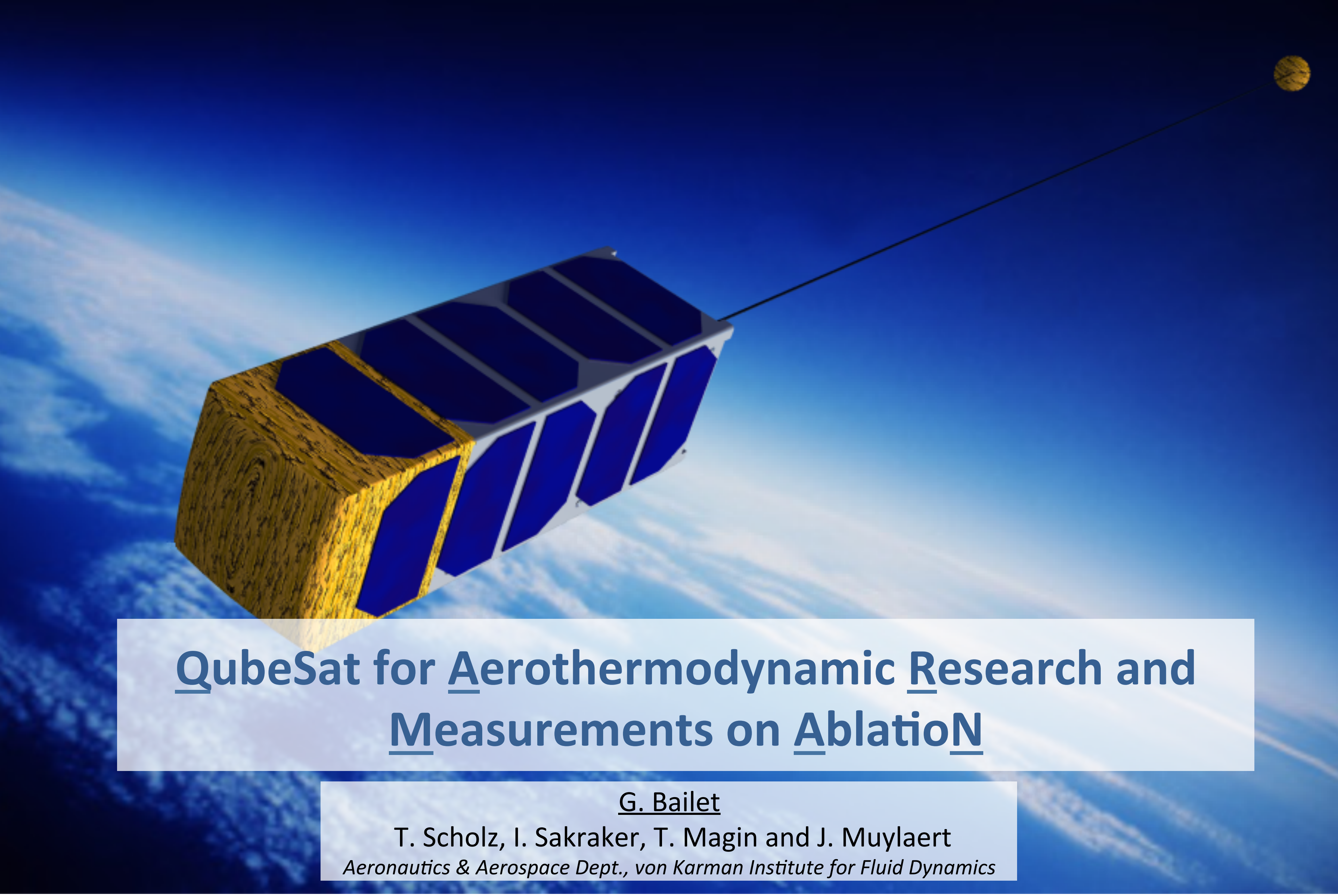


QubeSat for Aerothermodynamic Research and Measurements on AblatioN

G. Bailet

T. Scholz, I. Sakraker, T. Magin and J. Muylaert

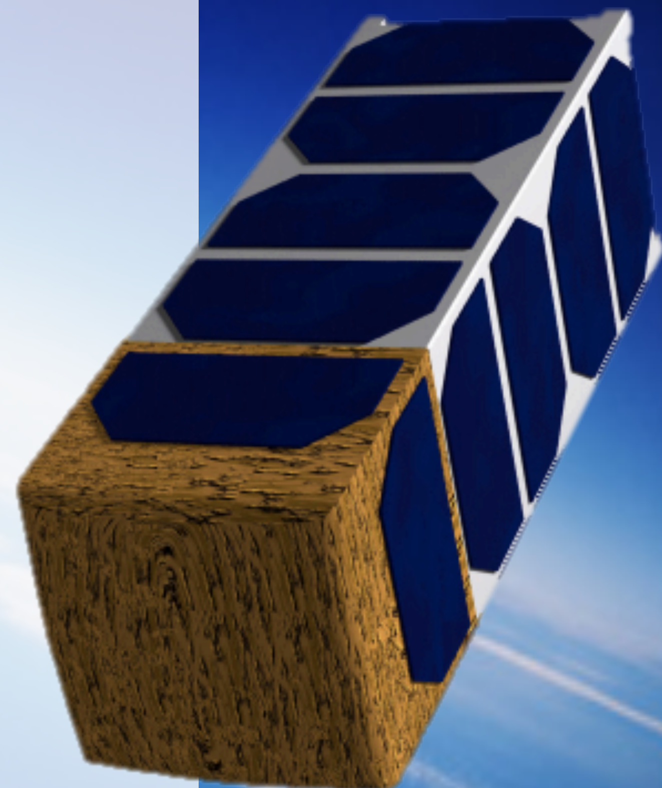
Aeronautics & Aerospace Dept., von Karman Institute for Fluid Dynamics

