Cubesats: A passive thermal analysis approach

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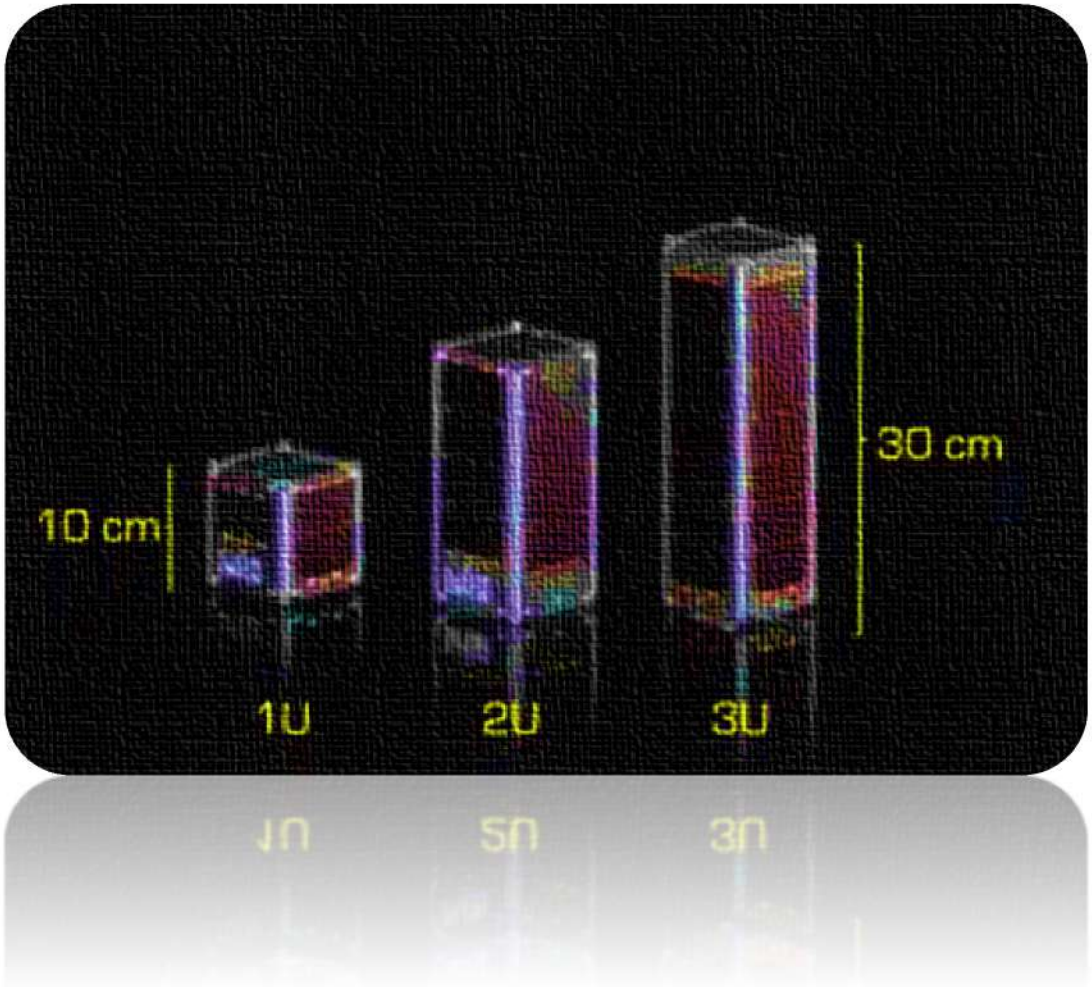
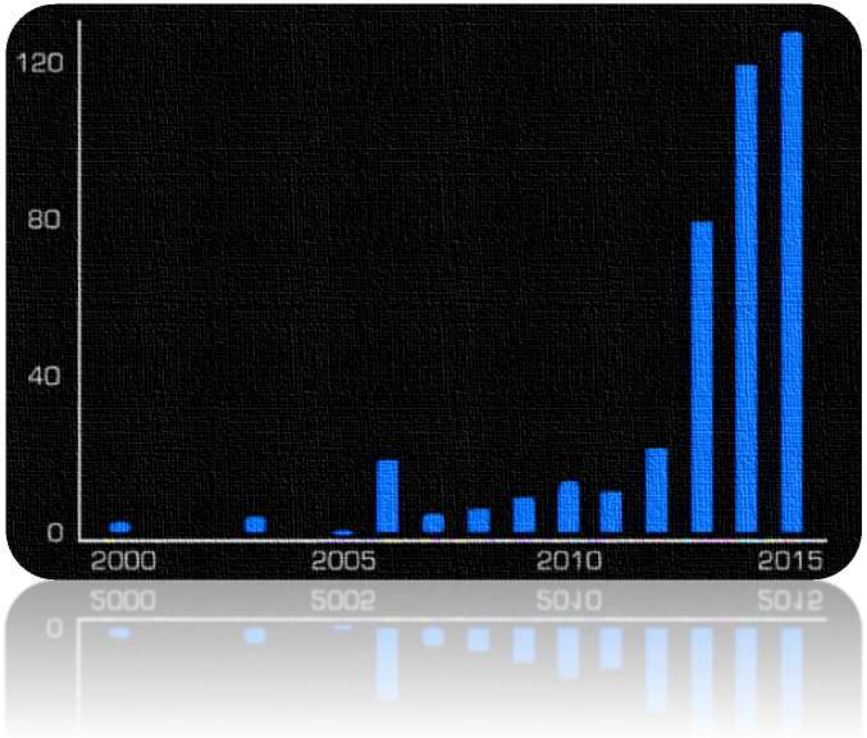
Introduction

