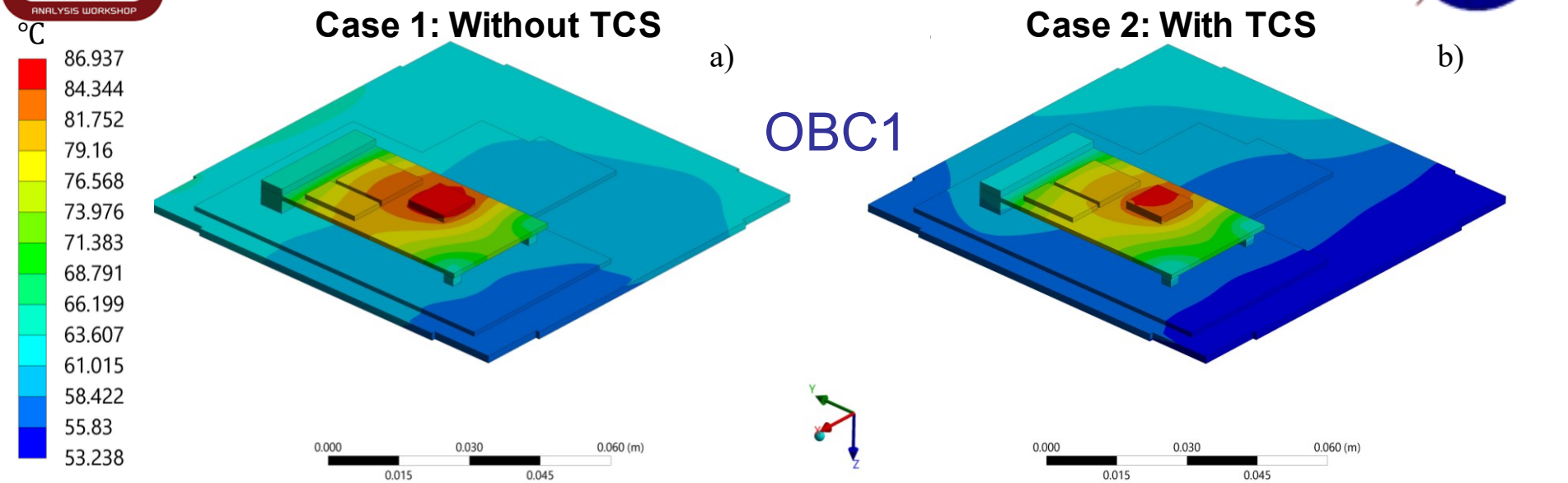


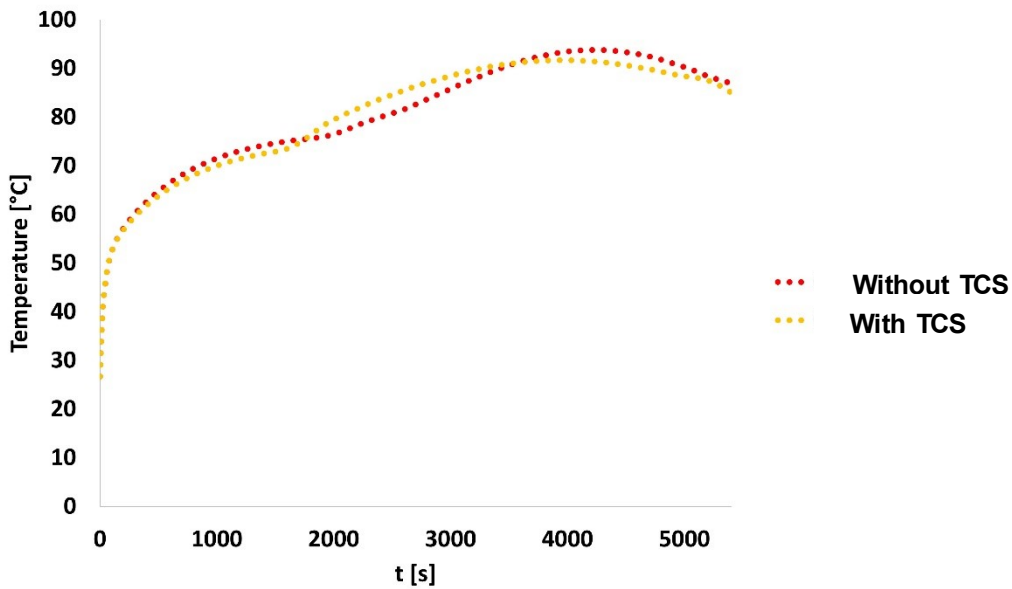
Without TCS
With TCS

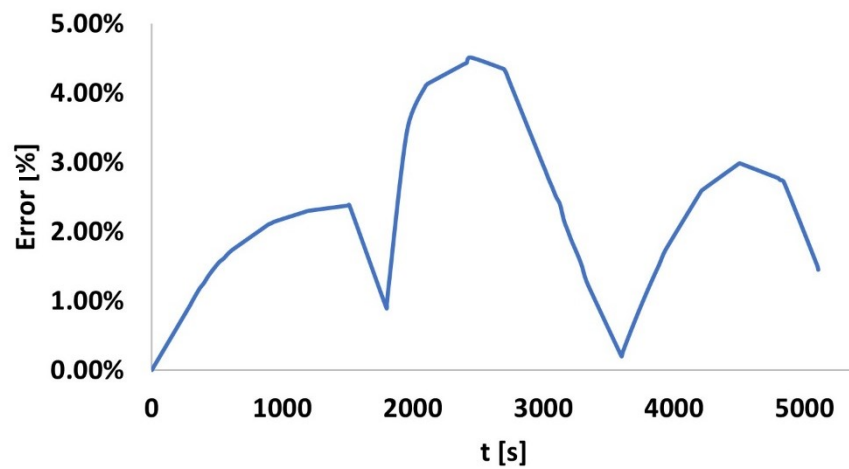


Op. Temp -40 °C to 85 °C

Results

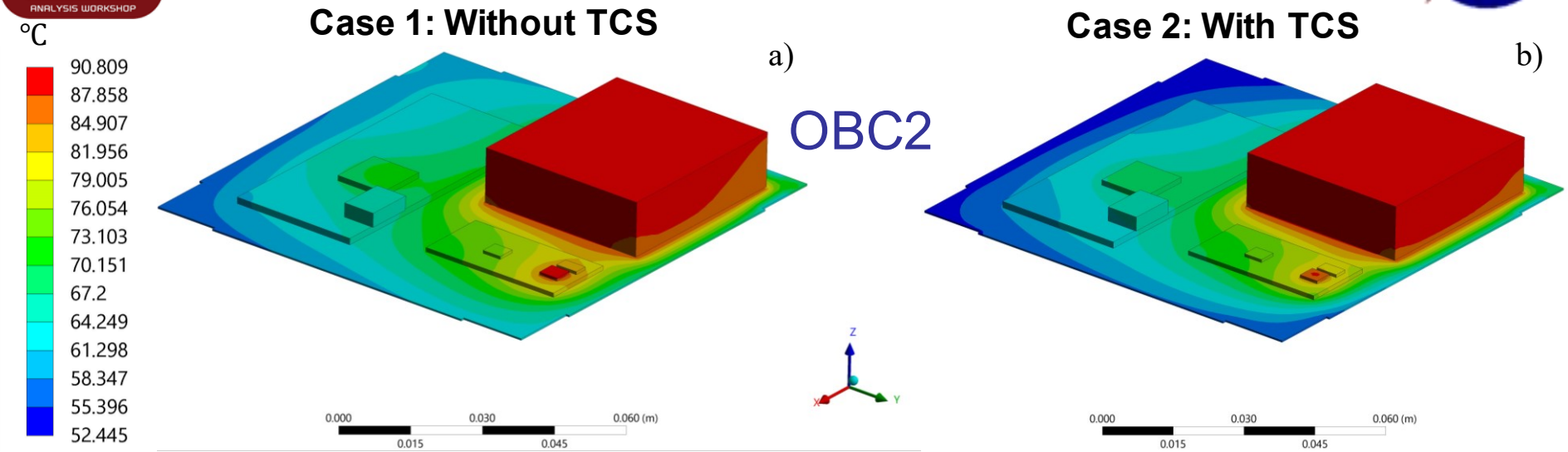


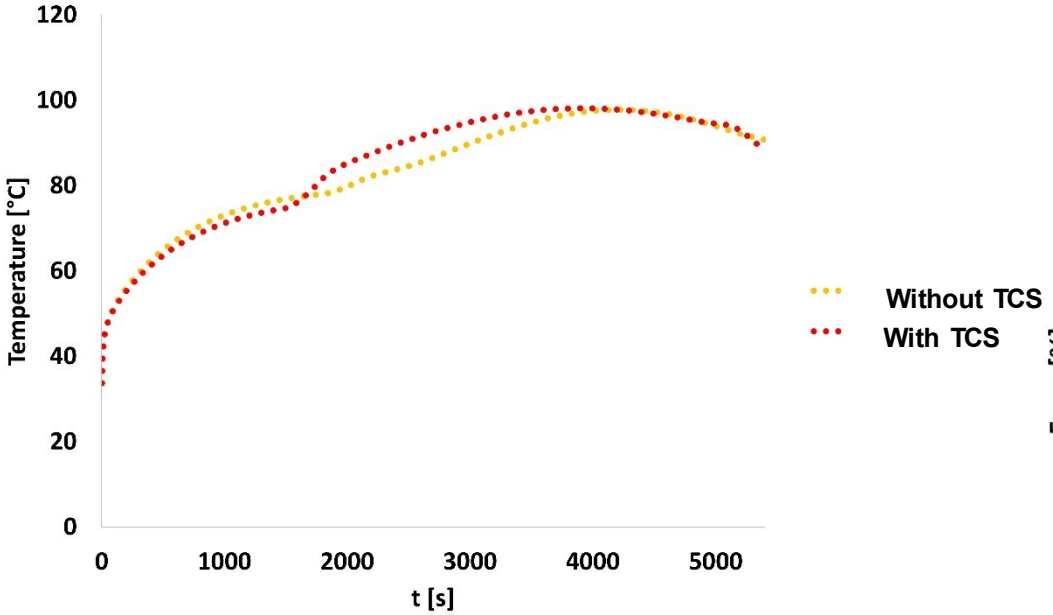


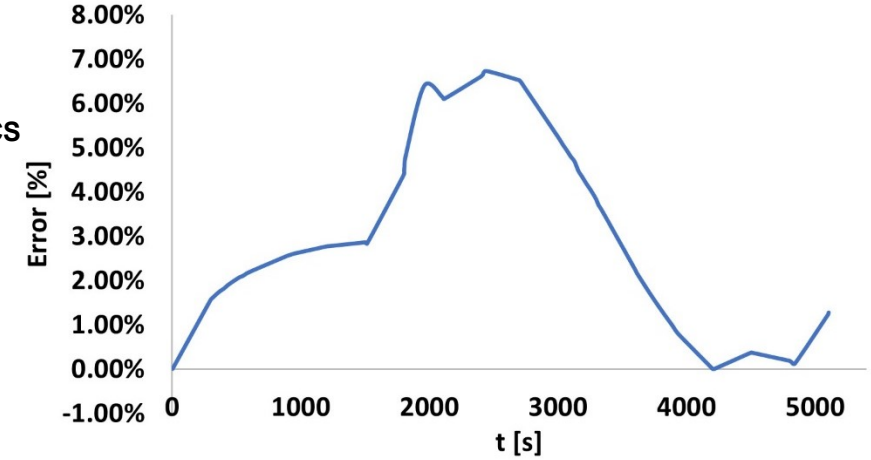


Op. Temp -40 °C to 85 °C

Results







Op. Temp -40 °C to 85 °C

Conclusions

- This work presented a methodology to analyze the distribution of temperatures for the transient hot case of K'OTO satellite using ANSYS Thermal. With this work we created lesson learned and best practices to use in new missions.

- Two cases were modeled, case 1: without a TCS and case 2: with a passive TCS. The TCS reduced around 53% of the temperature of the solar sensor and around 50% of the temperature of the batteries. However, the TCS proposed reduced just 3% of the temperature of the OBC1, the OBC2 and the ADCS components. Thus, it is recommended to add heat dissipators to these systems such as thermal straps.

- Further work is needed to model the cold case and to validate the numerical analysis versus experiments such as vacuum test or IR imaging. Moreover, the model will be improved adding five cycles (satellite's orbit) to reach the steady state.

Acknowledgements

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Thank you!

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