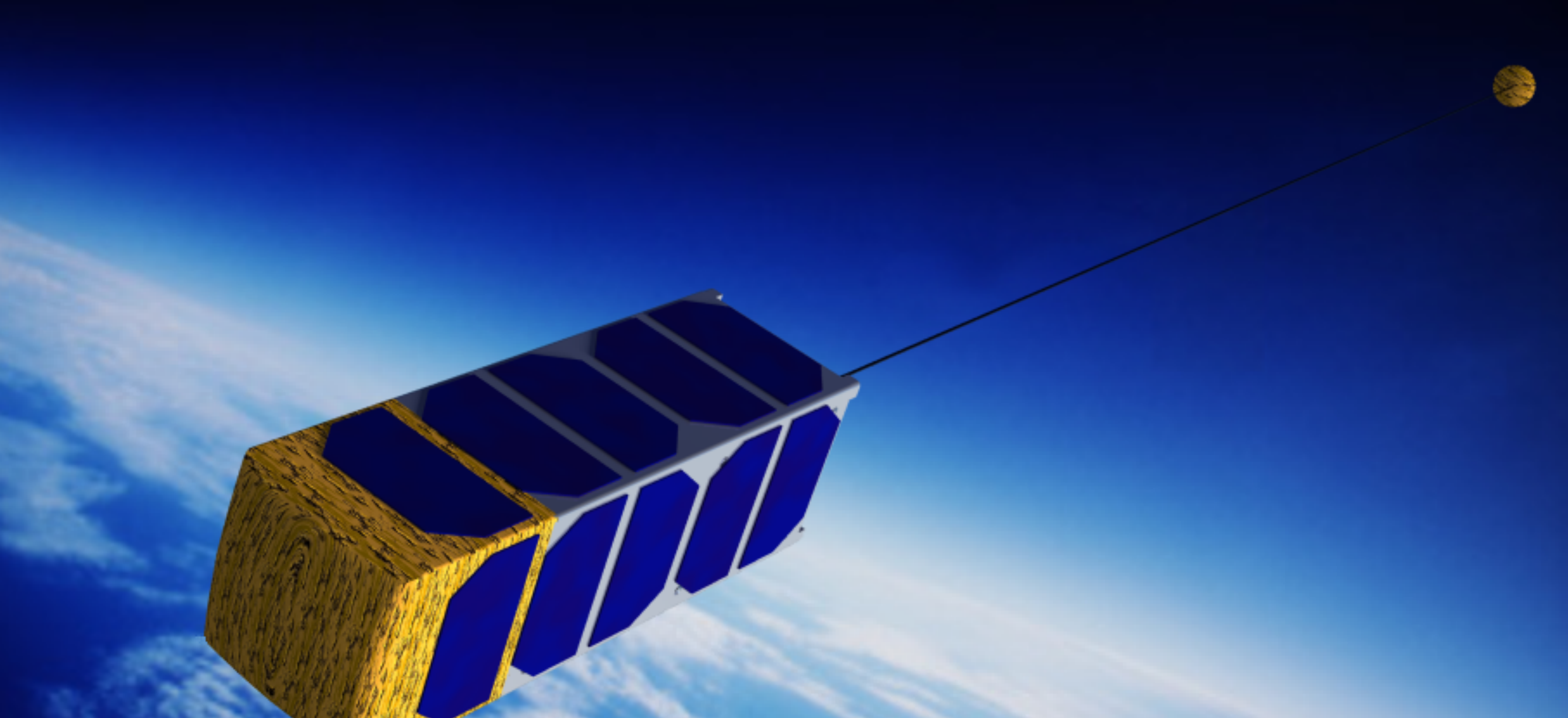

# RE-ENTSAT, AN ATMOSPHERIC TRIPLE UNIT RE-ENTRY CUBESAT


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*Aeronautics & Aerospace Dept., von Karman Institute for Fluid Dynamics*