9th International Planetary Probe Workshop

- Toulouse, June 16-22 2012 -

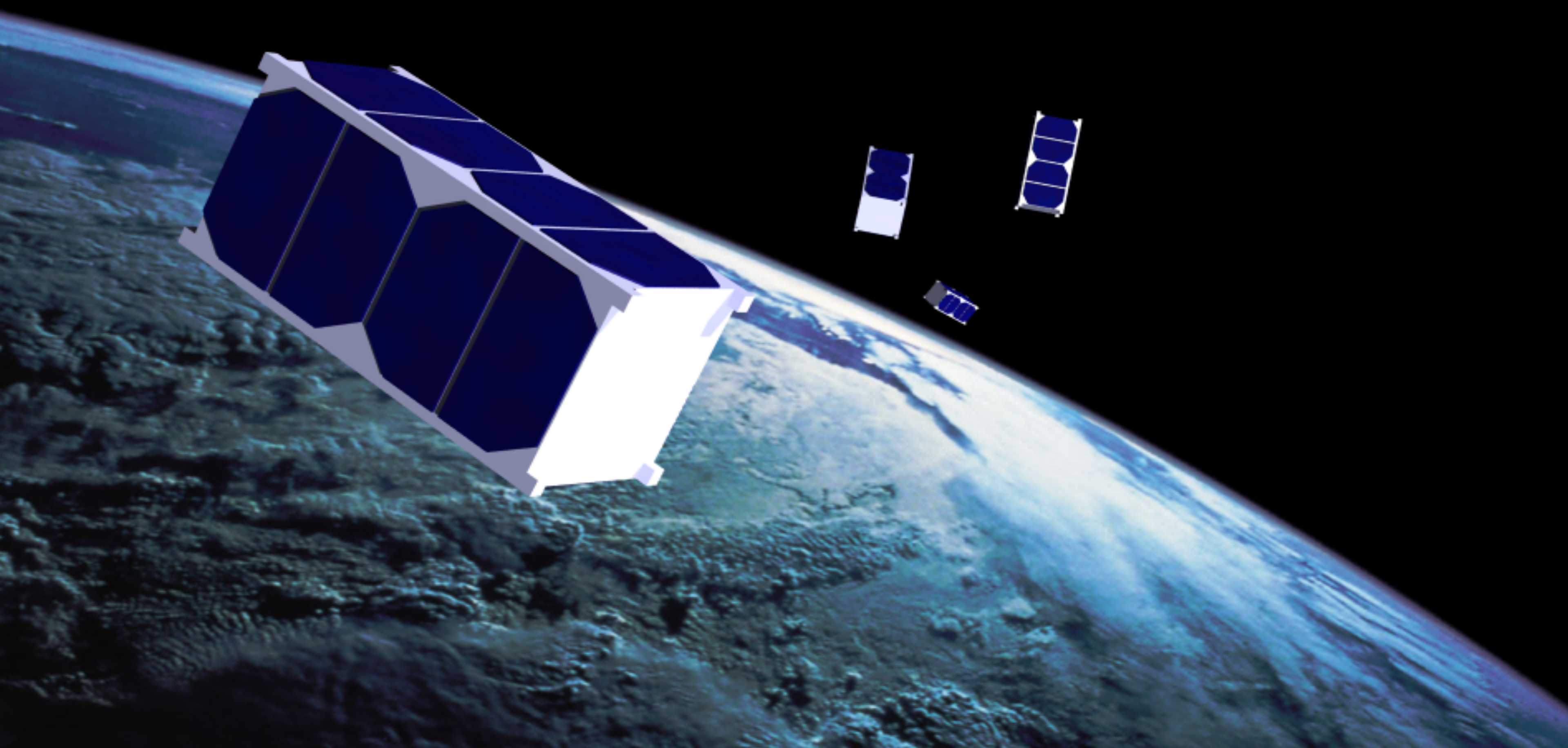
Content

- Introduction
- Conceptual design
- Challenges
- Specific payloads



Introduction

-www.qb50.eu-



9th International Planetary Probe Workshop

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Introduction

-www.qb50.eu-

QB50:

- First network of CubeSats
- 40 (+10 IOD) CubeSats sequentially deployed at an initial altitude of 320 km
- Each CubeSat will perform in-situ measurements of atmospheric parameters