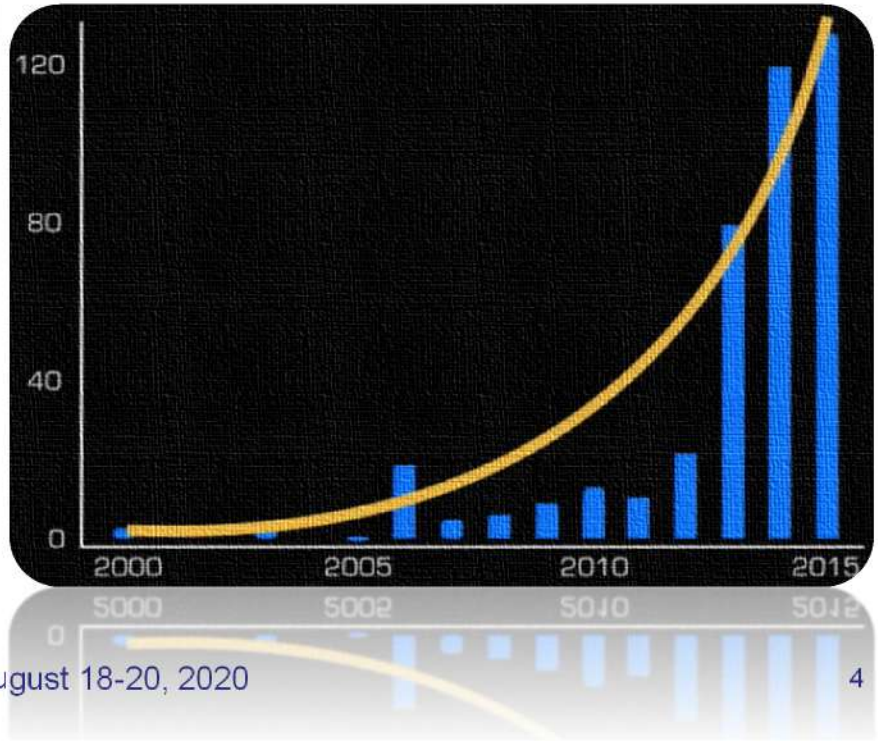
A brief reminder



Introduction

Cubesats launched since 2000





Introduction

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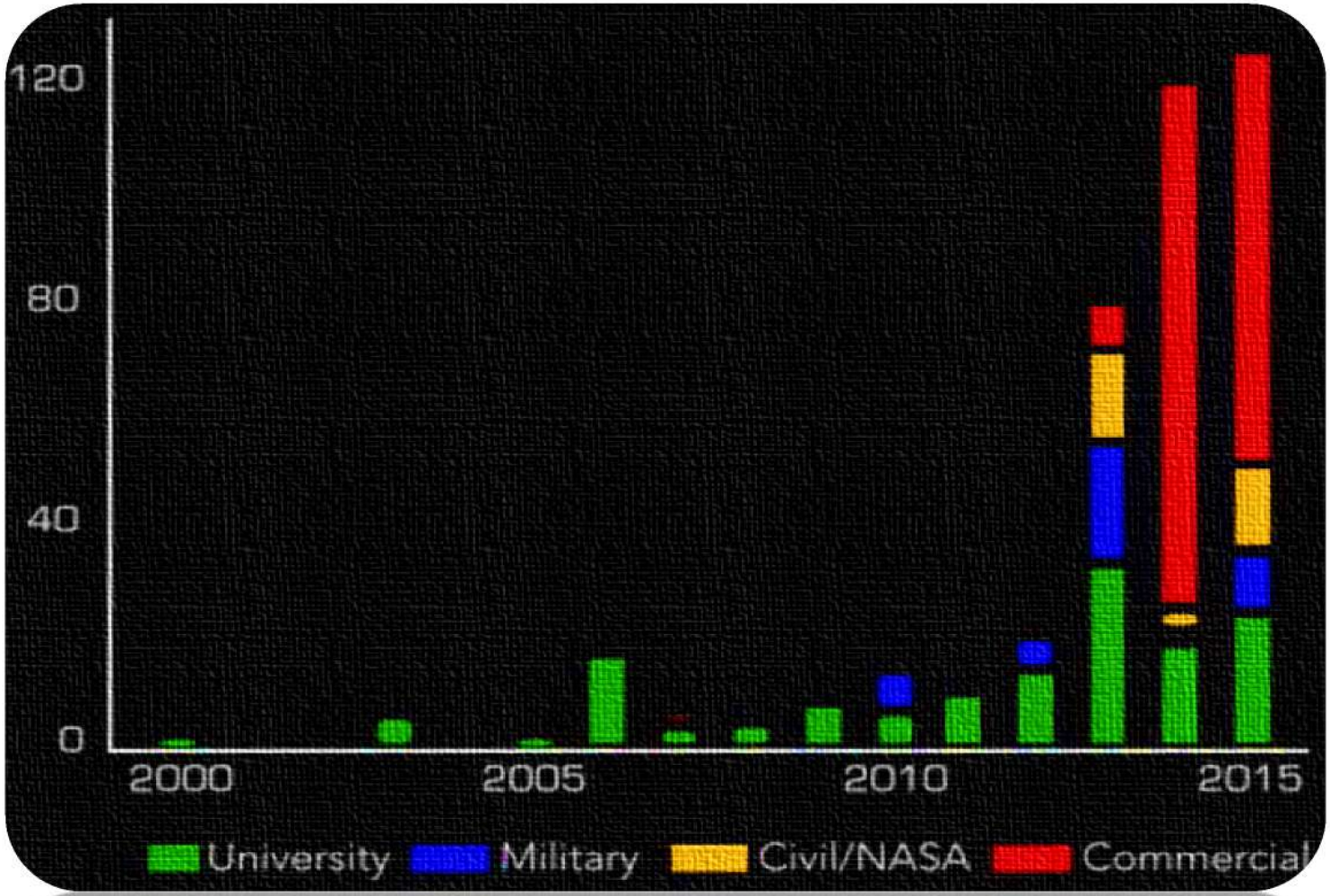
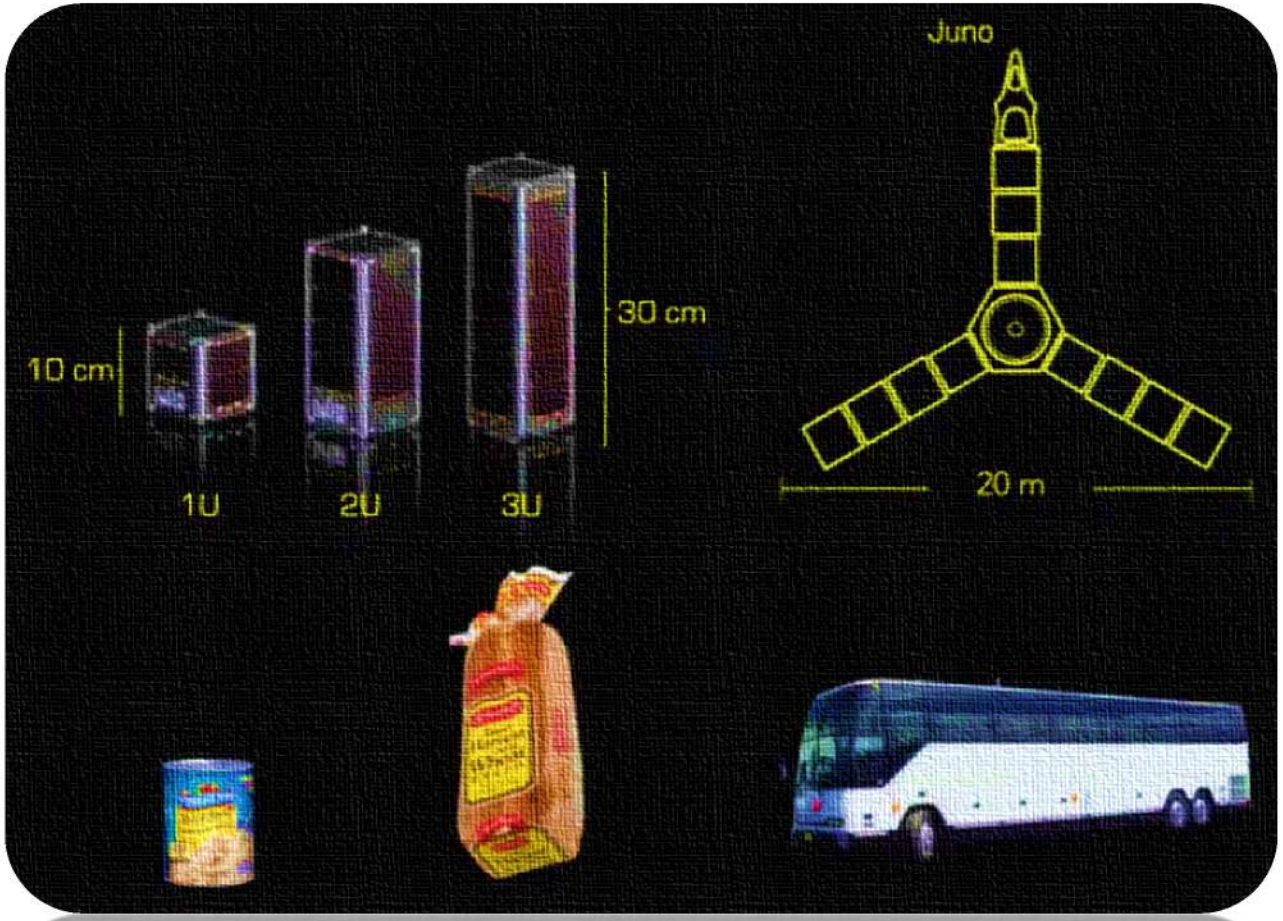