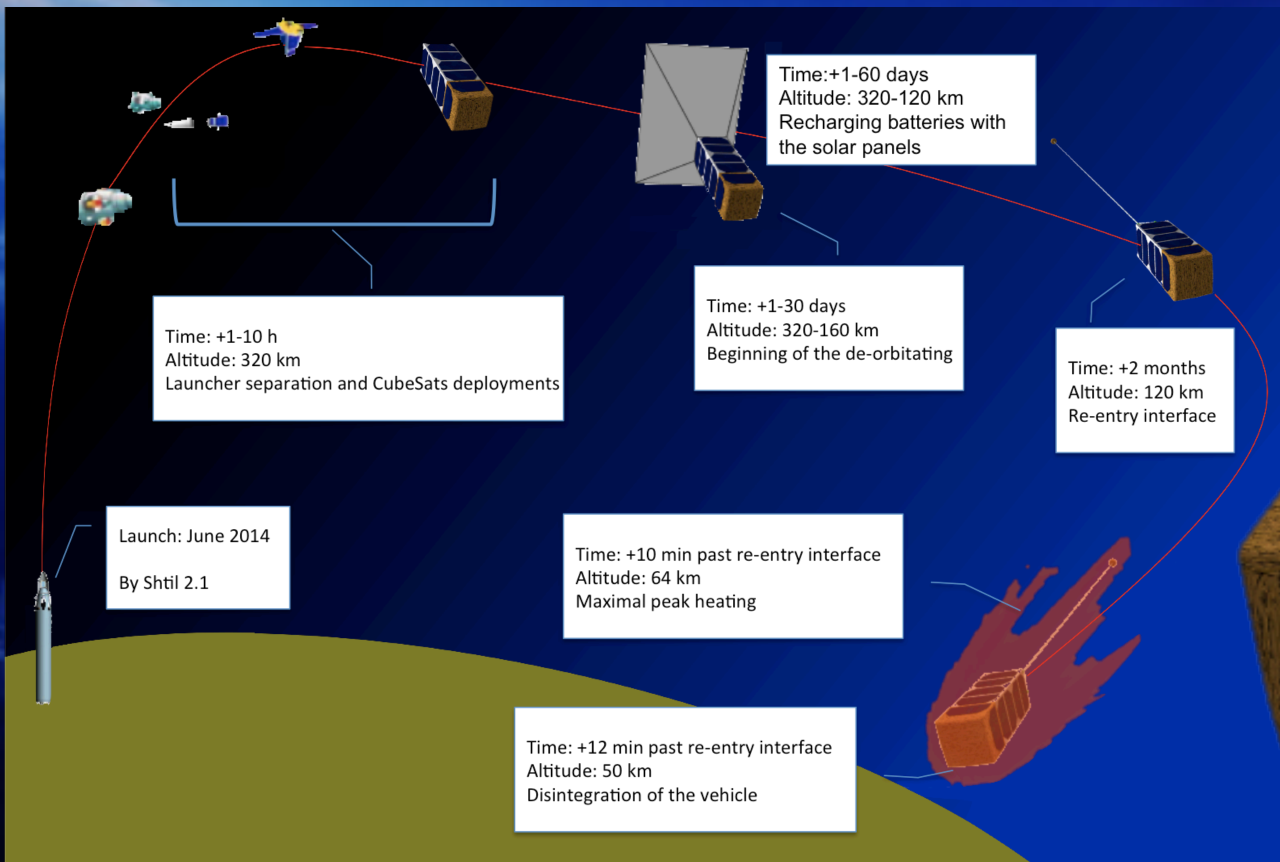


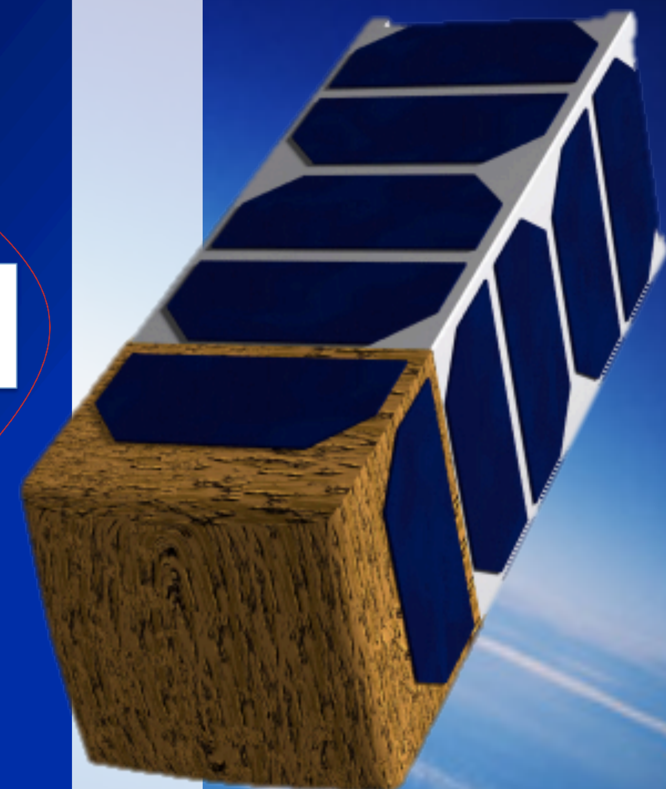
9th annual CubeSat Developers' workshop

- San Luis Obispo, April 18-20 -

# Context

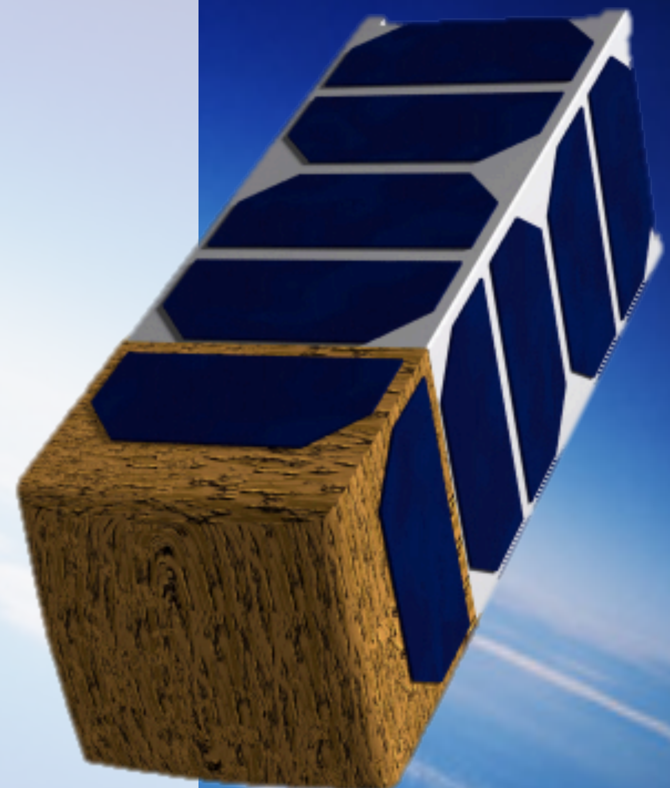
## -Scenario time line-



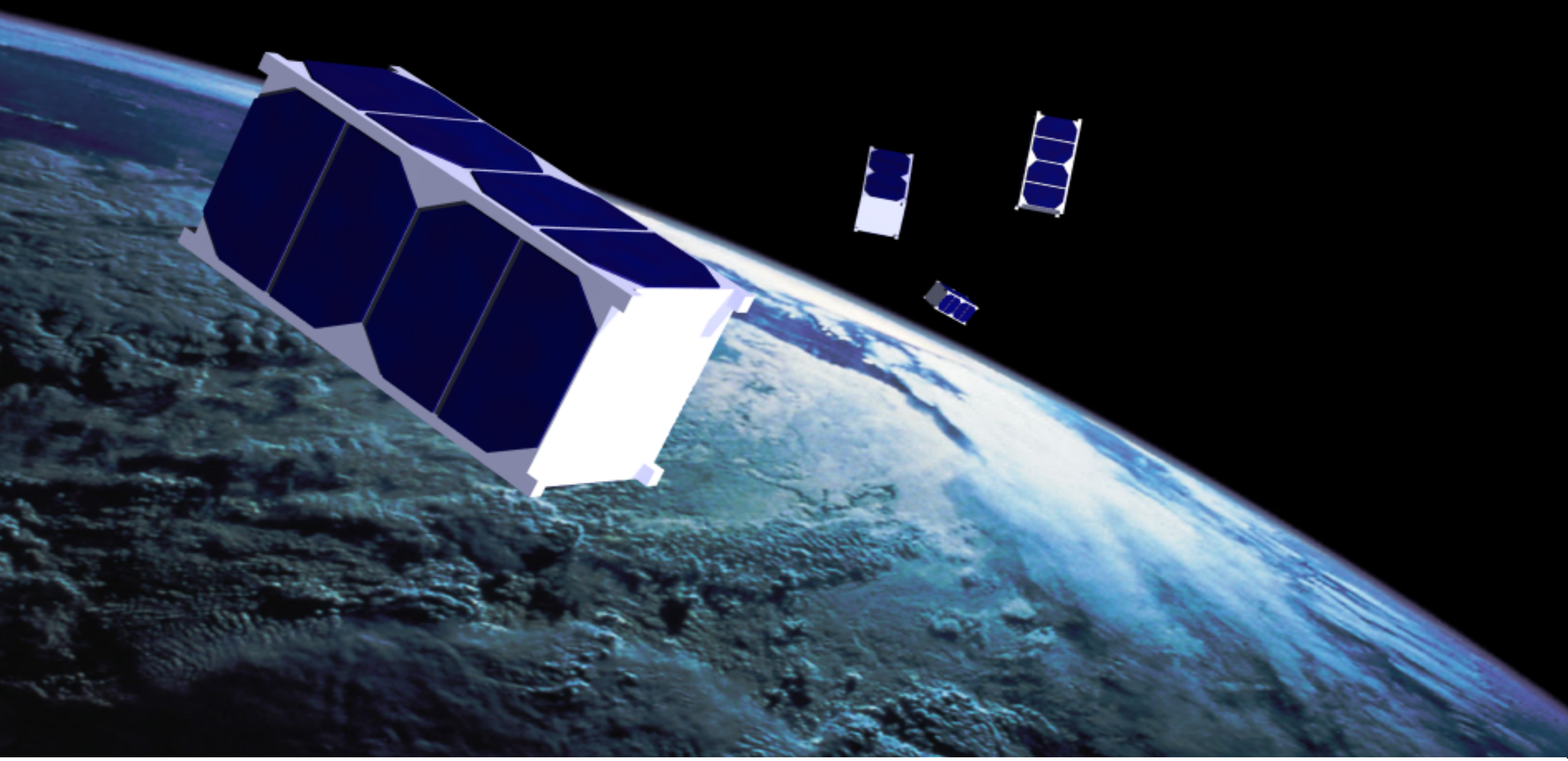
# Content

- Introduction
- Conceptual design
- Challenges
- Specific payloads



# Introduction

-www.qb50.eu-



# Introduction

-www.qb50.eu-

QB50:

- First network of CubeSat
- 50 CubeSats sequentially deployed at an initial altitude of 320 km
- Each CubeSat will perform in-situ measurements of atmospheric parameters

# Introduction

-www.qb50.eu-

SHTIL 2.1

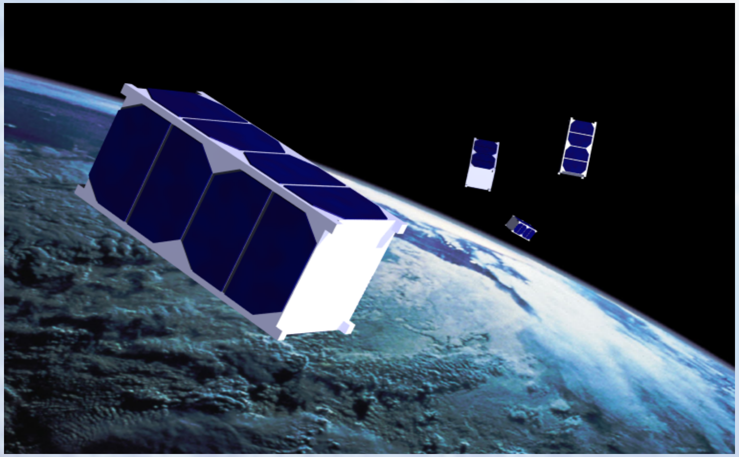
QB50:

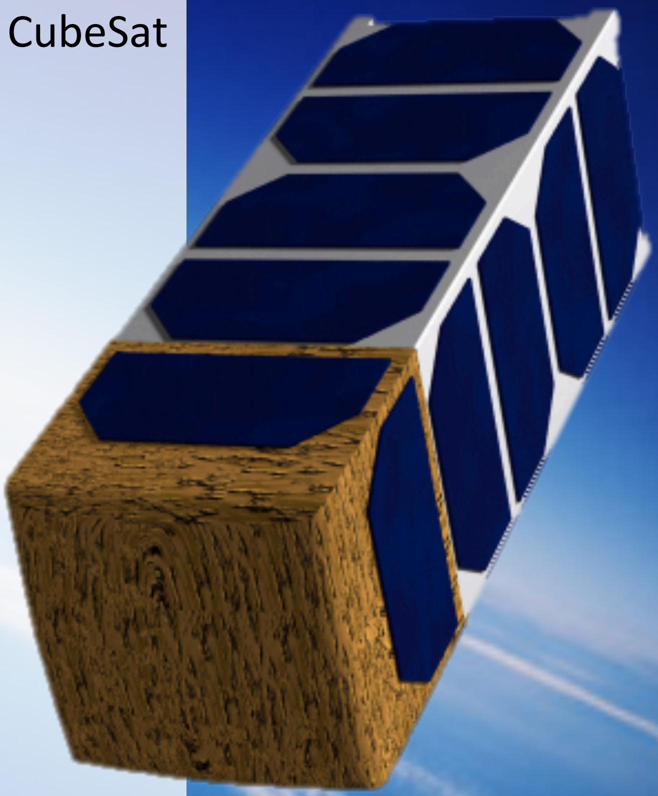
- First network of CubeSat
- 50 CubeSats sequentially deployed at an initial altitude of 320 km
- Each CubeSat will perform in-situ measurements of atmospheric parameters
- Launch together in June 2015

# Introduction

In addition of the main QB50 payload, the Re-entry CubeSat demonstrator will:

- Be deployed at the same time with the other QB50 CubeSats

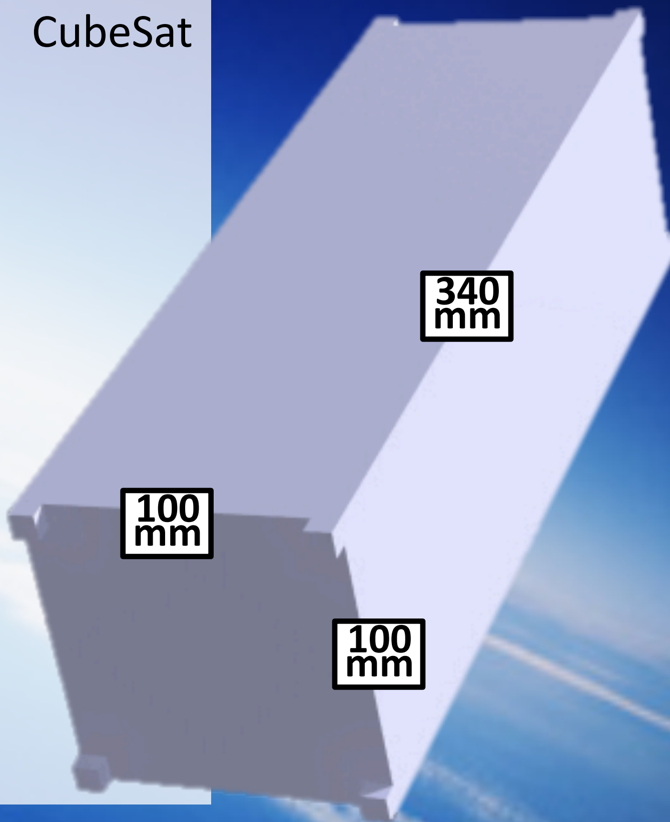




# Introduction

In addition of the main QB50 payload, the Re-entry CubeSat demonstrator will:

- Be deployed at the same time with the other QB50 CubeSats
- Based on the three unit CubeSat standard 100x100x340 mm

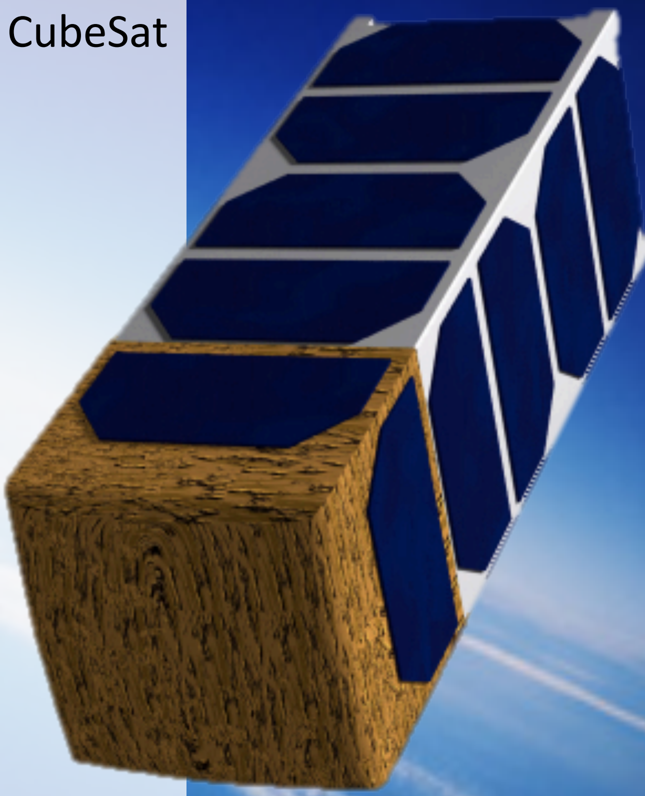


# Introduction

In addition of the main QB50 payload, the Re-entry CubeSat demonstrator will:

- Be deployed at the same time with the other QB50 CubeSats
- Based on the three unit CubeSat standard 100x100x300 mm
- Provide Re-entry flight data until the max heating point (>50 km)
- No debris should reach the ground

(DRAMA code: Debris Risk Assessment and Mitigation Analysis)

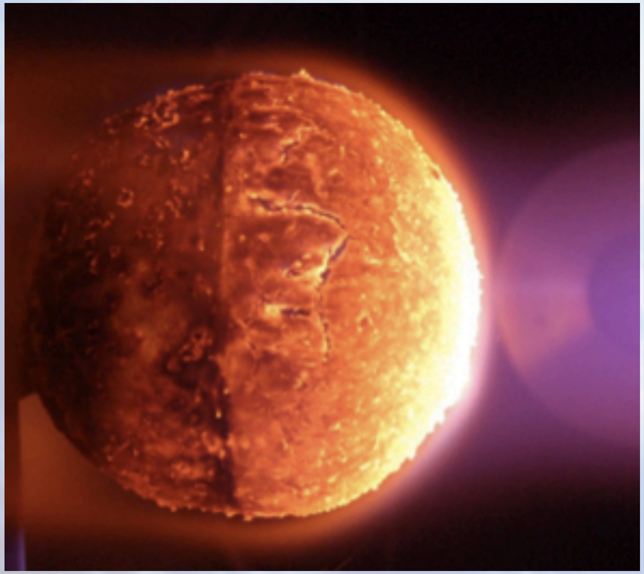


# Scientific opportunities for low-cost re-entry platforms

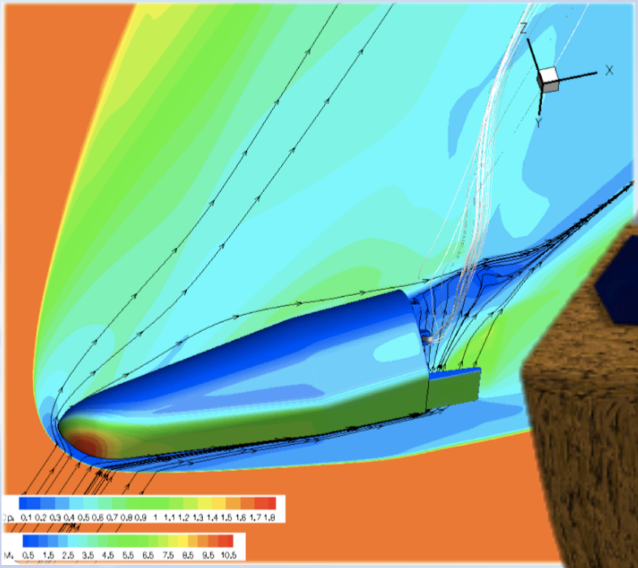
-Affordable platform for research oriented re-entry study-