Introduction

-www.qb50.eu-

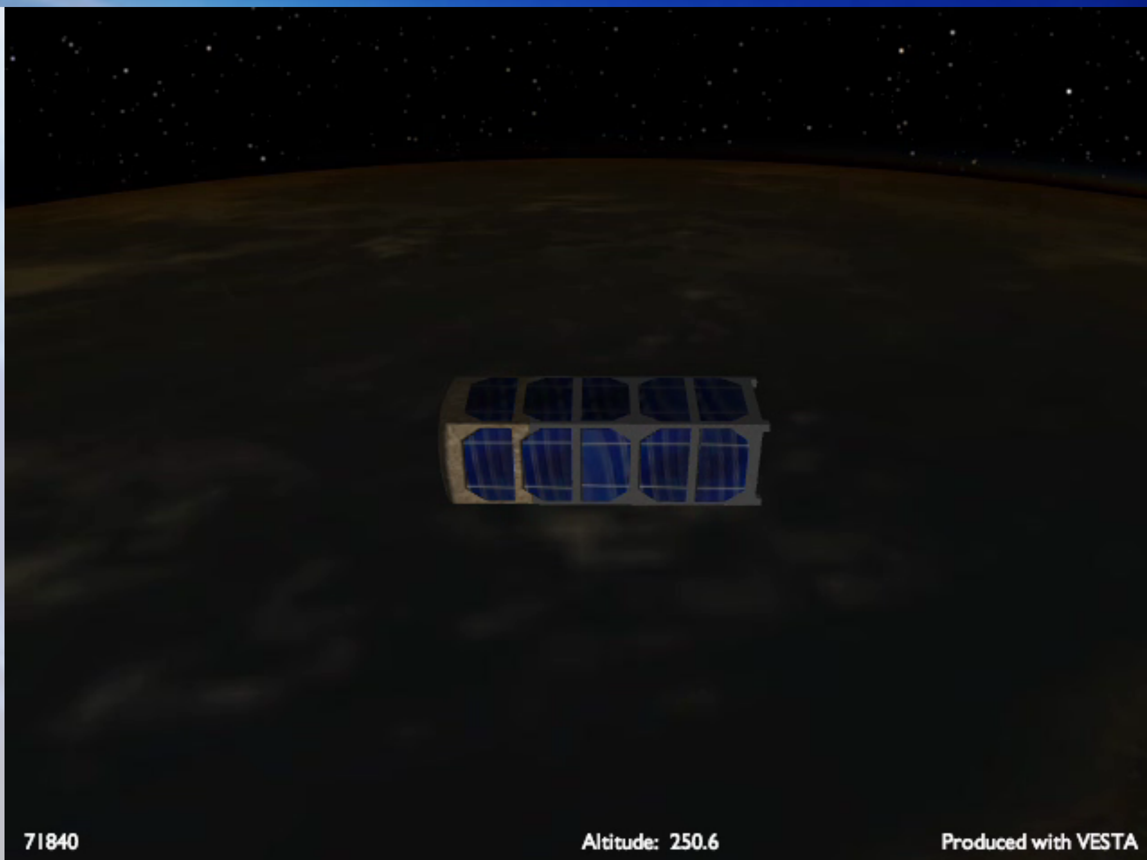
SHTIL 2.1

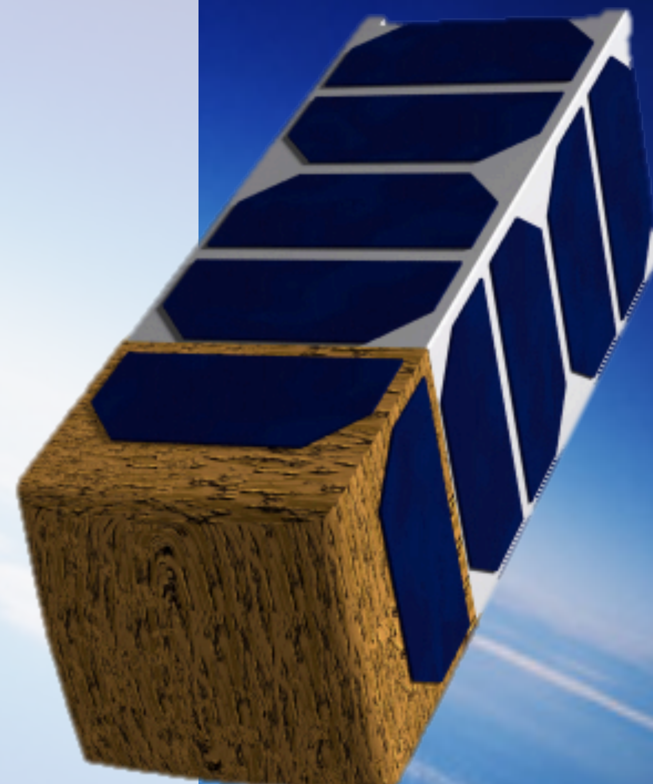
QB50:

- First network of CubeSats
- 40 (+10 IOD) CubeSats sequentially deployed at an initial altitude of 320 km
- Each CubeSat will perform in-situ measurements of atmospheric parameters
- Launch together in Spring 2015