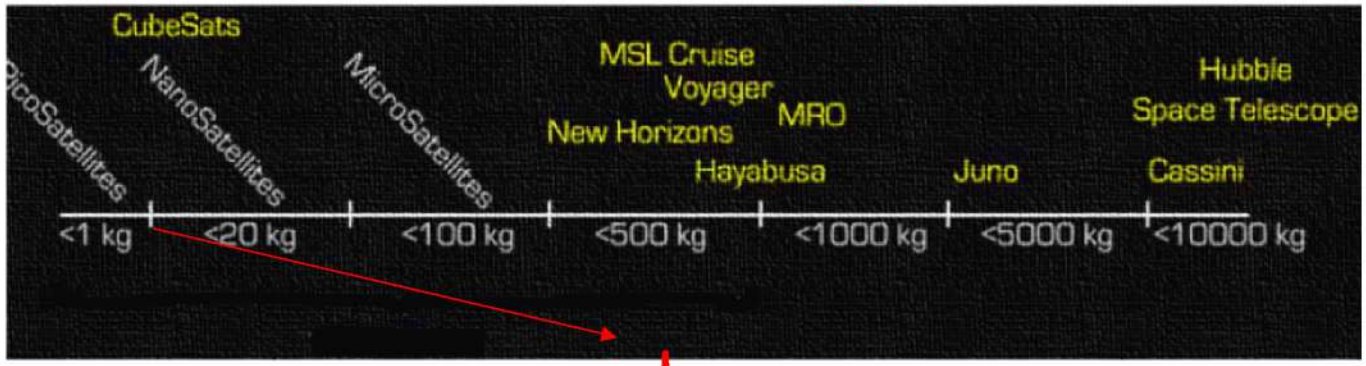
Introduction

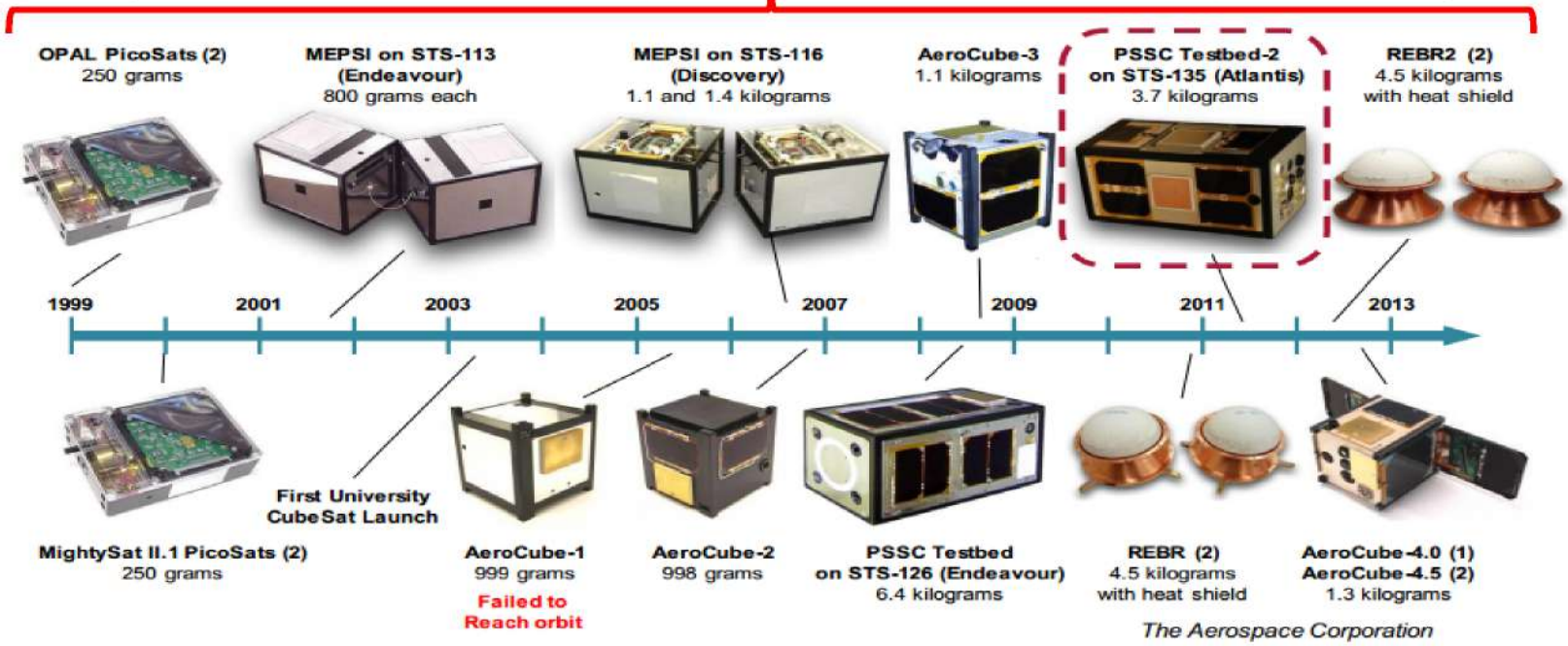
Idea about what Cubesats look like…



Introduction

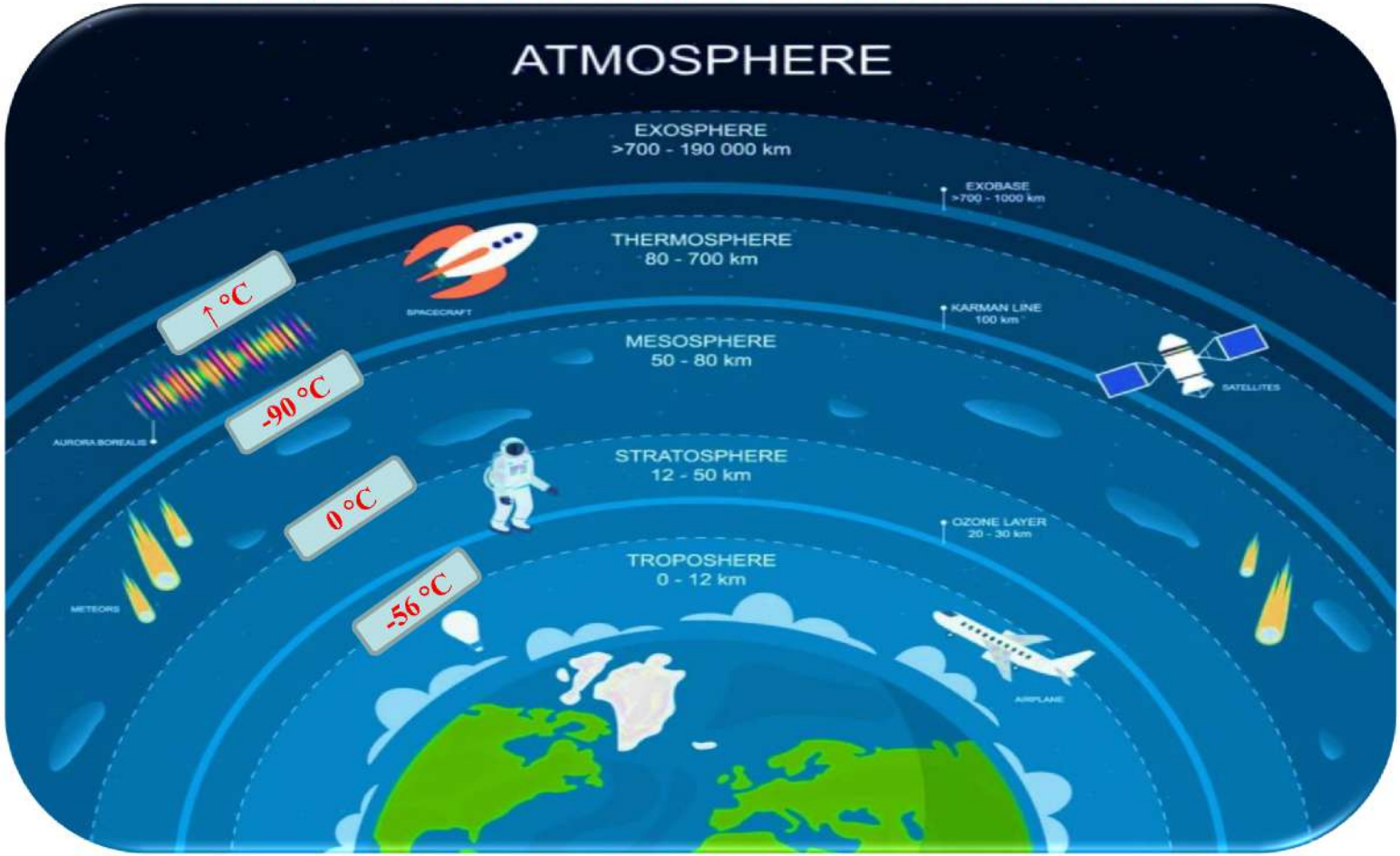
Cubesats weight





Context and objectives

The purpose of satellite thermal control?



- ***Adapting exchanges with the environment to ensure a suitable average temperature***
- ***Playing on internal exchanges to facilitate the evacuation of internally dissipated powers***

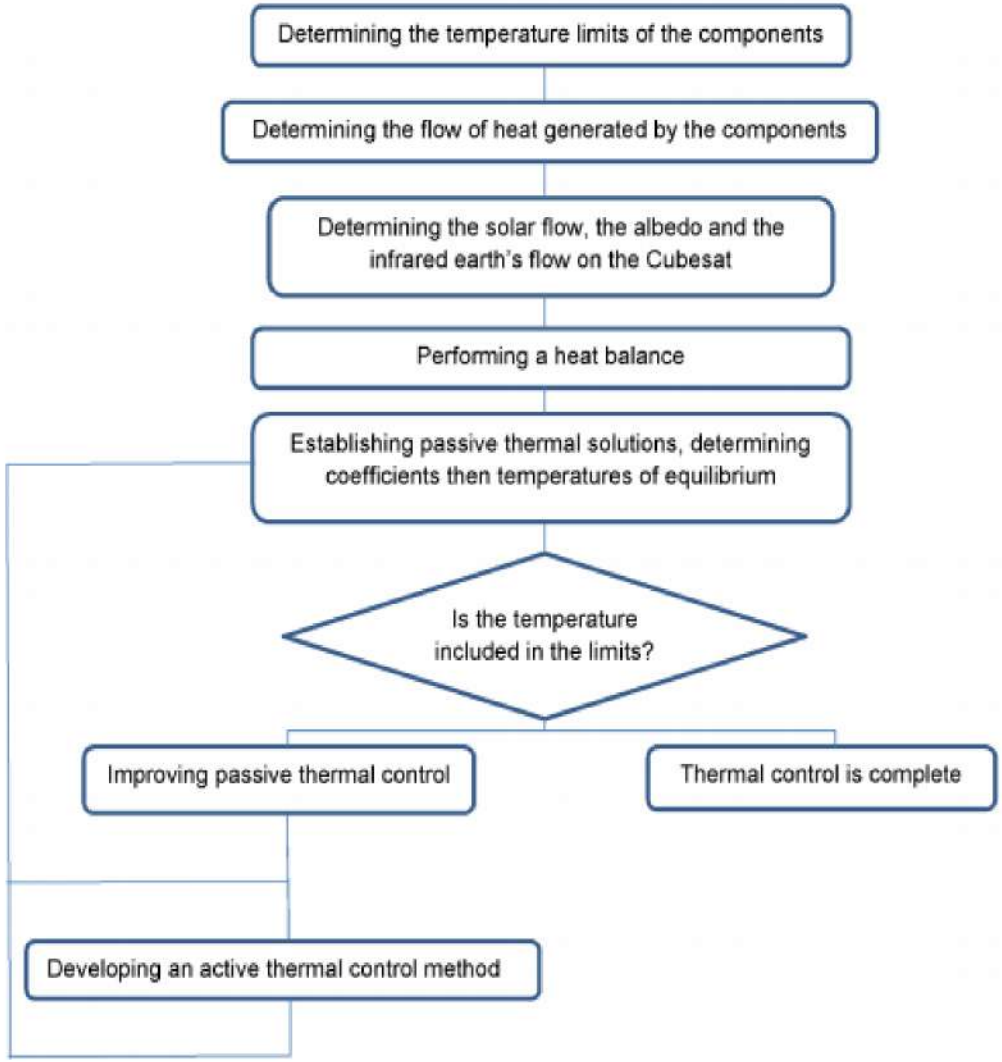
Context and objectives

There are two types of thermal control:

- Passive thermal control which attempts, by means of passive devices (paintings, multi-layer insulation, reflectors, etc.) to control heat transfers that are carried out by conduction and thermal radiation. It is a less expensive, lightweight, reliable solution with little impact on mass and power estimation.