- VKI's field of expertise at in  ground testing and simulations:

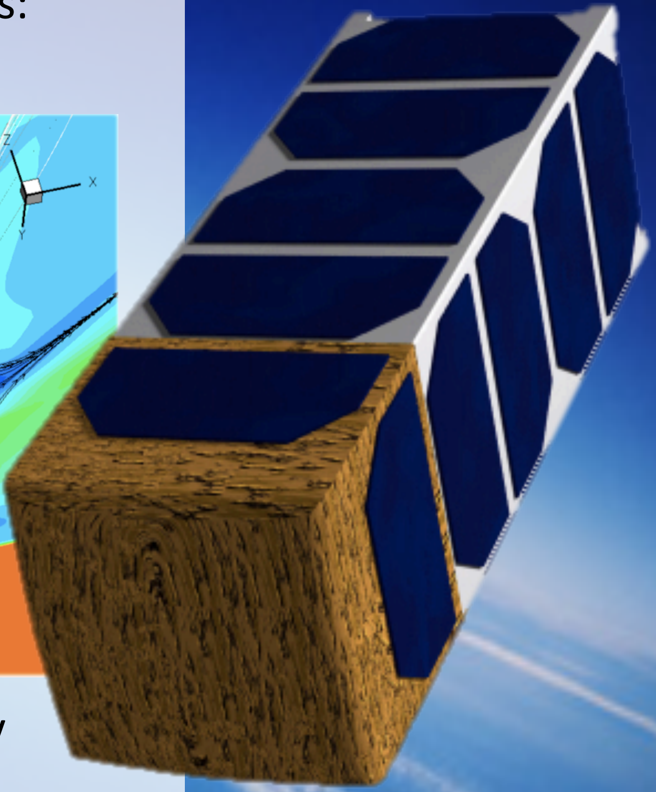
YES2, Expert, IXV



Ablation test in Plasmatron for the YES 2 capsule



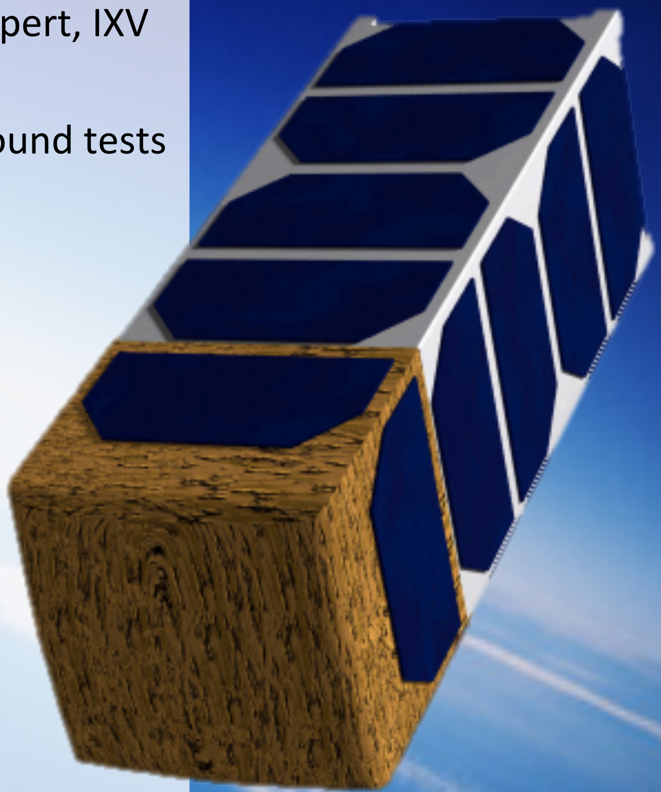
CFD simulation of IXV



# Scientific opportunities for low-cost re-entry platforms

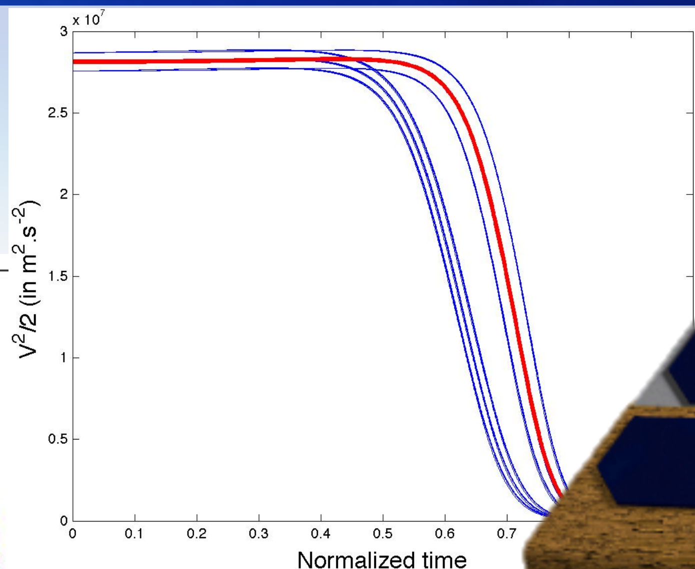
-Affordable platform for research oriented re-entry technology-

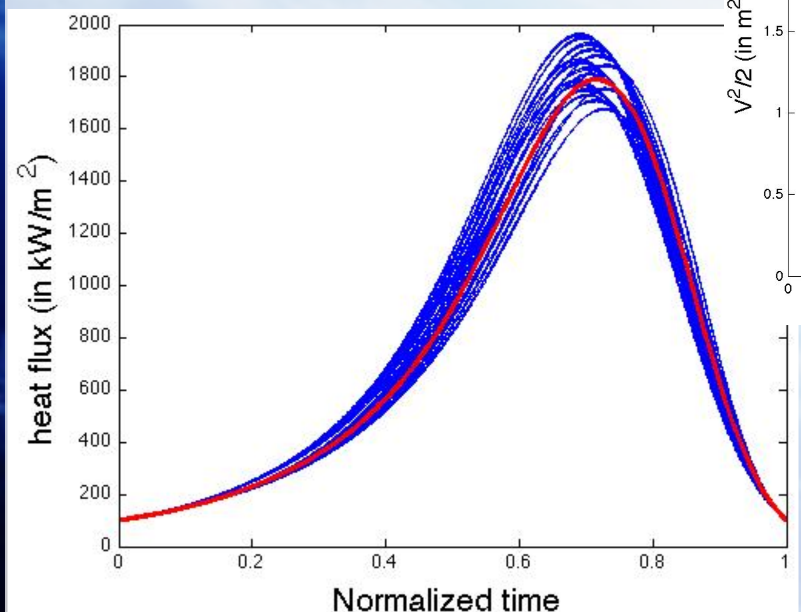
- Field of expertise at VKI in experiments and simulations: YES2, Expert, IXV
- Flight experiments for validation of numerical simulations and ground tests
- Characterization of TPS materials in flight conditions
- Re-entry Challenges & Solutions:
  - Deorbiting and trajectory
  - Stability and trimming
  - Max heating
  - Communication blackout
  - Debris mitigation and disintegration

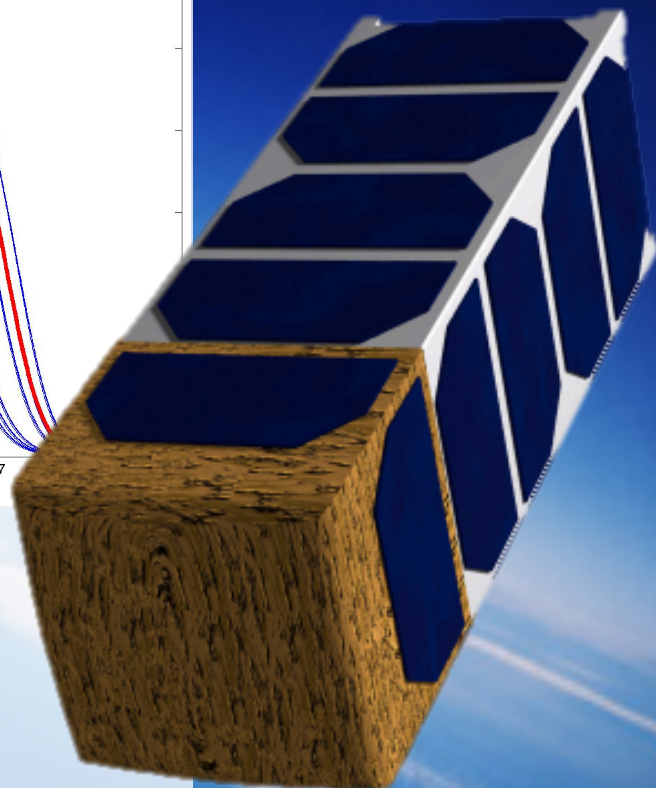


# Conceptual design

-Result for the proposed geometry with uncertainty analysis-



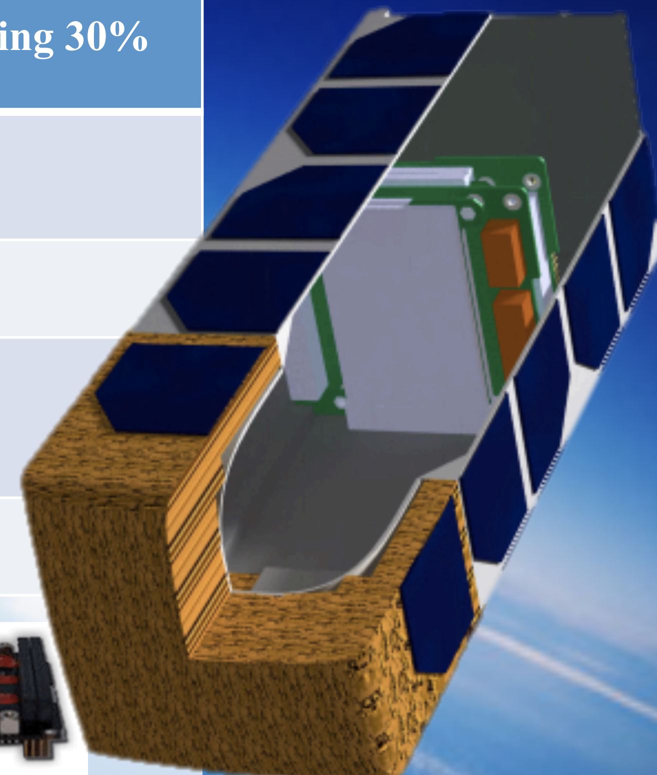



# Conceptual design

-Result for the proposed geometry with uncertainty analysis-

| Entity | Energy needed (in Whr, including 30% margin) |
|---|---|
| Functional unit (OBC, EPS…) | 2 |
| Payload + amplifier | 2 |
| Telecommunication system (Antenna + Iridium transceiver) | 6 |
| **Total** | **10** |