Context

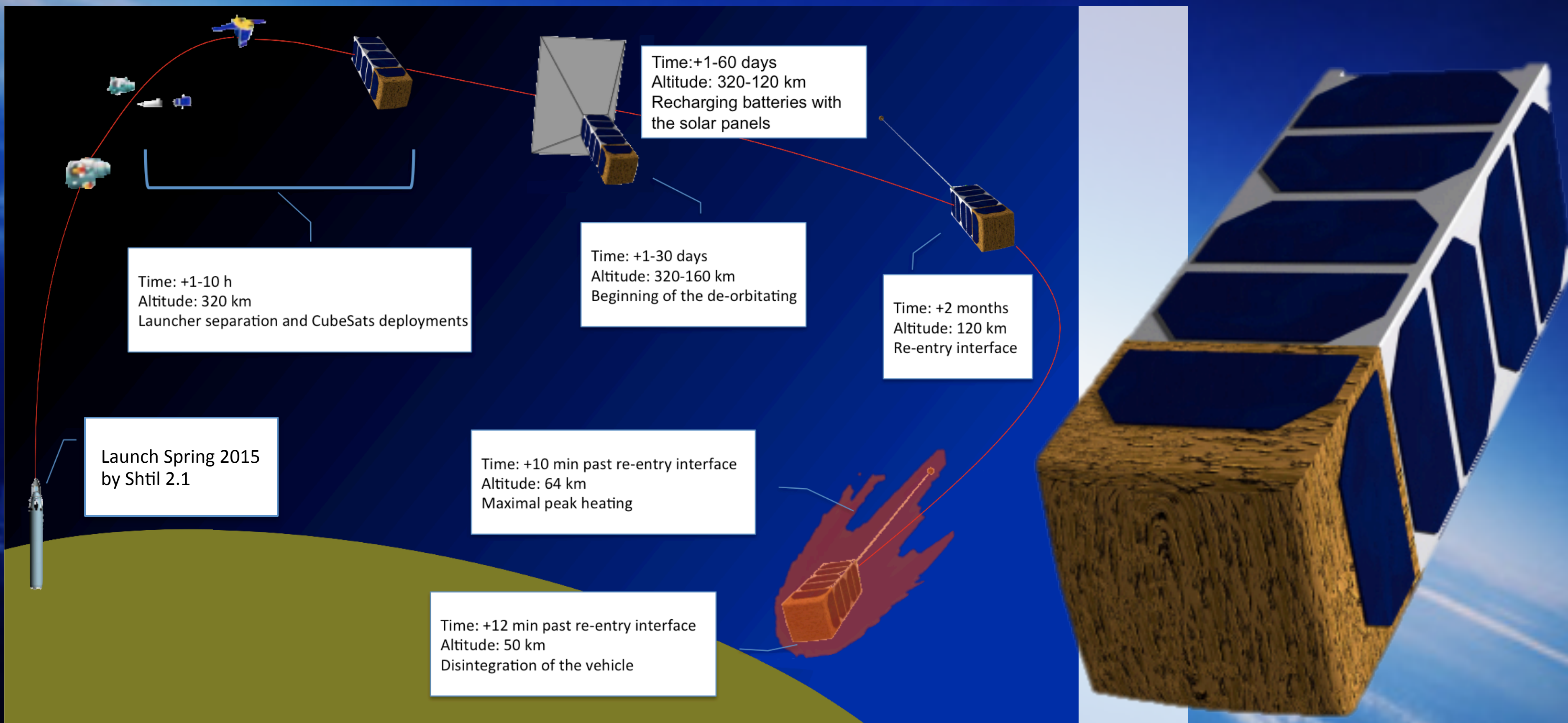
-Scenario time line-





Context

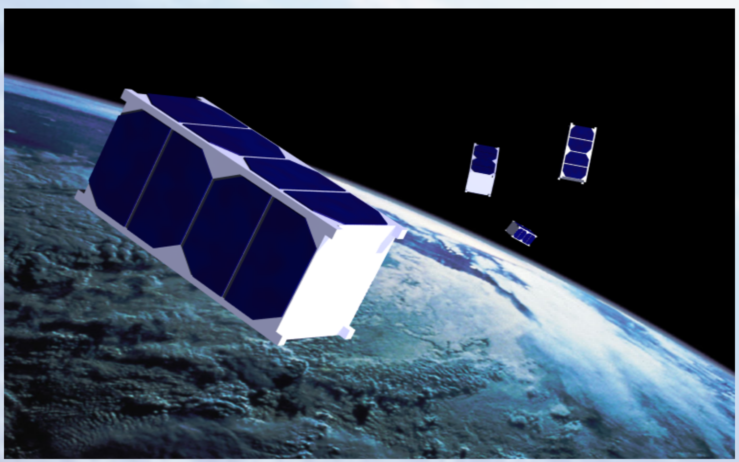
-Scenario time line-

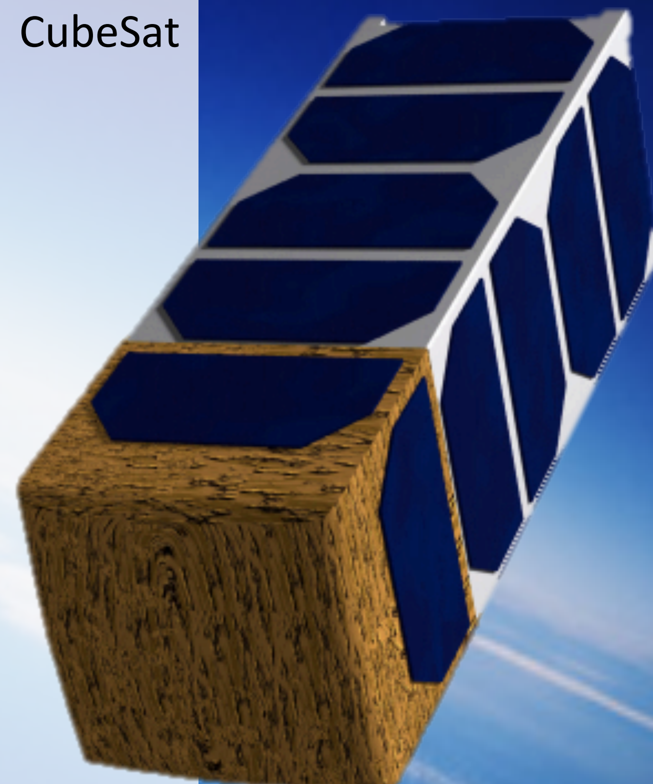


Introduction

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

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