- Active thermal control which is often justified by the uncertainties of the model, the variable environment and the aging of the microsatellite.

Passive thermal flow chart



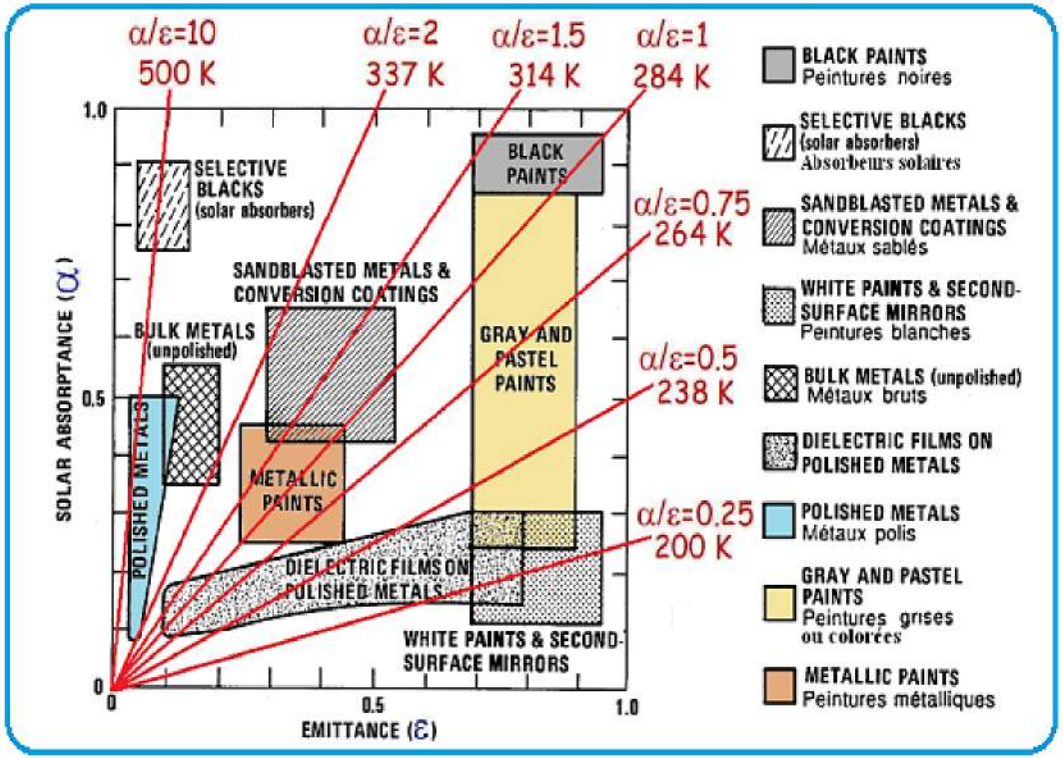
Context and objectives

Means of controlling radiative exchanges

The temperature of a body in space depends heavily on the thermo-optical characteristics of its coatings: Solar Absorptivity α and IR emissivity ε.

If we consider the ratio α/ε as a criterion, these coatings can be classified into four categories :

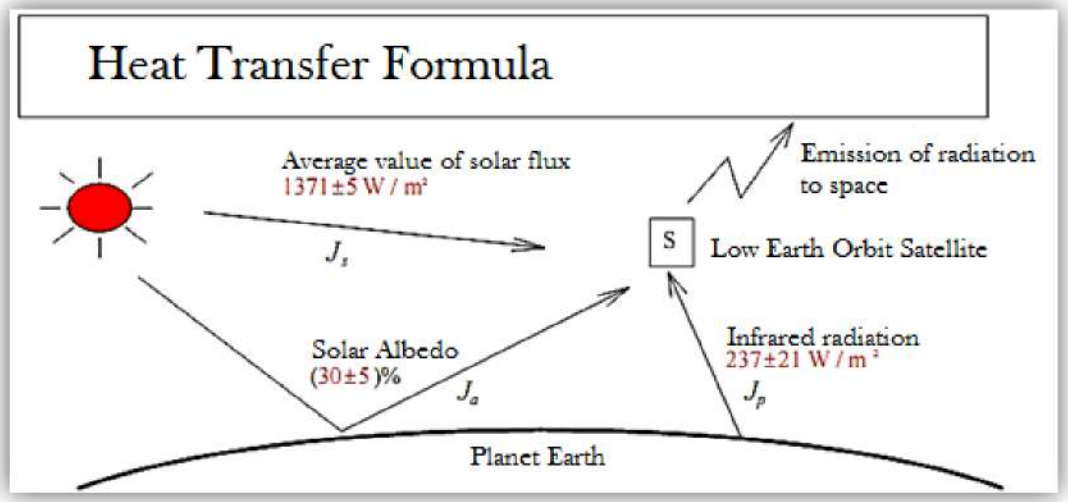
- **Cold coatings with low α / ε <1: White paint.**
- **Average coatings at α / ε ~ 1: Black paint.**
- **Hot coatings at α / ε> 1: Polished golden aluminum.**
- **Super hot coatings at α / ε> 4: Black chrome.**



Methodologies

Thermal analysis process

The main heat source when the Cubesat is in orbit is the Photosphere, the thermal transfer is governed by :



$$\sigma A_{Sat} \epsilon T^4 = Q_i + \alpha J_s A_{Sun} + \alpha J_a A_{albedo} + \epsilon J_p A_{Earth}$$

(Thermal emission)

(Internal flow)

(Solar radiation)

(Reflected Solar radiation)

(Infrared Terrestrial radiation)

Methodologies

Assumptions and boundary conditions

The expression of the calculation of the temperature is :

$$T^4 = \frac{A_{Earth} J_p}{A_{Sat}\sigma} + \frac{Q_i}{A_{Sat}\sigma\varepsilon} + \left[\frac{A_{Sun} J_s}{A_{Sat}\sigma} + \frac{A_{albedo} J_{albedo}}{A_{Sat}\sigma} \right] \times \frac{\alpha}{\varepsilon}$$

With,

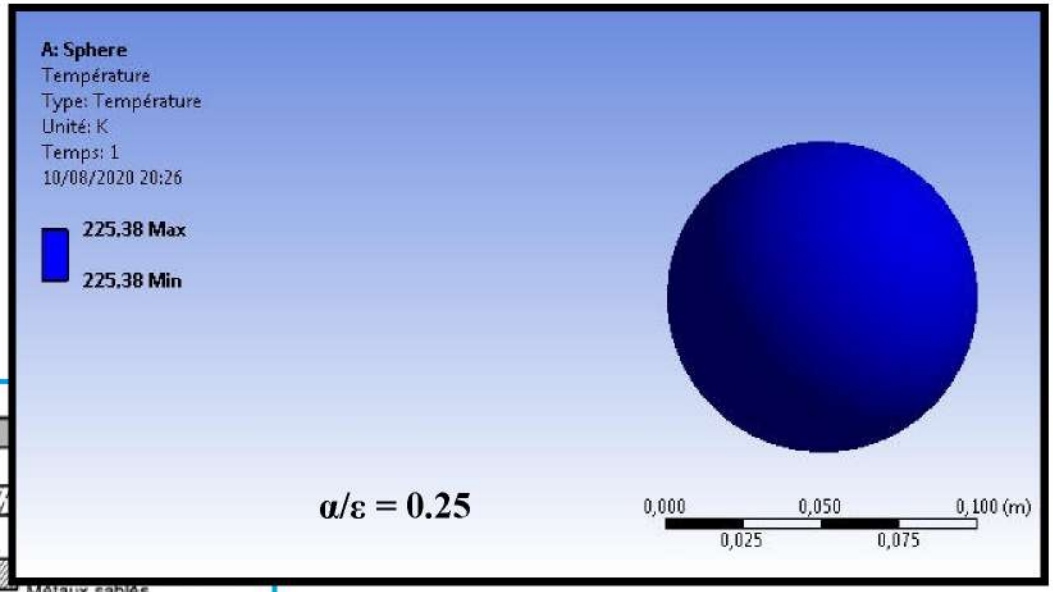
- **Circular dawn-dusk Orbit is a near-polar orbit at low altitude, which does not suffer from eclipses.**
- **Js, Ja, Jp and Qi are constant.**
- **The sidereal temperature is 2,7K.**
- **The solar flux, the albedo and the infrared terrestrial flux reach the nanosatellite perpendicularly.**
- **The nanosatellite is considered to be a real body.**