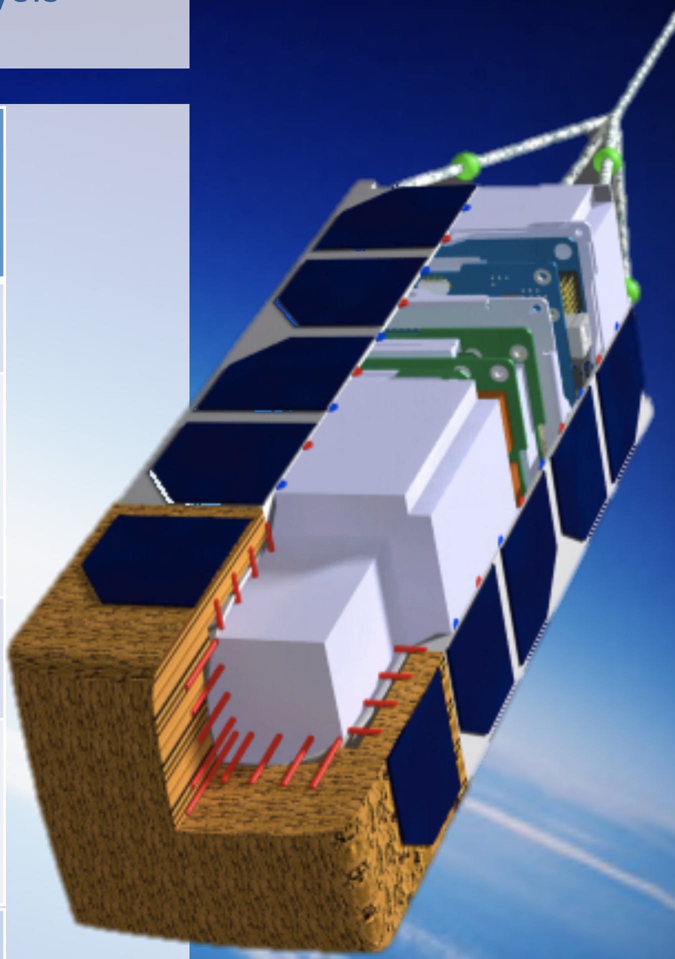
2 batteries needed to survive complete the 10 min mission (including the margins)

**CubeSat Battery Board for 3U EPS (ISIS)**
For one battery: 8.2V and 10Whr

# Conceptual design

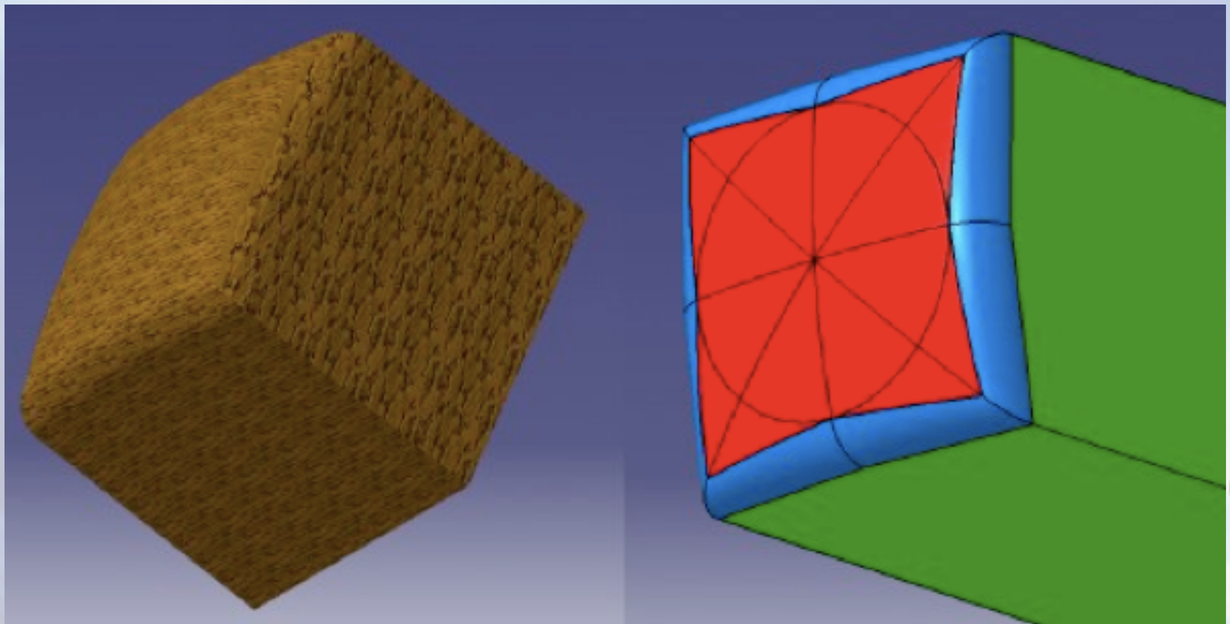
-Result for the proposed geometry with uncertainty analysis-

| Subsystem | Mass (in g) | Margin | Mass with margin (in g) |
|---|---|---|---|
| Heat shield | 317 | 20% | 380 |
| Functional unit +Structure +telecommunication system | 1008 | 24% | 1248 |
| Deorbiting and stability system | 500 | 20 | 600 |
| **Functional unit** | 1825 | 22% | **2228** |
| **Payload** | **-** | **-** | **772** |

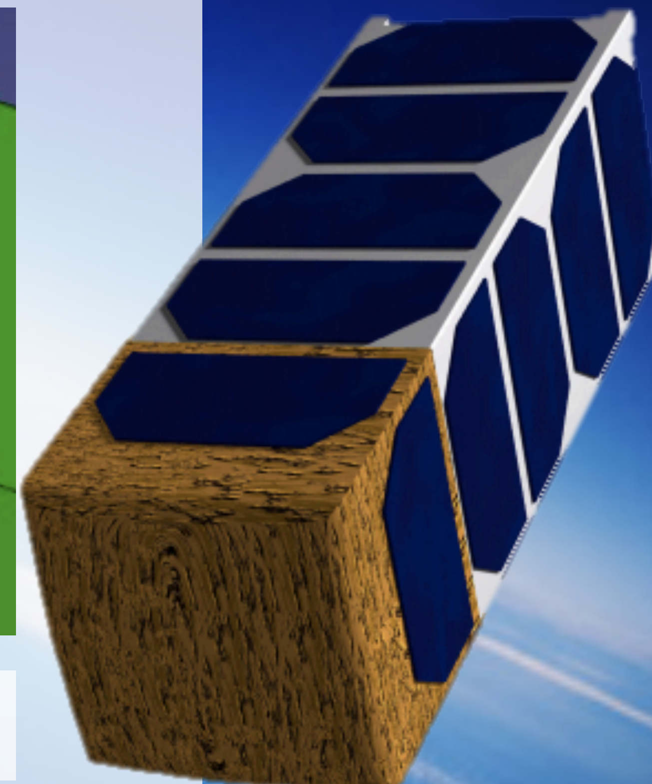


# Challenges

-TPS sizing-



*An artistic impression (left) and the tree critical parameters(right;*
*1: nose radius= 230 mm, 2: edge radius= 12 mm , 3: inclined surface (α=0))*

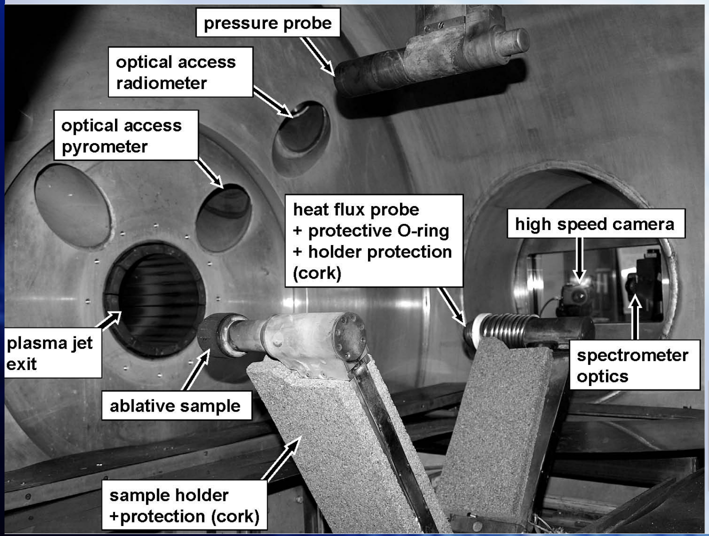


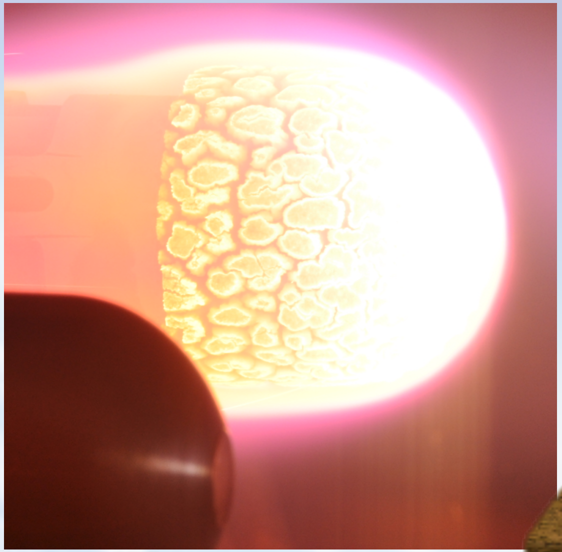
# Challenges

-TPS sizing-

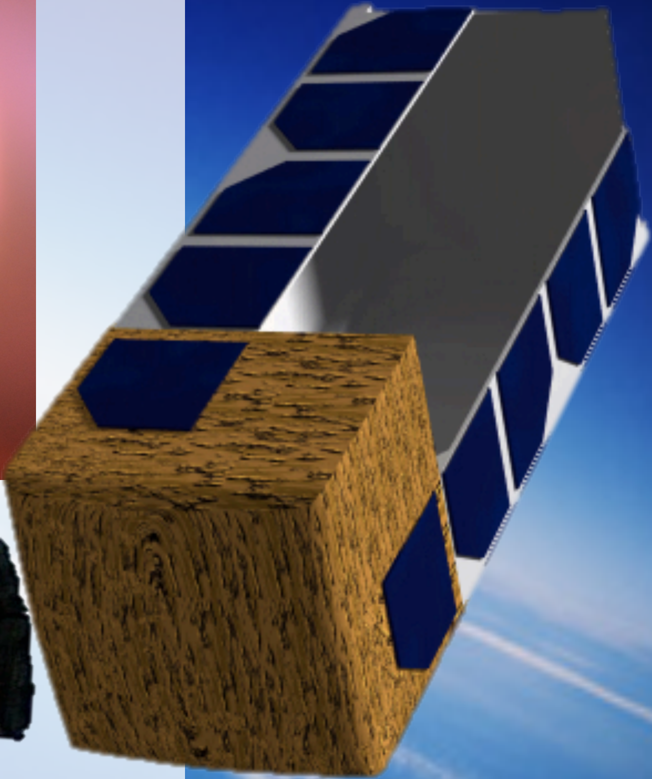
➢ Plasmatron tests

(Material characterisation)



Cork P50 (Amorim)

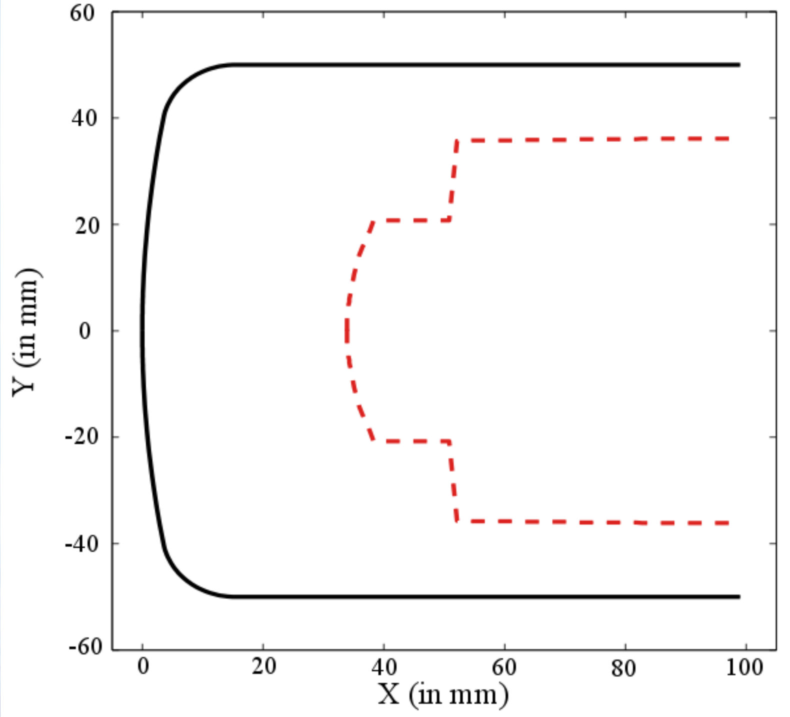


# Challenges

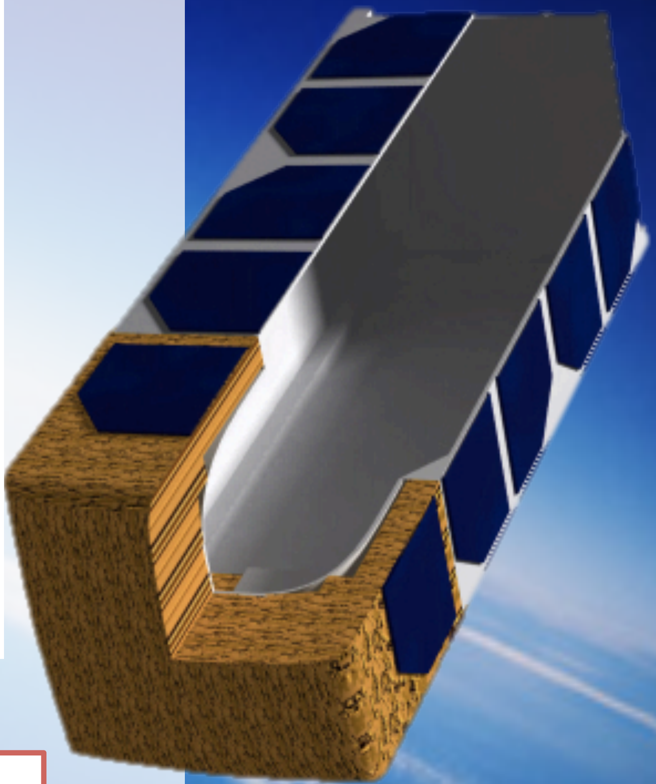
-TPS sizing-

By considering:

- Recession rate
- 1d conduction
- 3D CFD
- No safety margins




Cross section of the heat shield

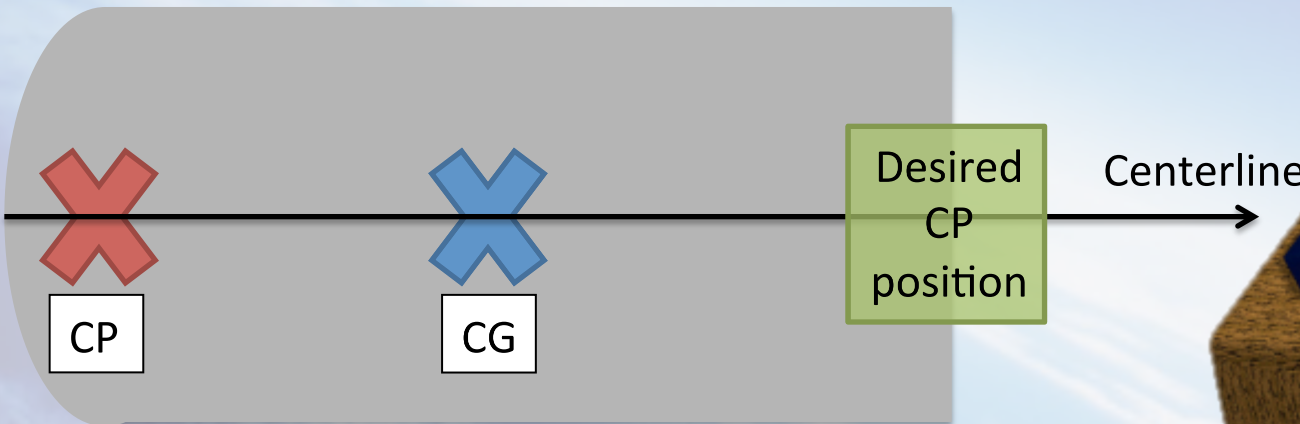


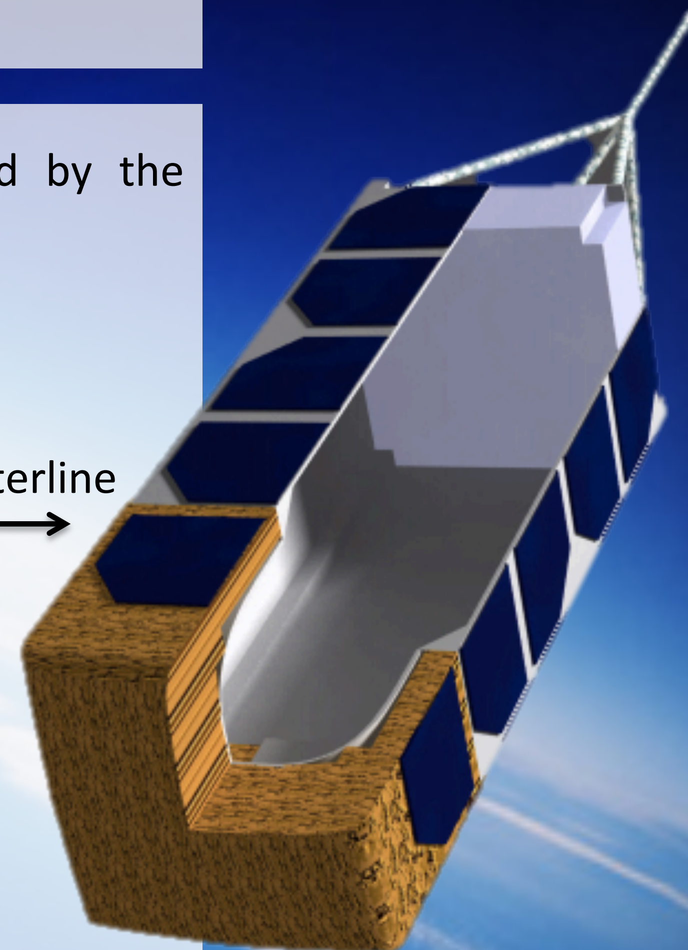
➢ Future work: use of EADS codes for more accurate sizing

# Challenges

## -Stability of the vehicle-

- Position of the center of pressure (CP) evaluated by the Modified Newtonian Theory code

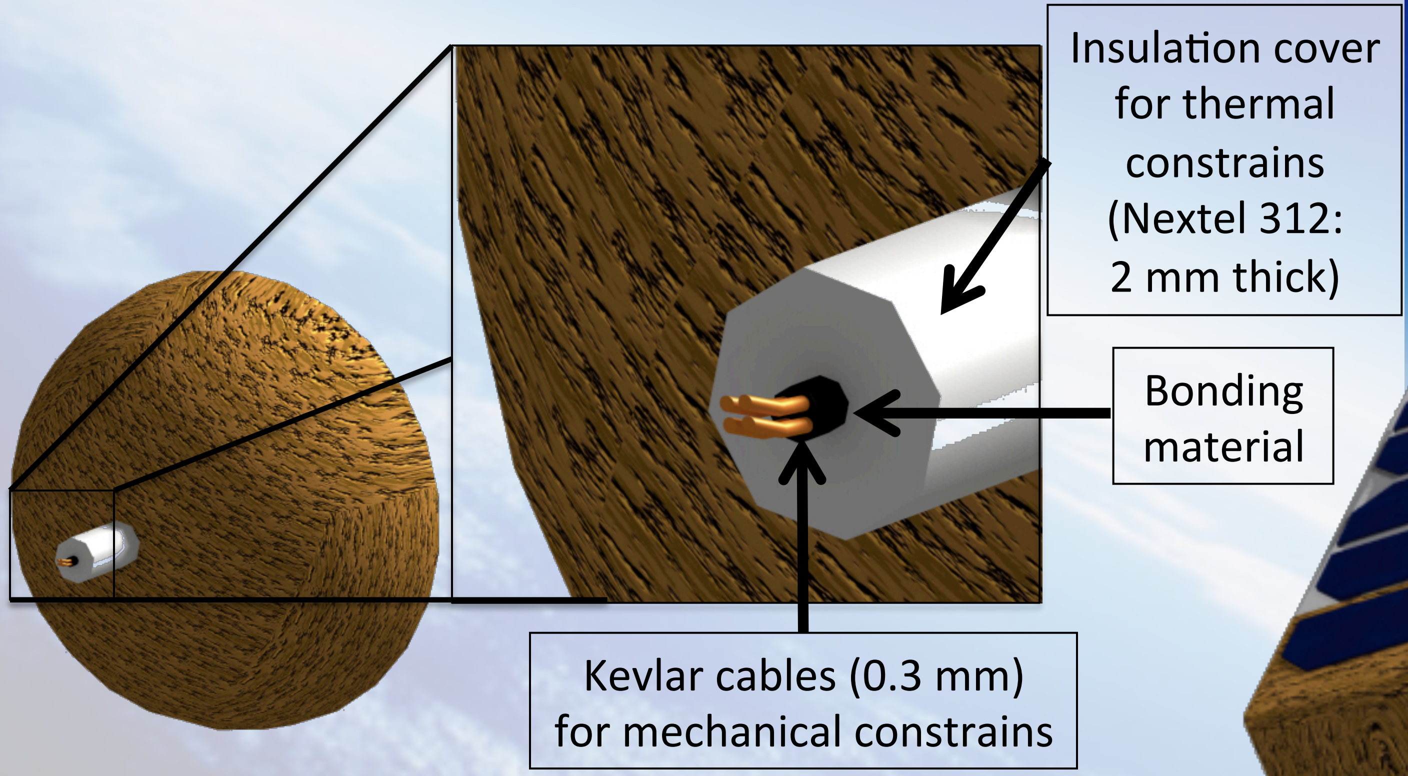


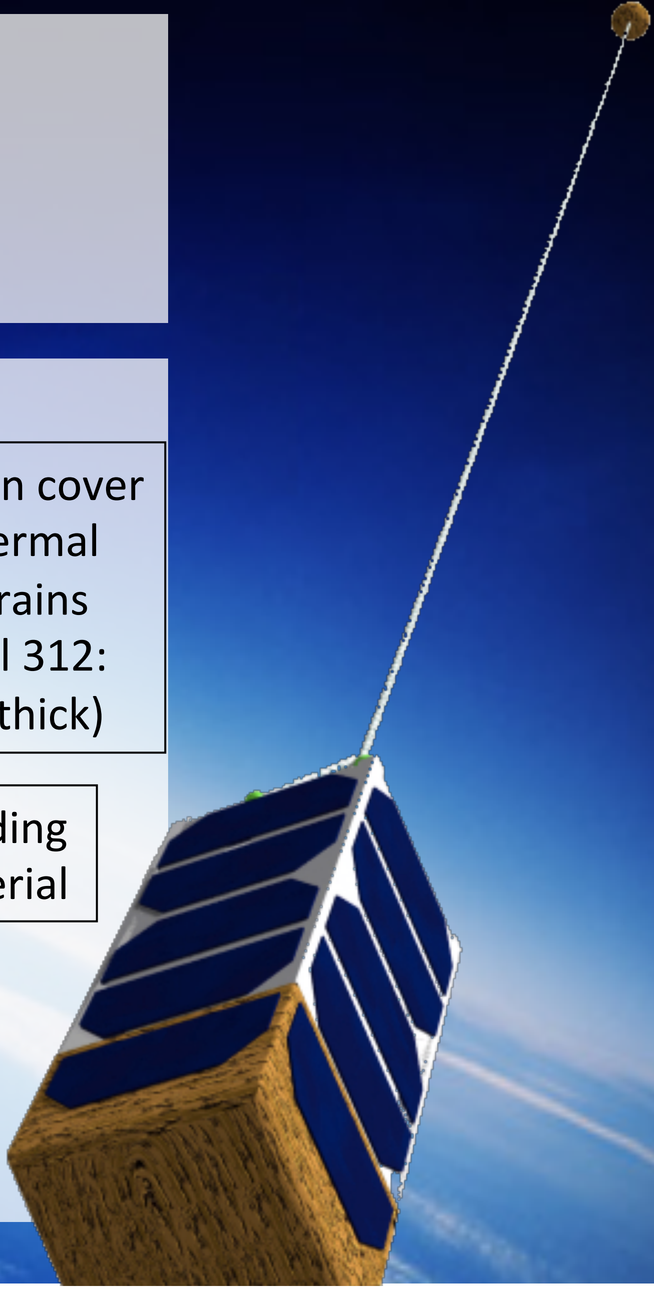



# Challenges

-Stability of the vehicle-

- Stability system proposed:

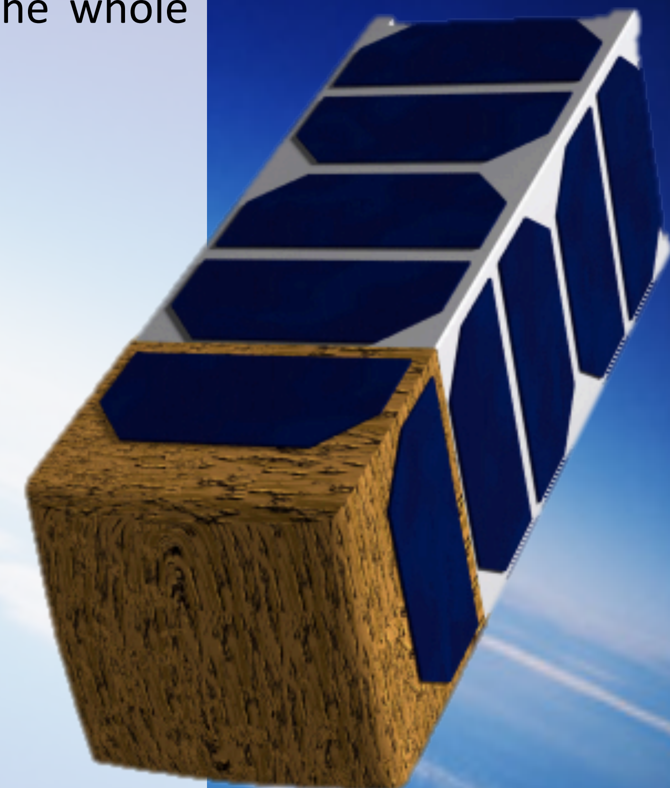


# Challenges

## -Deorbiting system-

- Quantify the impact of the deorbiting system on the whole trajectory within the mission constrains.

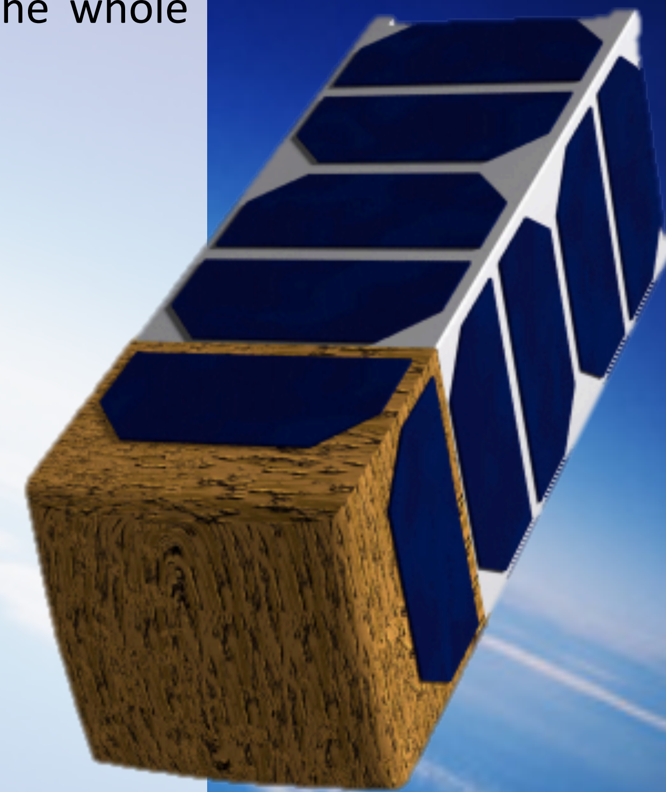


# Challenges

## -Deorbiting system-

- Quantify the impact of the deorbiting system on the whole trajectory within the mission constrains.

  - Limit the heat load within heat flux constrains (our case)
  - Collect data from a specific phenomenon or range of altitude
  - Any specific mission (where you can associate an efficiency coefficient)



# Challenges

## -Deorbiting system-

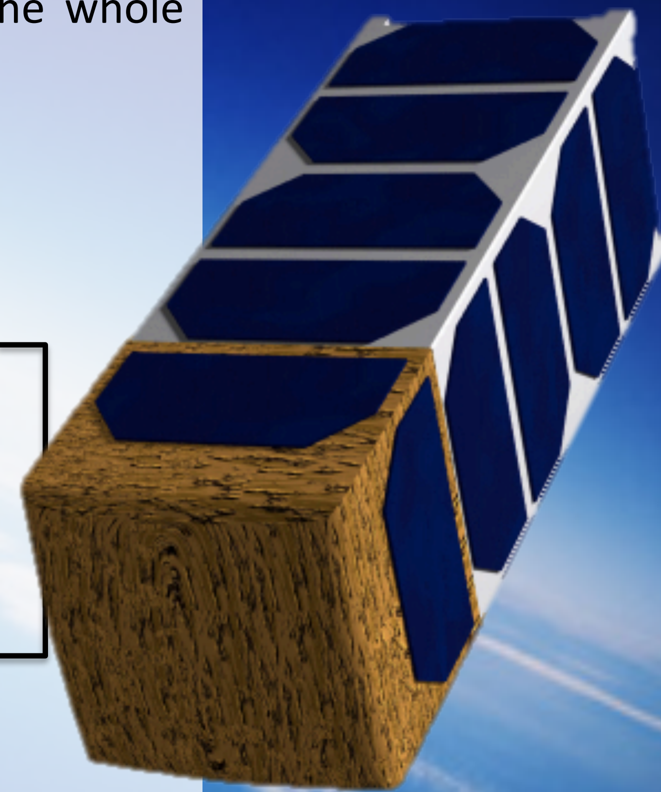
- Quantify the impact of the deorbiting system on the whole trajectory within the mission constrains.

Fast aerodynamic database building
(Free molecular
+ Bridging function
+ Modified Newtonian
>140.000 points)

6 DoF and round earth trajectory code

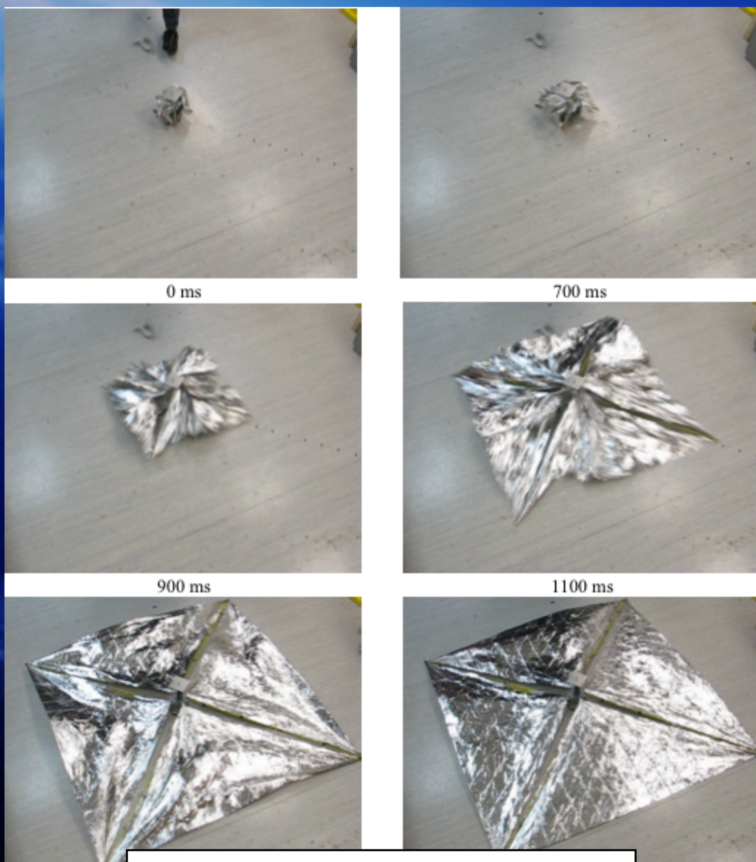
Trajectory evaluation (Heat flux…)