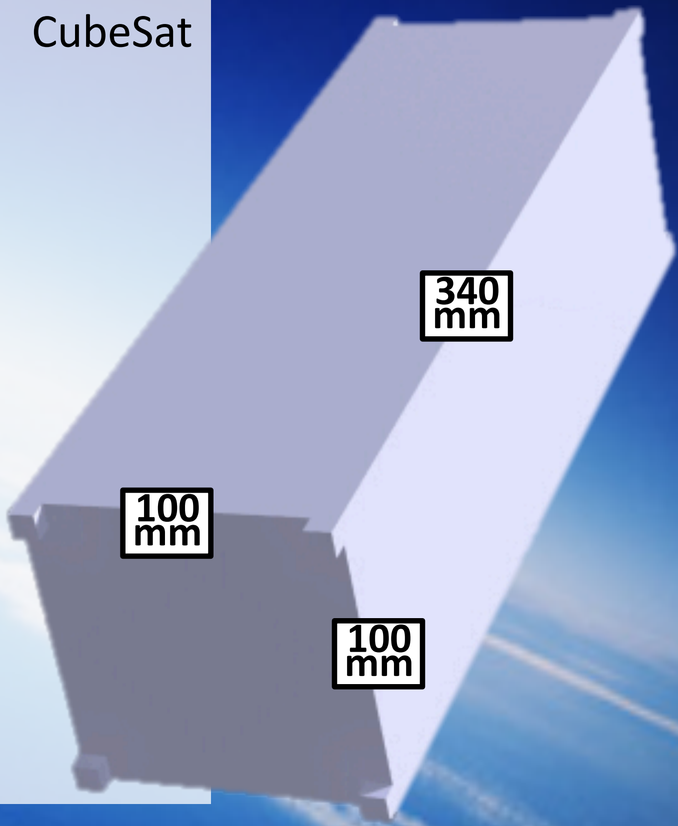




Introduction

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

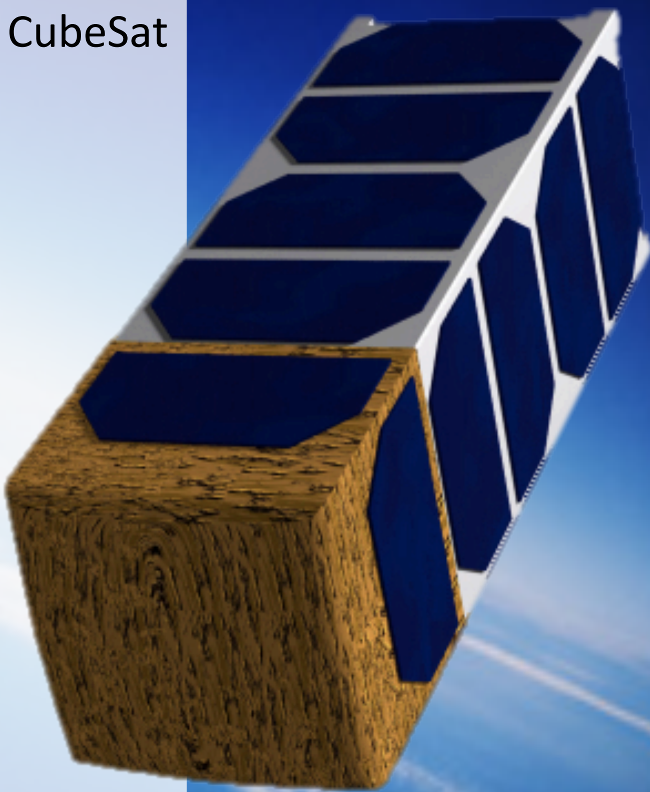


Introduction

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)



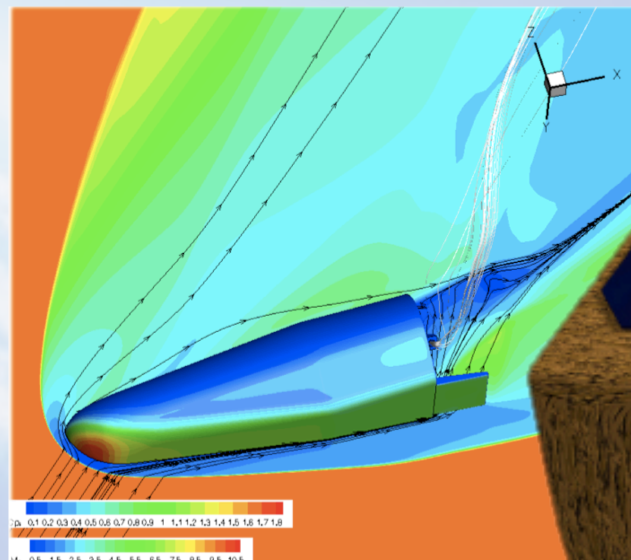
Scientific opportunities for low-cost re-entry platforms