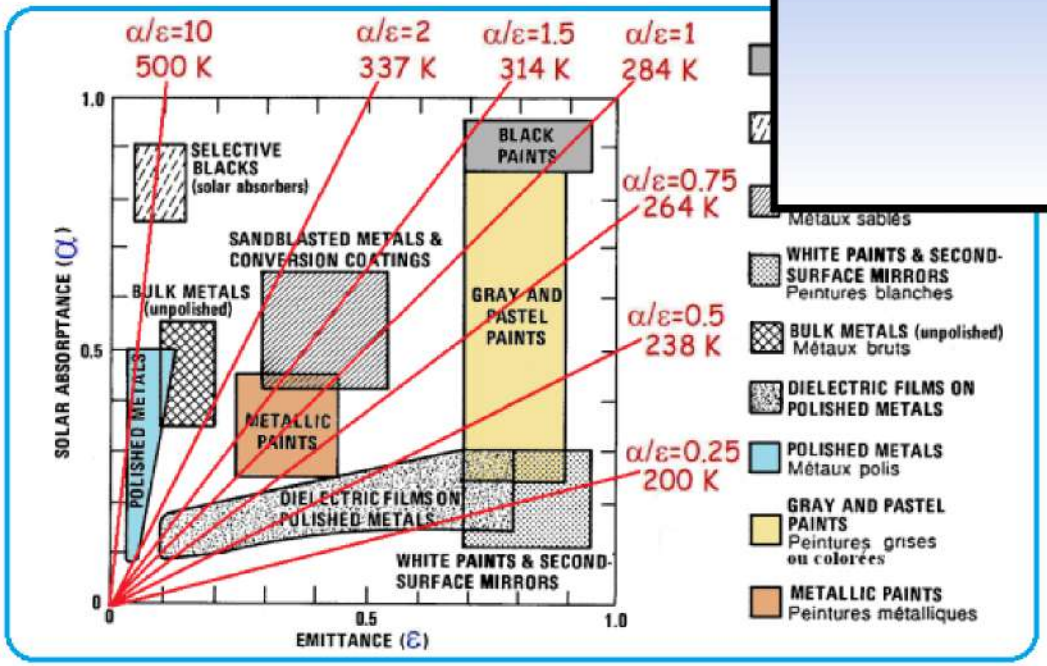
- Orbit at 240Km
- Js = 1371 W/m^2
- Ja = 67,8645 W/m^2
- Jp = 220 W/m^2
- Qi = 0 W/m^2

Results

System validation

The results are :





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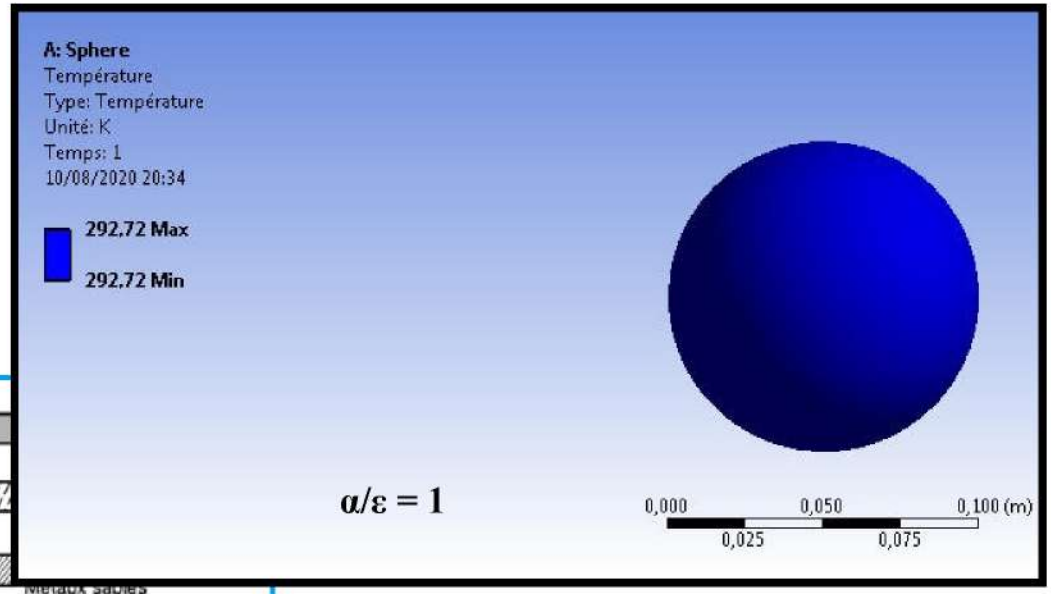