Optimizer
(genetic algorithm)
1000 initial points
1000 generations

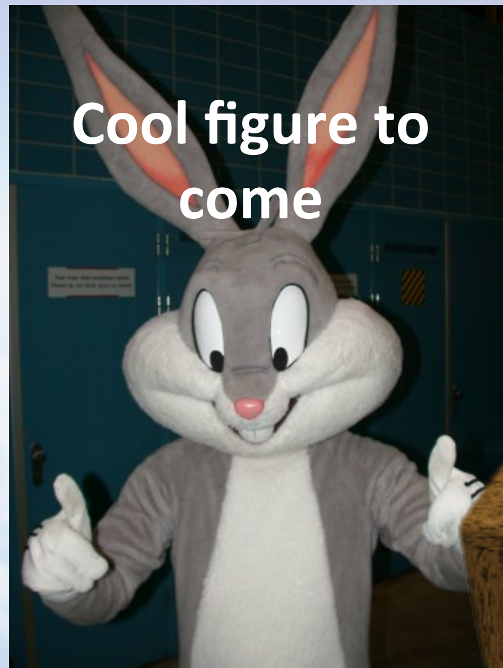


# Challenges

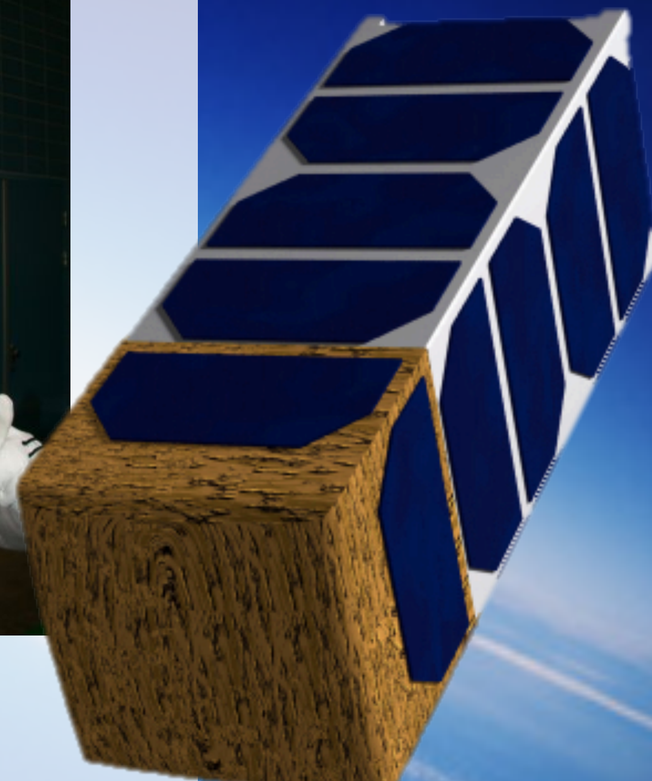
## -Deorbiting system-




Credit Surrey Space Center

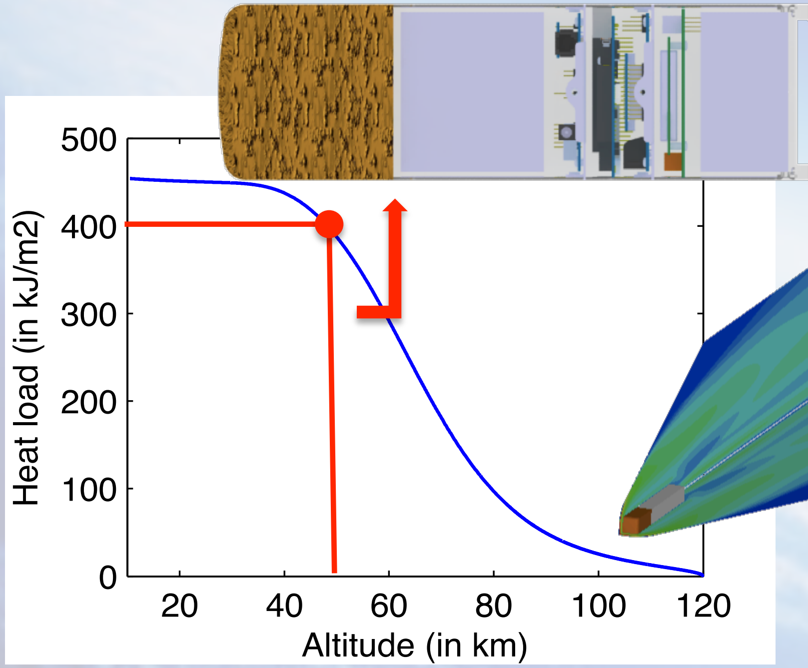


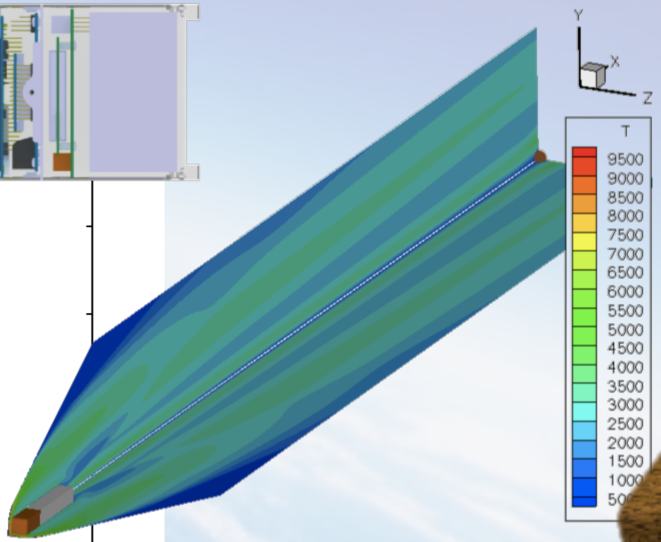

Optimum of the deorbiting system

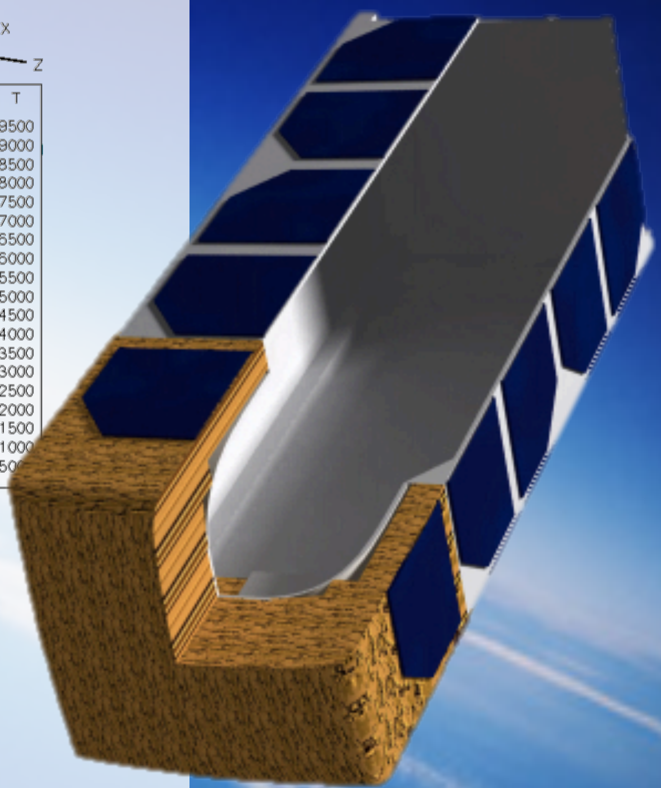


# Challenges

-Thermal management-



Heat load on at the side panel interface versus time during re-entry

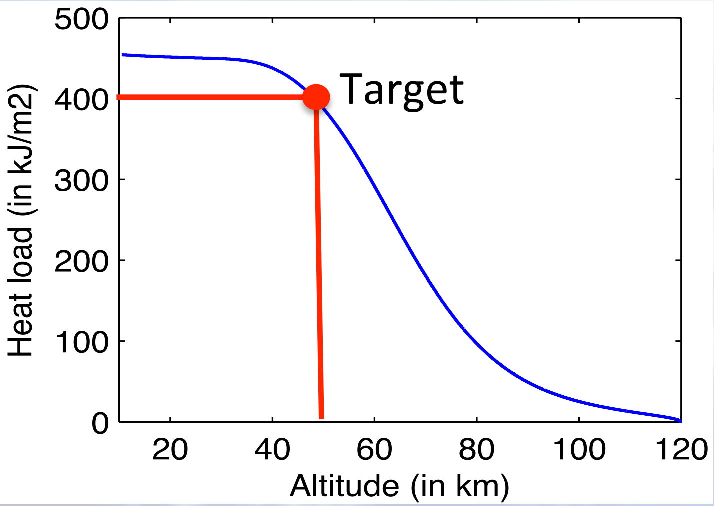
# Challenges

## -Thermal management-

After a review of the possible side panels configurations, the final configuration is proposed as following:

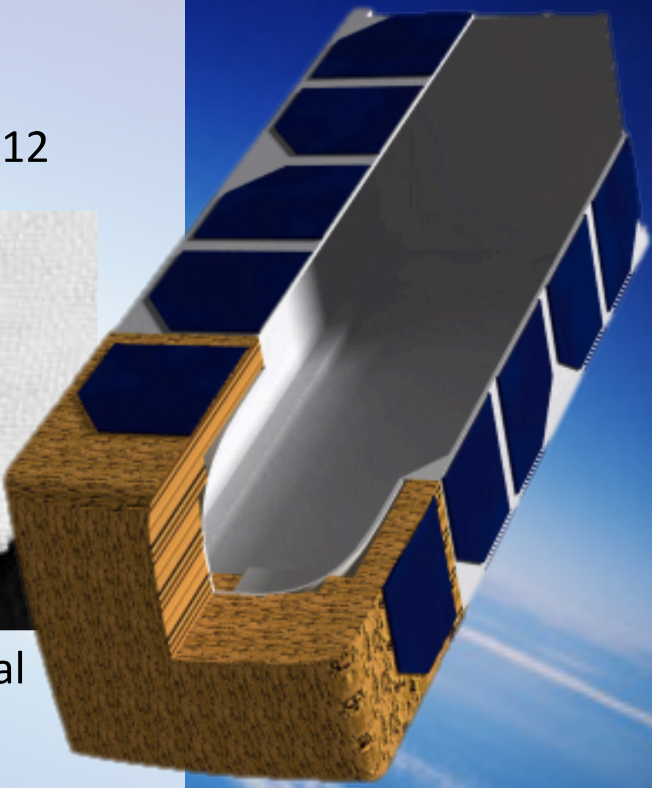
- Standard Aluminium panel (thickness of 1.5 mm)

+ 1.6 mm of thermal blankets made out of 3M Nextel 312




Heat load on a side panel versus time during re-entry

3M Nextel 312 thermal blanket sample

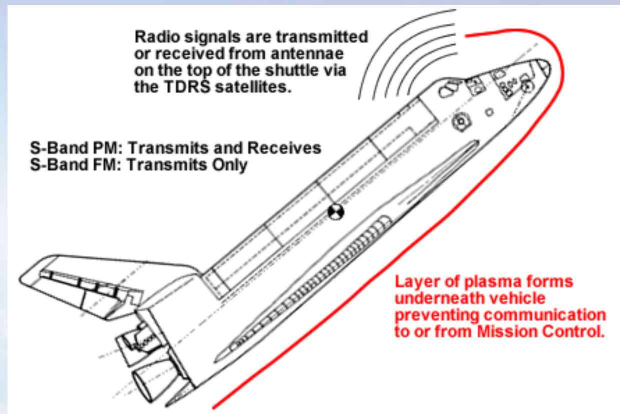


# Challenges

## -Telecommunication system-

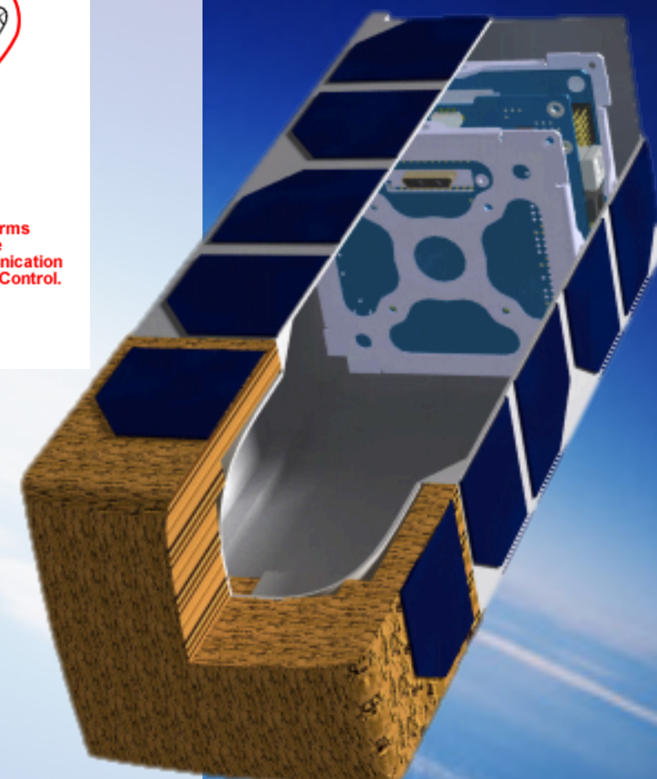
Maximum of 10 minutes for the Re-entry and the vehicle will not survive:

- ➢Needs to transmit the data before disintegration




Utilization of the Iridium constellation:

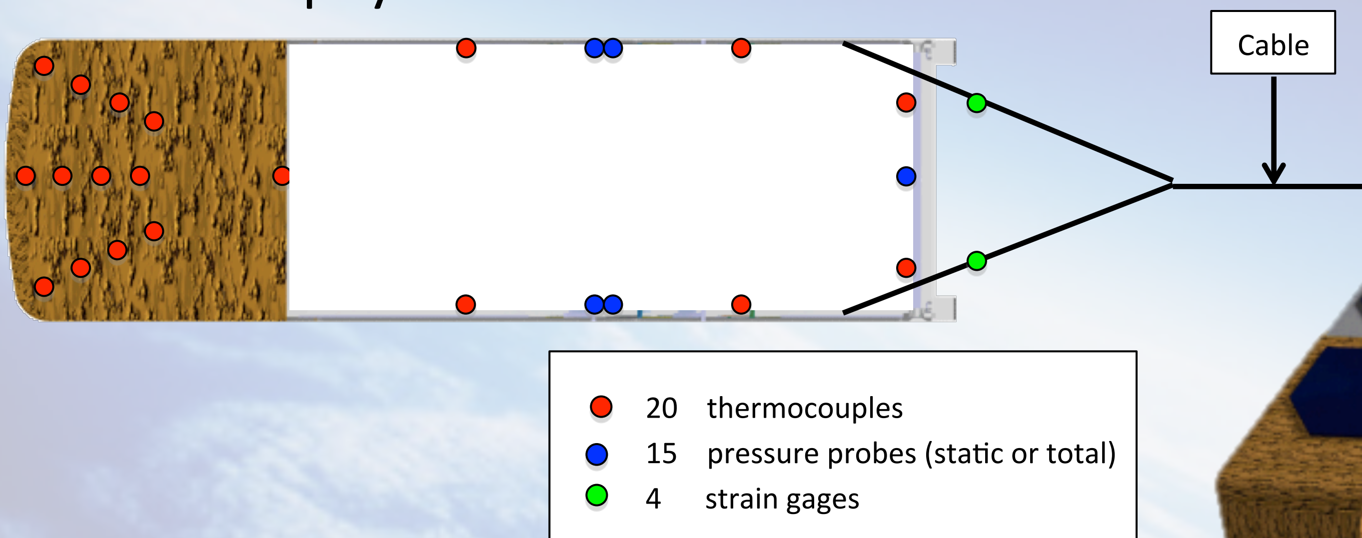
- ➢ Permanent coverage of all the trajectory (by 4-6 satellites with 10 Mo/s link for each)