-Affordable platform for research oriented re-entry study-

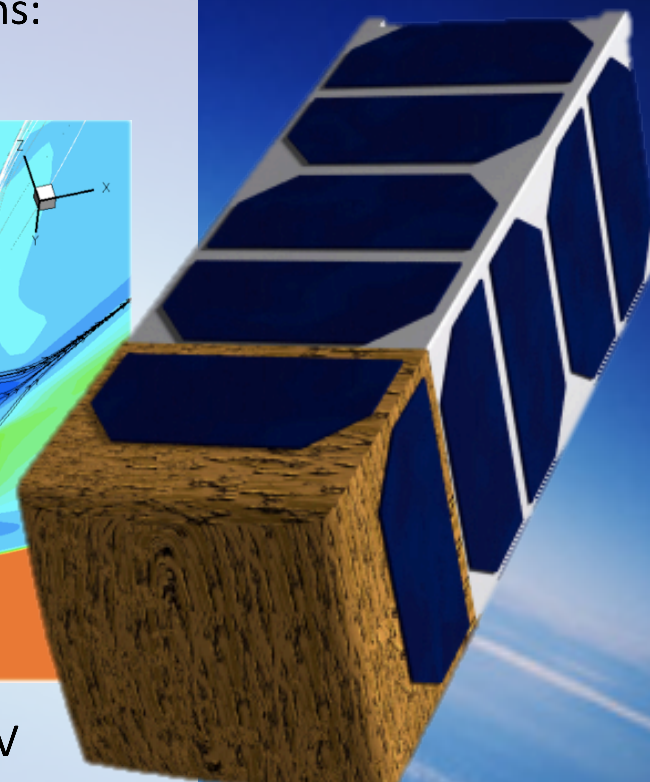
- VKI's field of expertise at in ground testing and simulations:

YES2, Expert, IXV

Ablation test in Plasmatron for the YES 2 capsule



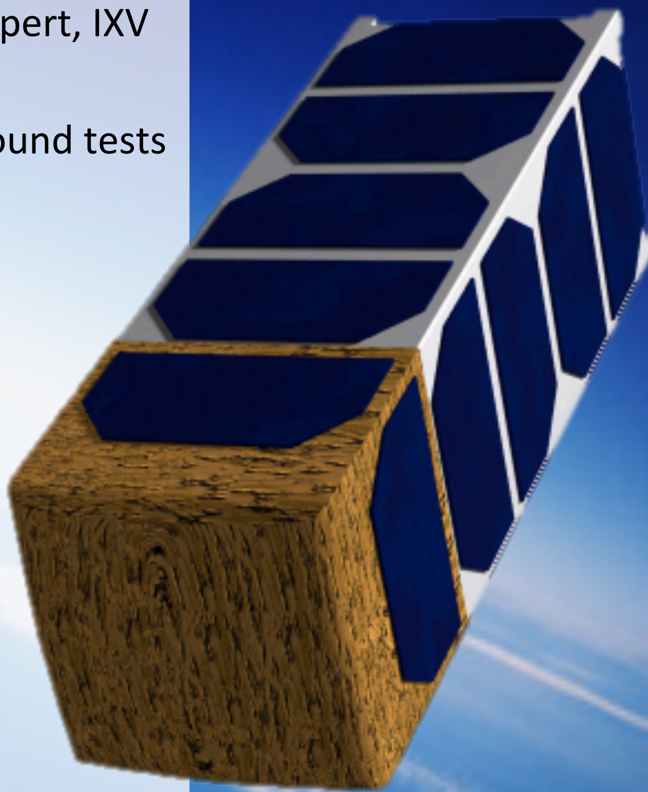
CFD simulation of IXV



Scientific opportunities for low-cost re-entry platforms

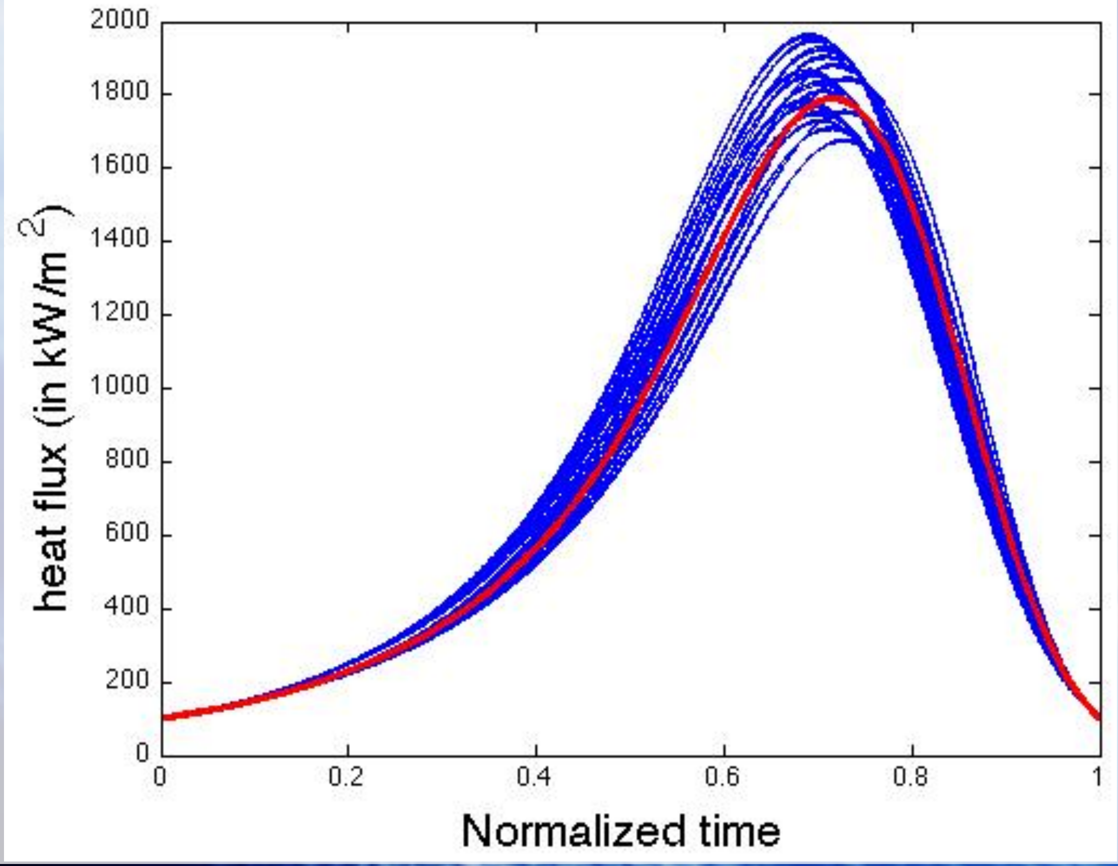
-Affordable platform for research oriented re-entry technology-