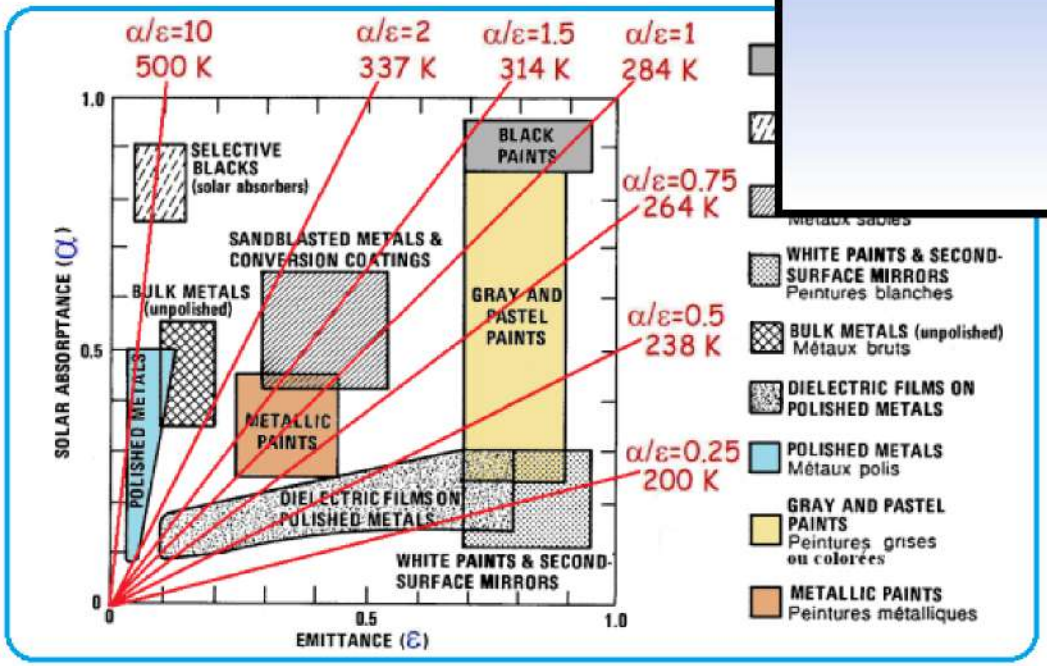

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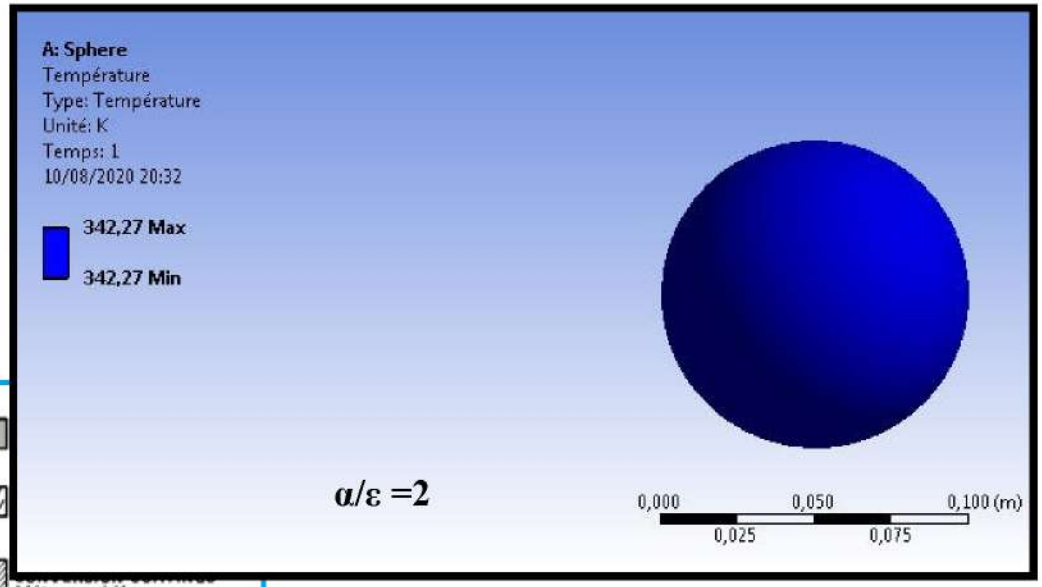
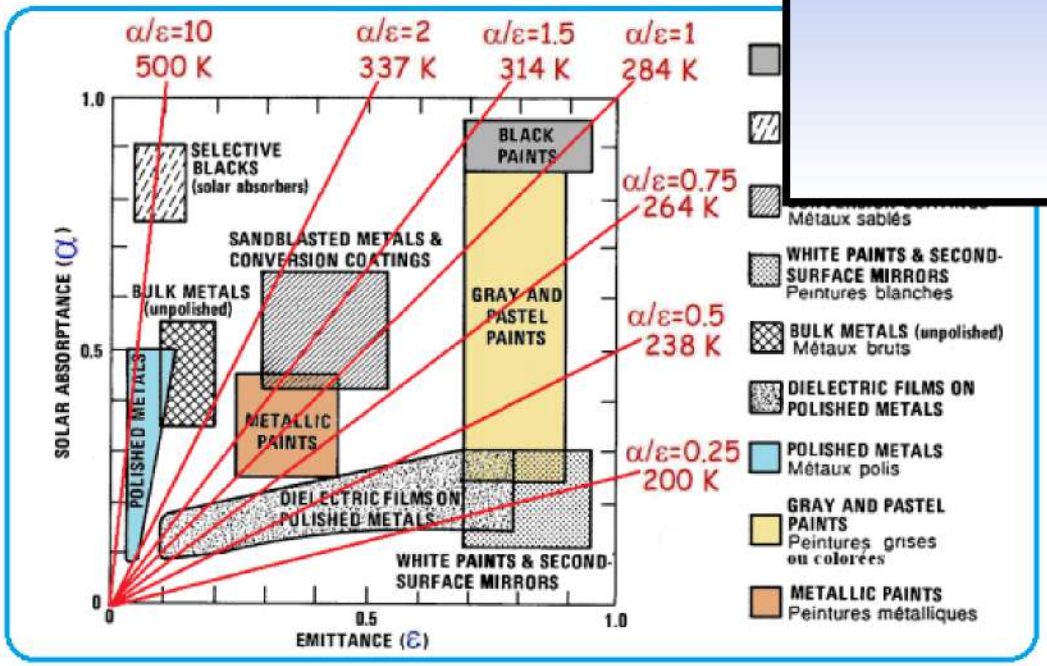
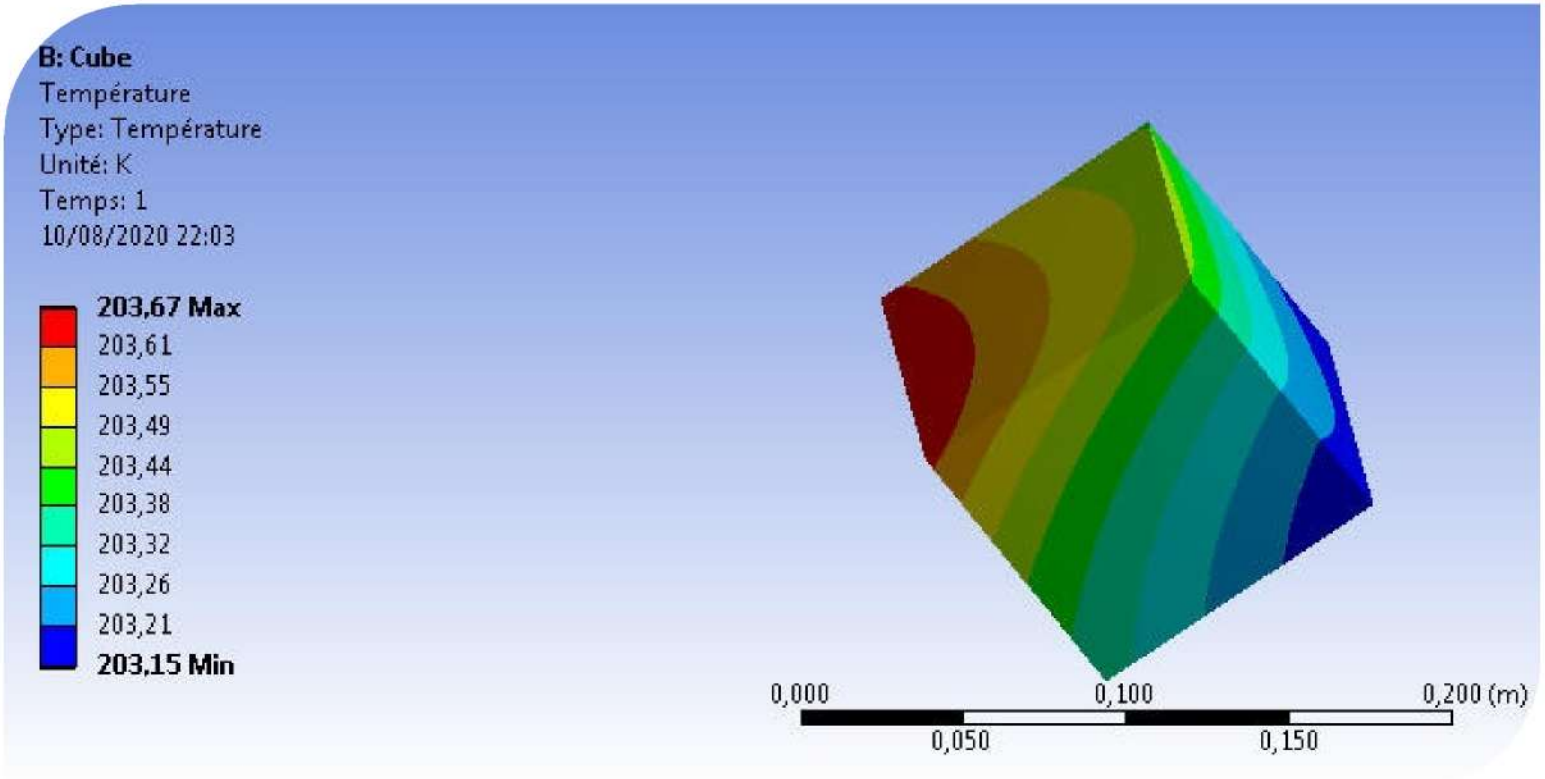




Results

Cubesat analysis “Steady state”

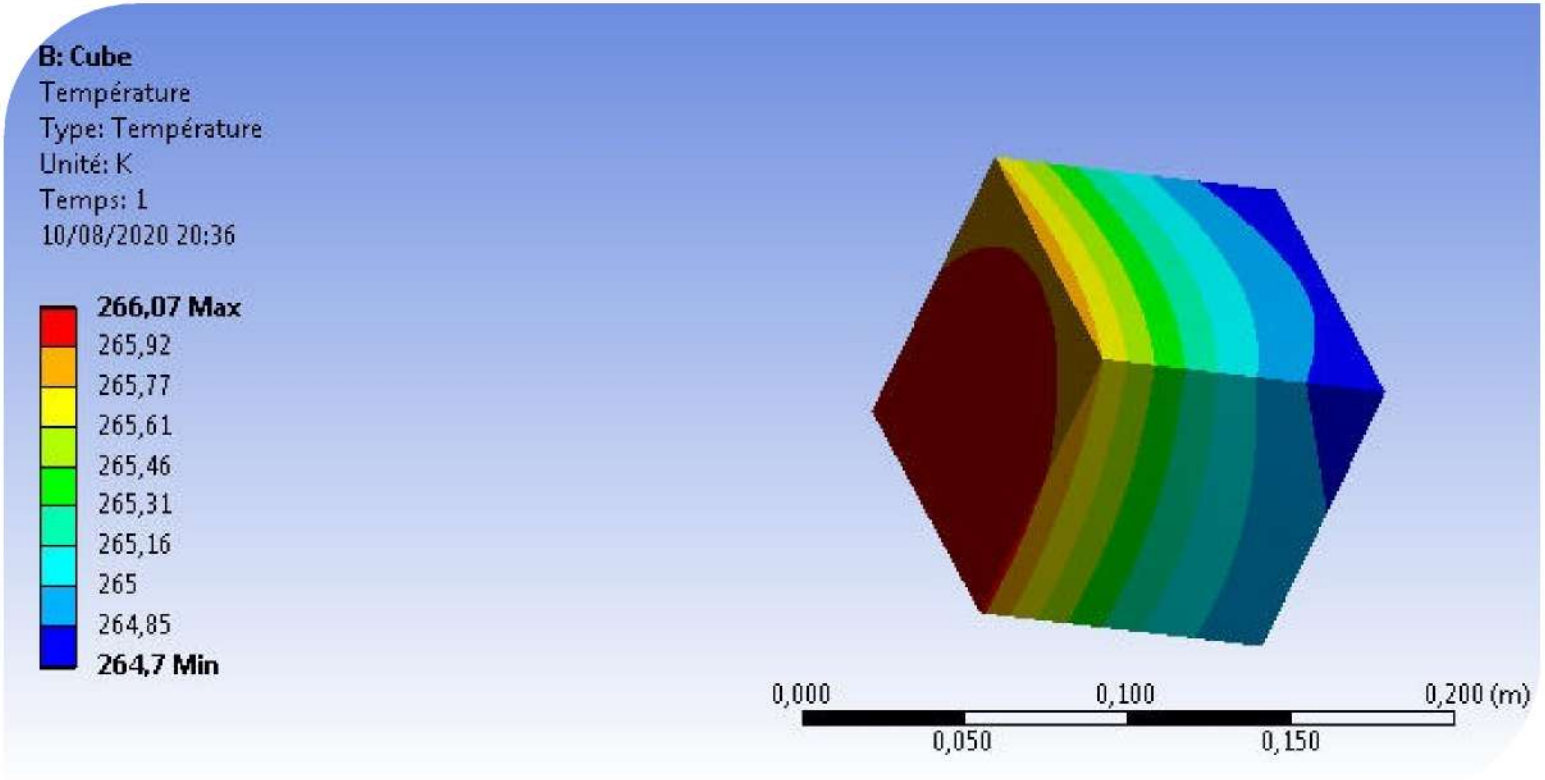
- α/ε = 0.25 ; T = -69.483 ° C ~ -70.001 ° C