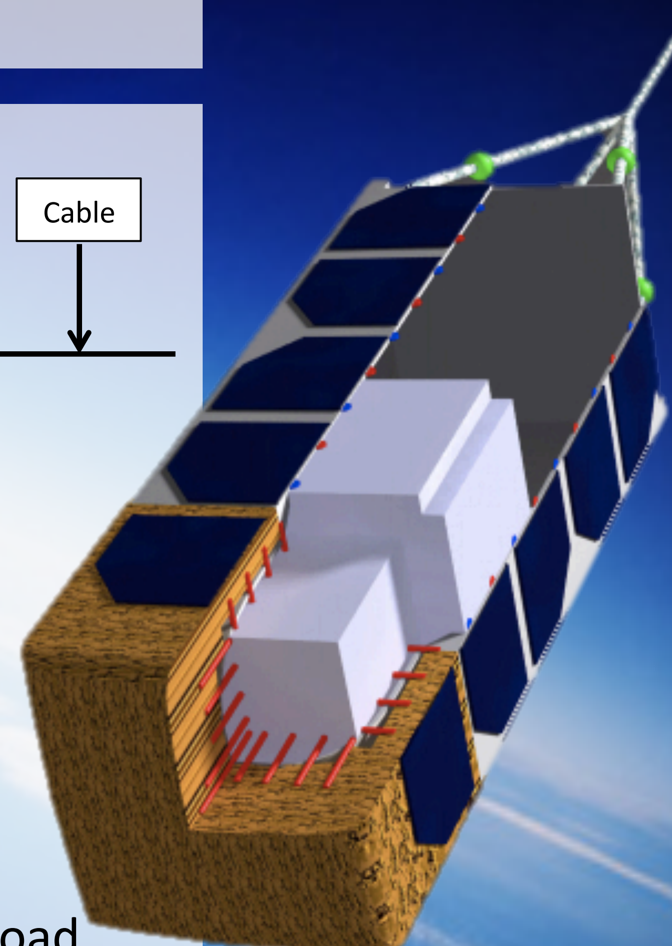


# Specific payloads

-minimal configuration-

➢ Minimal payload



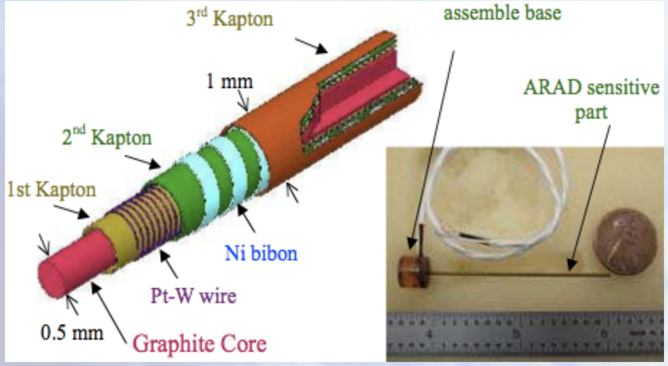
➢ Power supply needed: 2 W (with margins)

➢ Data rate: 1 kbytes/s (with margins)

+ Extra data rate to be evaluated for the extra payload

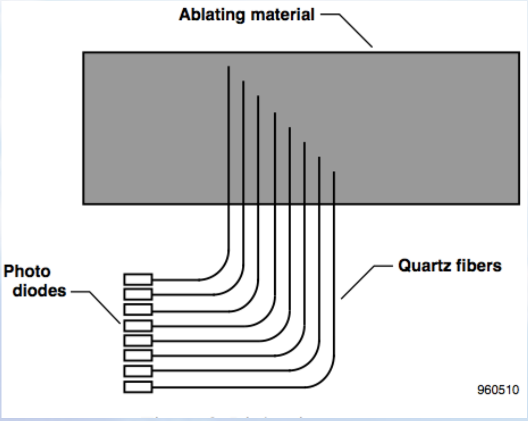
# Specific payloads

-Ablation characterization: example of a recession sensor-

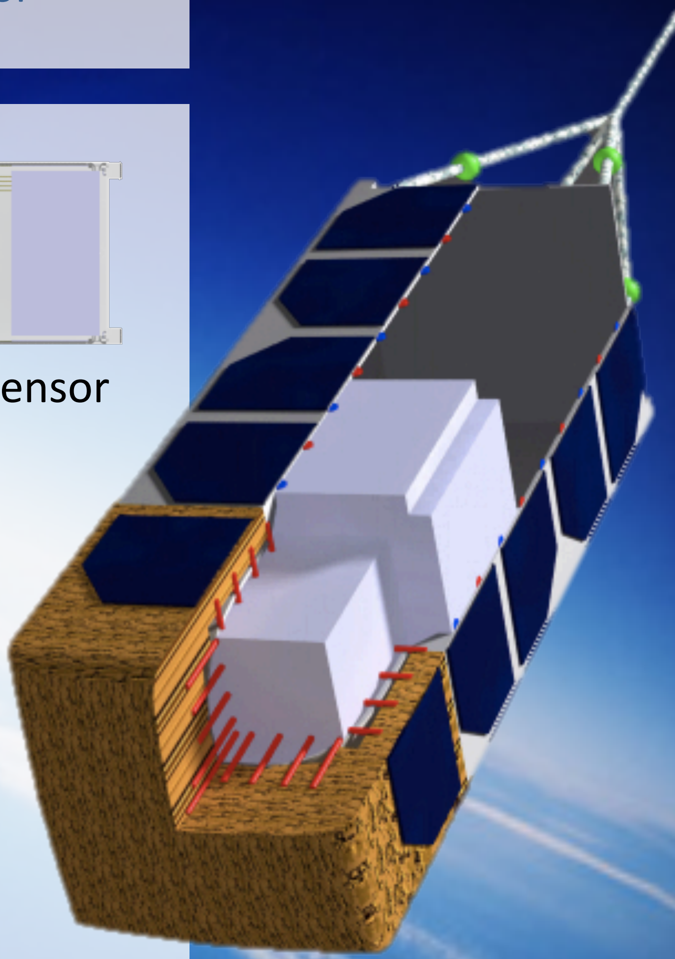



ARAD recession sensor (NASA Ames)

Ultrasound recession sensor



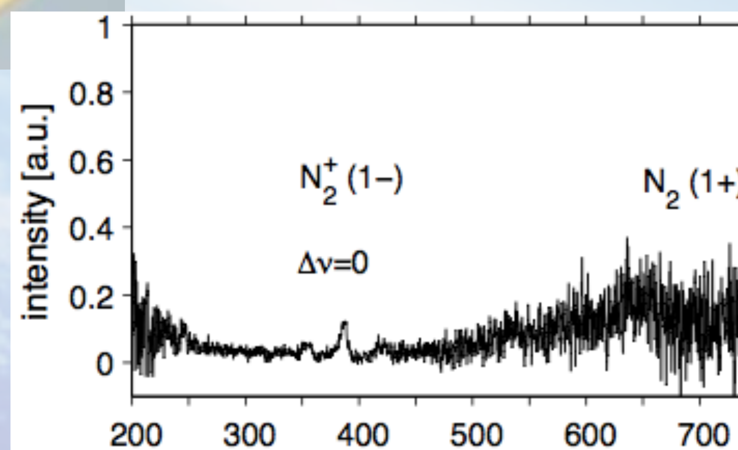

Light pipe gage



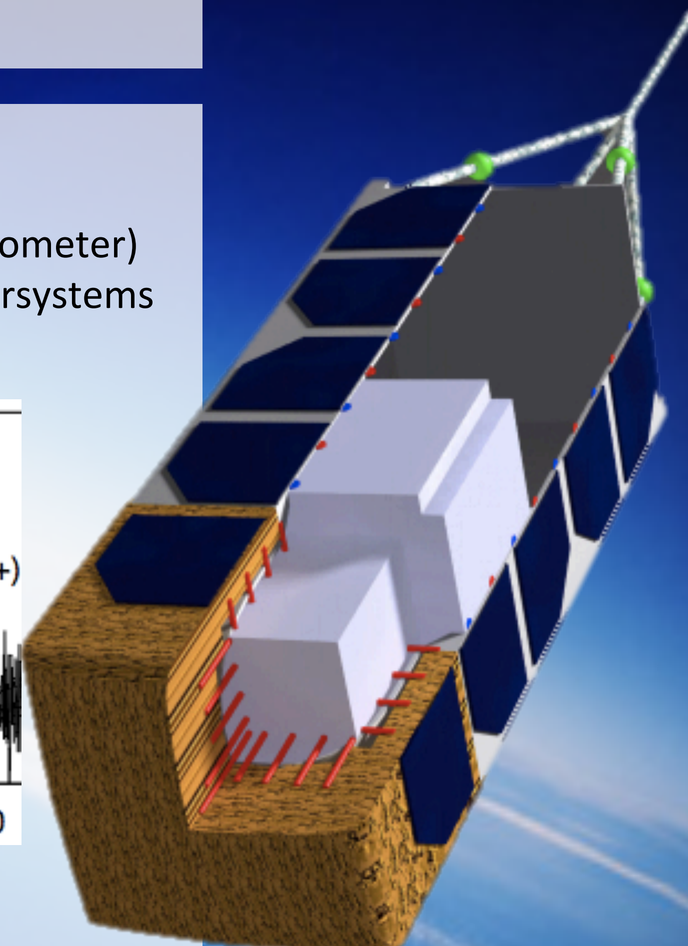
# Specific payload

-Emission spectroscopy-

Qmini (highly integrated spectrometer) range 200-700 nm, from rgblasersystems




Example of Nitrogen diagnostic in an Air plasma

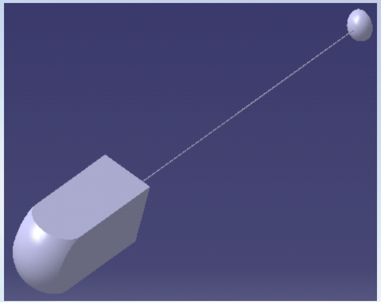


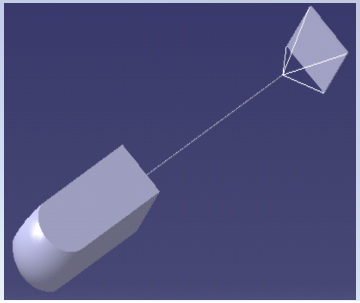
# Thank you for your attention

-gilles.bailet@vki.ac.be-

# Stability system

-How can a brick fly?-





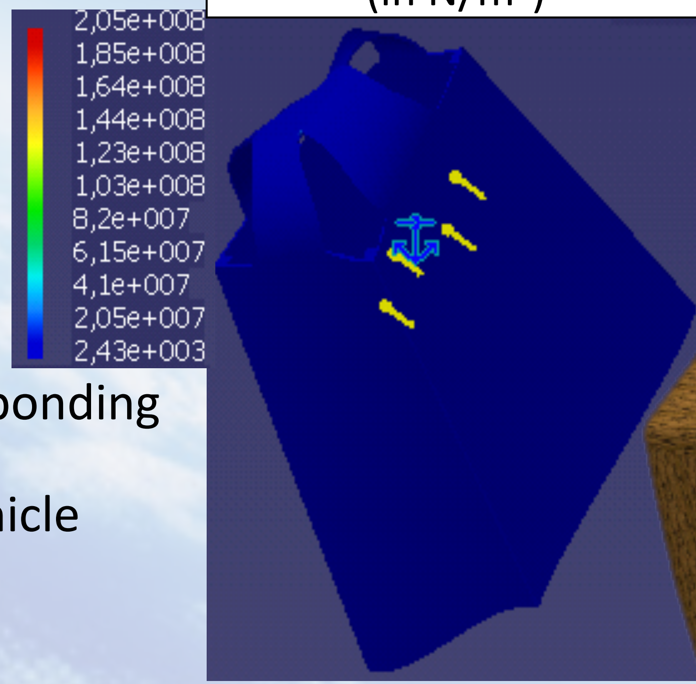
| | Low drag increment (hemisphere) | High drag increment (flat plate) |
|---|---|---|
| Surface area (in $cm^2$) | 42.25 | 100 |
| Position downstream the vehicle (in m) | 1.3 | 0.32 |
| Drag coefficient increment | 0.38 | 2 |

- Future work: PASDA code (Parachute System Design and Analysis Tool)

# Structural consideration

-CATIA FEM module-

von Mises criteria
(in N/m$^2$)




- Small increment of mass
- Good substrate for TPS bonding
- Keep integrity of the vehicle

  (safety factor of 5)