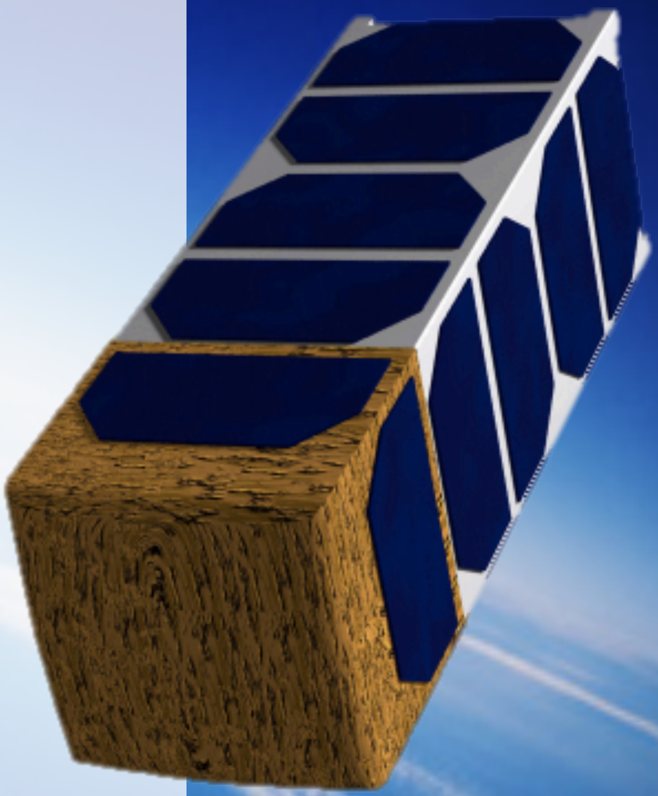
- Field of expertise at VKI in experiments and simulations: YES2, Expert, IXV
- Flight experiments for validation of numerical simulations and ground tests
- Characterization of TPS materials in flight conditions
- Re-entry Challenges & Solutions:
  - Deorbiting
  - Stability and trimming
  - Max heating/TPS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



Conceptual design

-Result for the proposed geometry with uncertainty analysis-



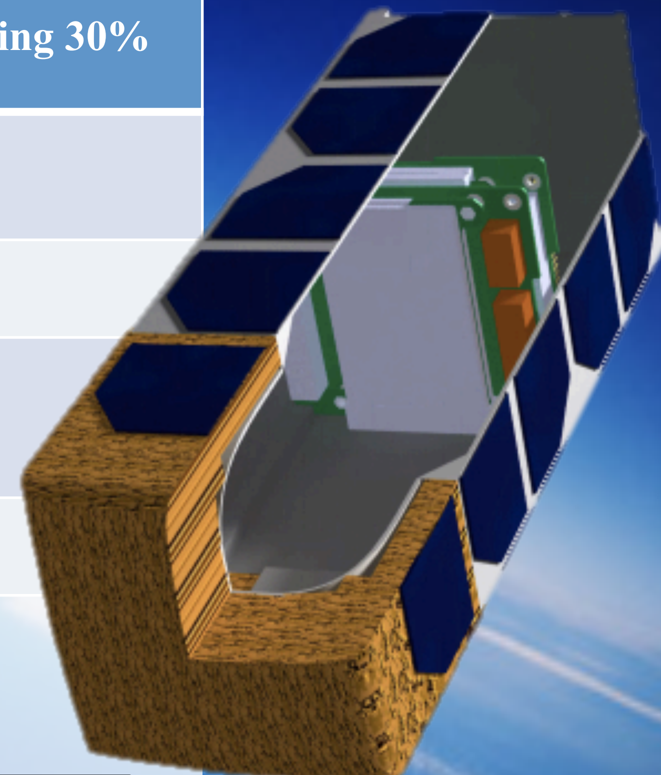


Conceptual design

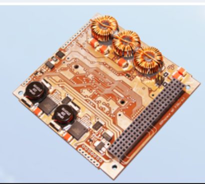
-Result for the proposed geometry with uncertainty analysis-

Reference: QARMAN proposal for QB50 call

Entity	Energy needed (in Whr, including 30% margin)
Functional unit (OBC, EPS…)	1.09
Payload + amplifier	6.28
Telecommunication system (Antenna + Iridium transceiver)	1.25
Total	**8.62**