Results

Cubesat analysis “Steady state”

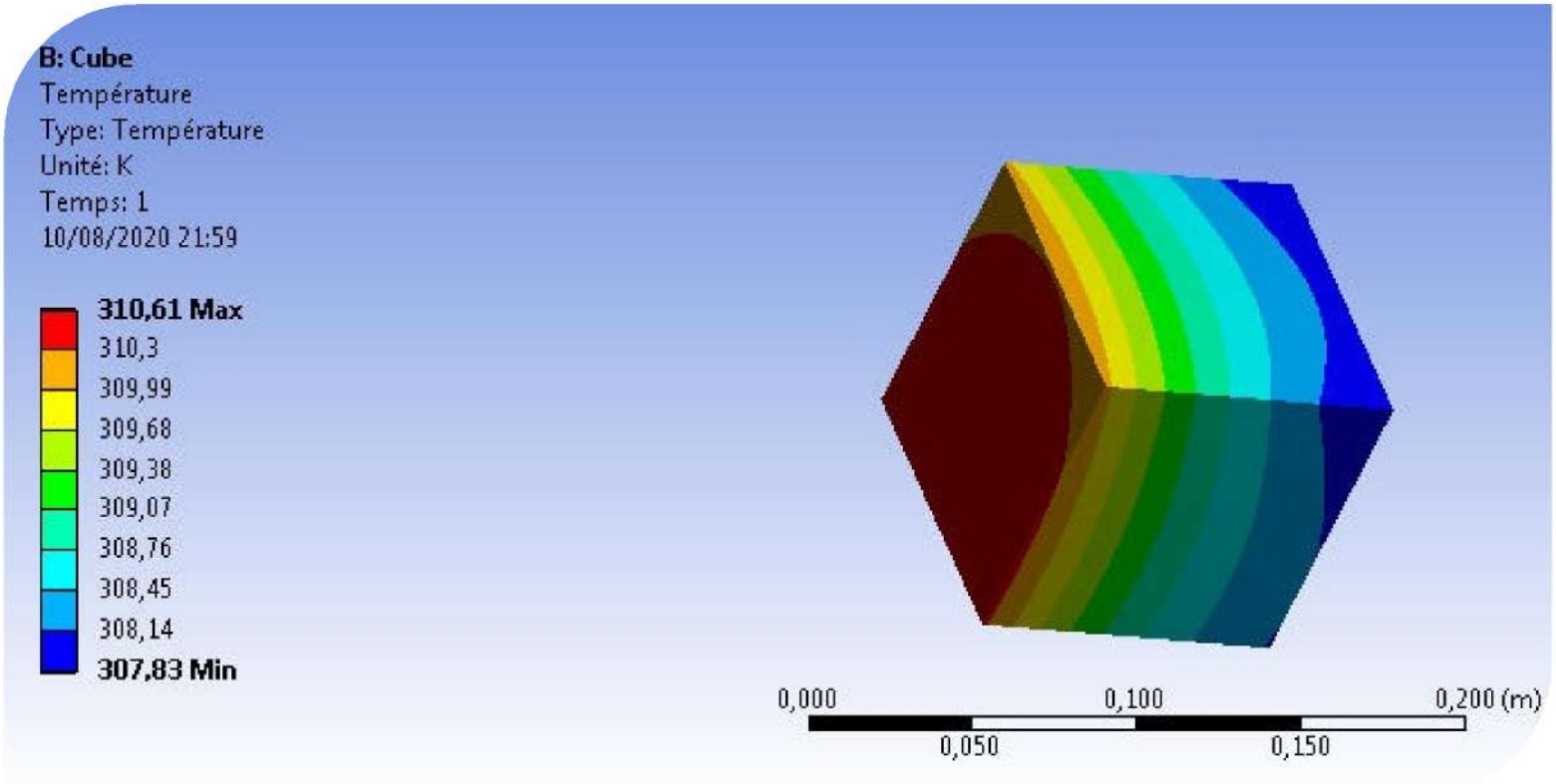
- α/ε = 1 ; T = -7.07 ° C ~ -8.45 ° C



Results

Cubesat analysis “Steady state”

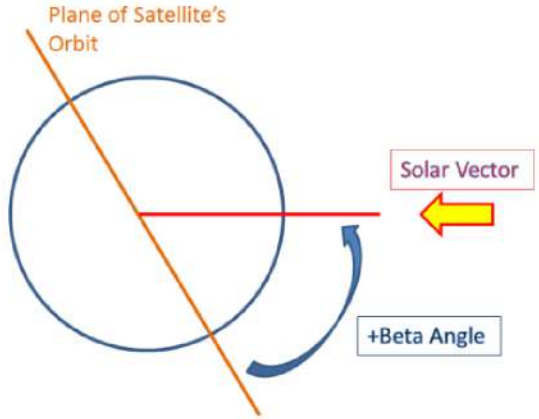
- α/ε = 2 ; T = 37.41 ° C ~ 34.63 ° C



Results

Cubesat analysis "Transient state"

- For transient analysis, some parameters should be defined :
- Beta Angle is still positive while revolving (Counter clock revolution).
- R_{Earth} = 6378 Km
- H = 240 Km
- Orbit's semi major axis a = H + R_{Earth} = 6618 Km
- Gravitational parameter μ = 3.986 10^5 Km^3/s^2
- Period revolution P = 2*π*(a^3/μ)^0.5 = 5358 s
- Number of periods per day n=(3600*24)/P = 16 Rev/day
- Velocity v = (μ/a)^0.5 = 7.76 Km/s

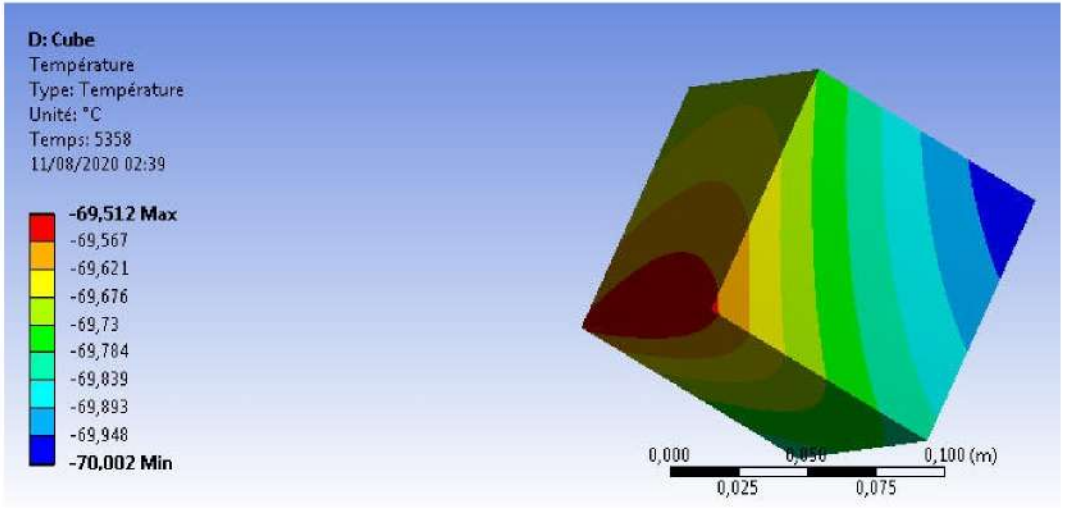


Results

Cubesat analysis “Transient state”

- α/ε = 0.25 ; [T = -69.48° C ~ -70.00° C] Steady state Temperature ➔➔ [T_{moy} = -69.74° C] Initial Temperature injected in Transient analysis

P	1	2	3	4	5	6	7	8	9
Tmax	-69.51	-69.52	-69.53	-69.54	-69.55	-69.56	-69.57	-69.58	-69.59
Tmin	-70	-70.01	-70.02	-70.03	-70.04	-70.05	-70.06	-70.07	-70.08

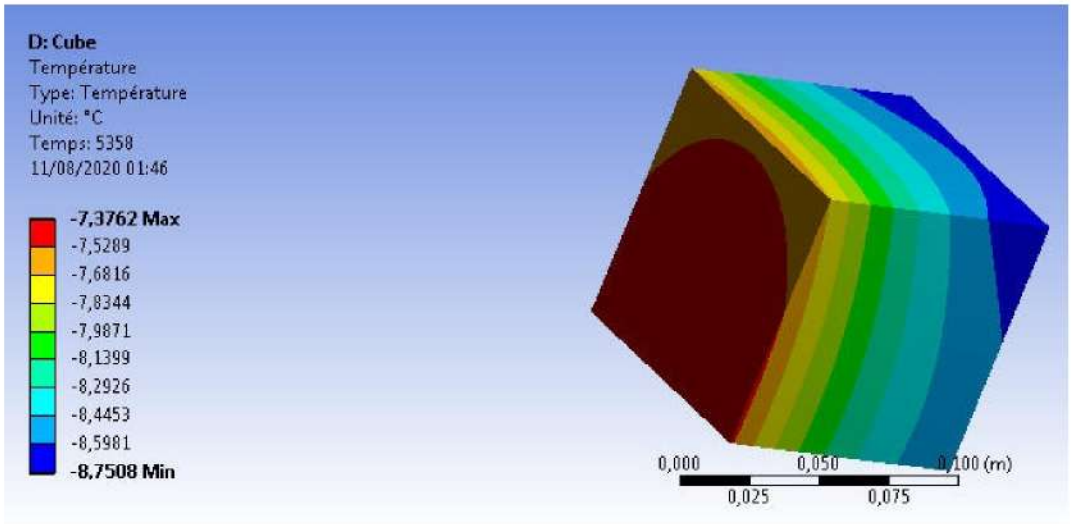


Results

Cubesat analysis “Transient state”

- α/ε = 1 ; [T = -7.07° C ~ -8.45° C] Steady state Temperature ➔➔ ➔➔ [T_{moy} = -7.76° C] Initial Temperature injected in Transient analysis

P	1	2	3	4	5	6	7	8	9
Tmax	-7.37	-7.58	-7.71	-7.8	-7.87	-7.91	-7.94	-7.96	-7.97
Tmin	-8.75	-8.95	-9.09	-9.18	-9.24	-9.28	-9.31	-9.33	-9.34

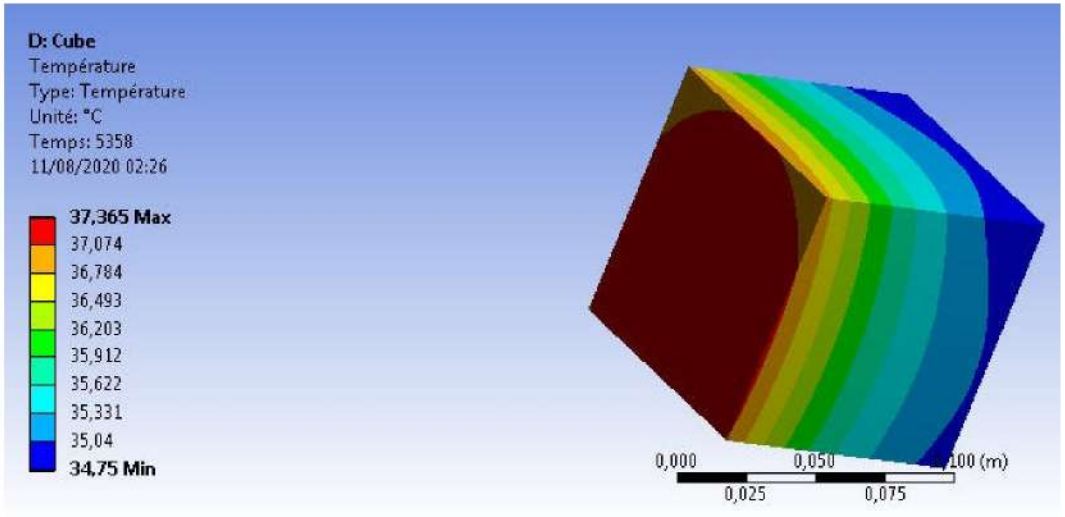


Results

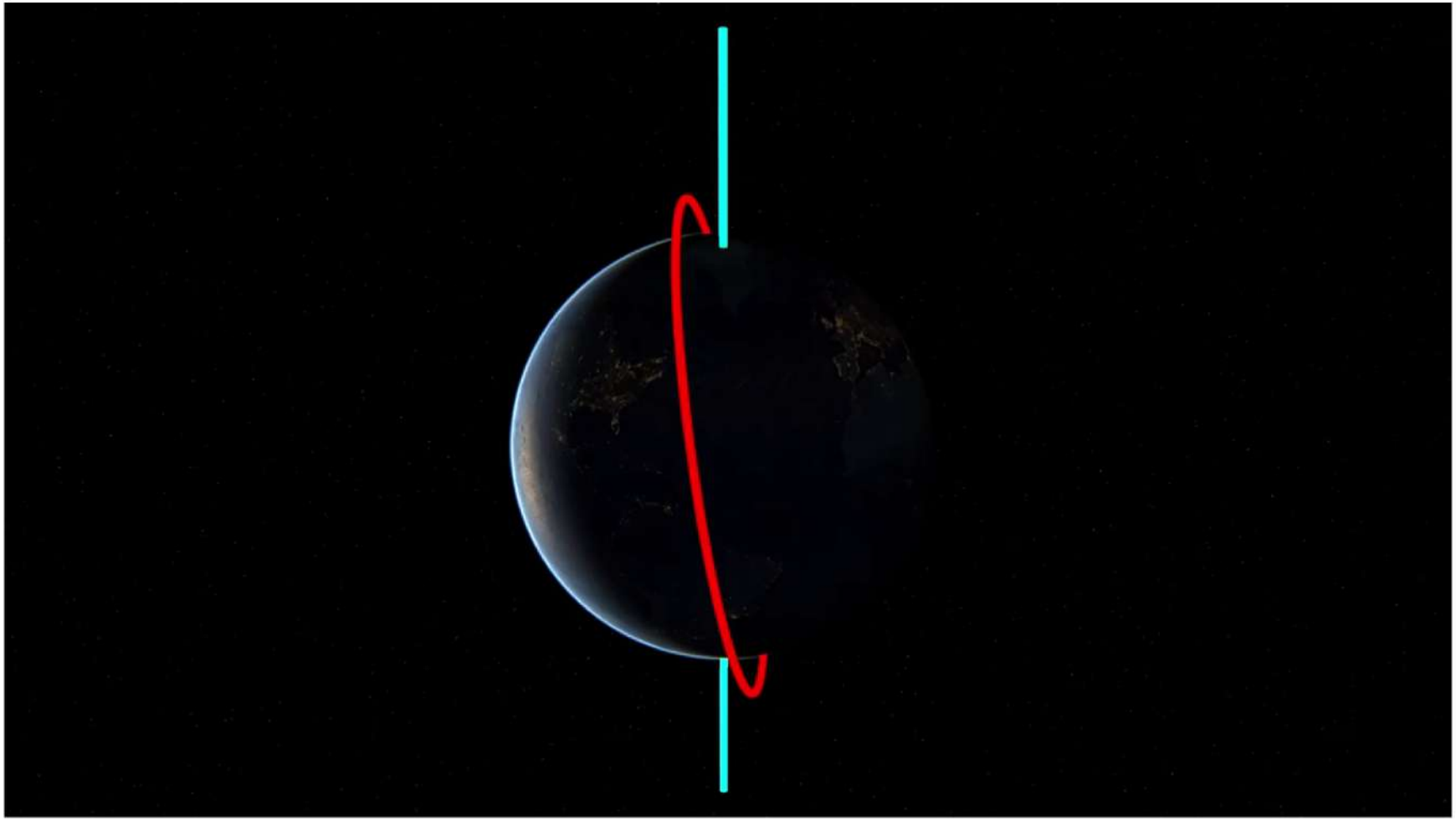
Cubesat analysis “Transient state”

- α/ε = 2 ; [T = 37.46° C ~ 34.68° C] Steady state Temperature ➔➔ ➔➔ [T_{moy} = 36.02° C] Initial Temperature injected in Transient analysis

P	1	2	3	4	5	6	7	8	9
Tmax	37.36	37.38	37.39	37.39	37.39	37.39			
Tmin	34.75	34.76	34.77	34.78	34.78	34.78			



CONCLUSION



Thanks for attending the presentation

Please feel free to ask questions

Mail: a_akka@hotmail.com