NanoPower BP4 battery needed to survive for the 10 min mission (including the 45 min margins)



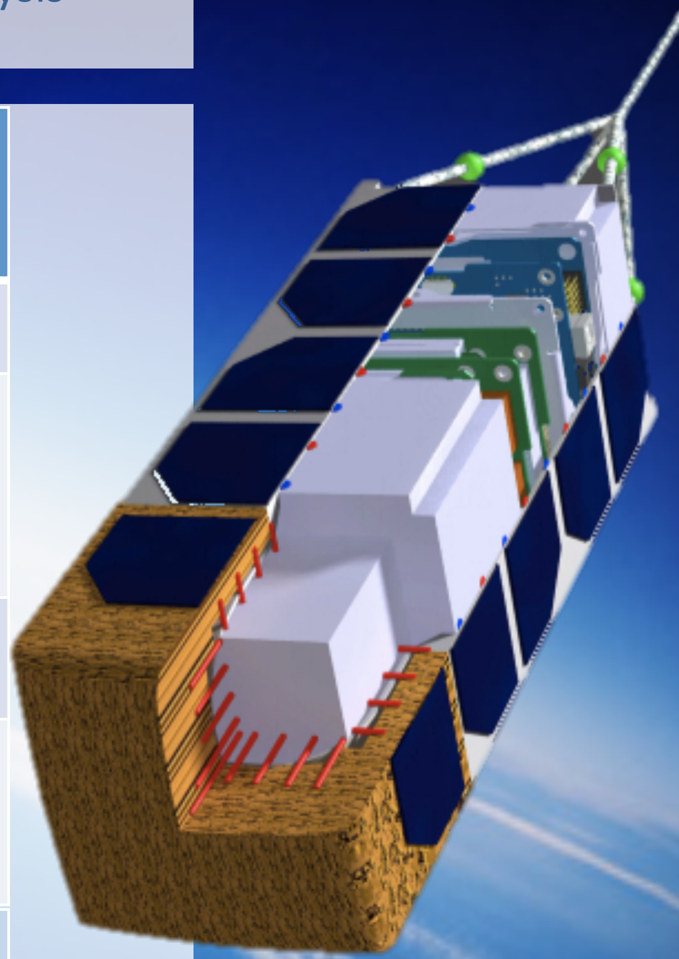
NanoPower BP4
8.4V 5200mAh

Conceptual design

-Result for the proposed geometry with uncertainty analysis-

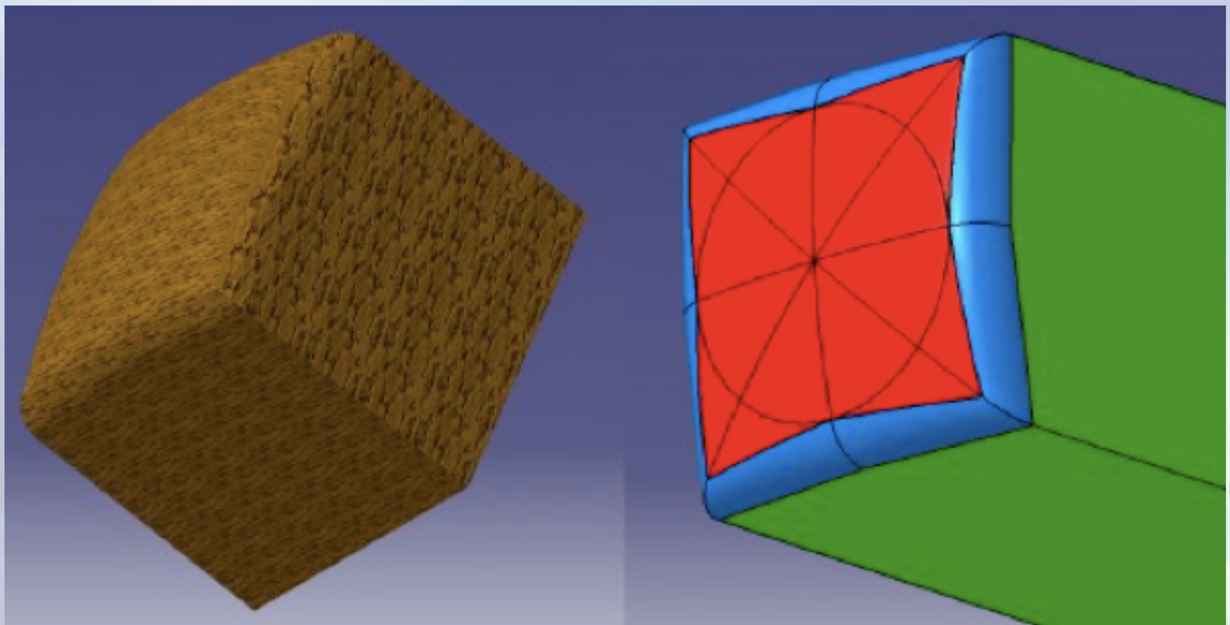
Reference: QARMAN proposal for QB50 call

Subsystem	Mass (in g)	Margin	Mass with margin (in g)
Heat shield	300	20%	360
Functional unit +Structure +telecommunication system	1411	20%	1693
Deorbiting and stability system	240	25	300
Functional unit	1951	20%	**2353**
Payload	**-**	**-**	**647**

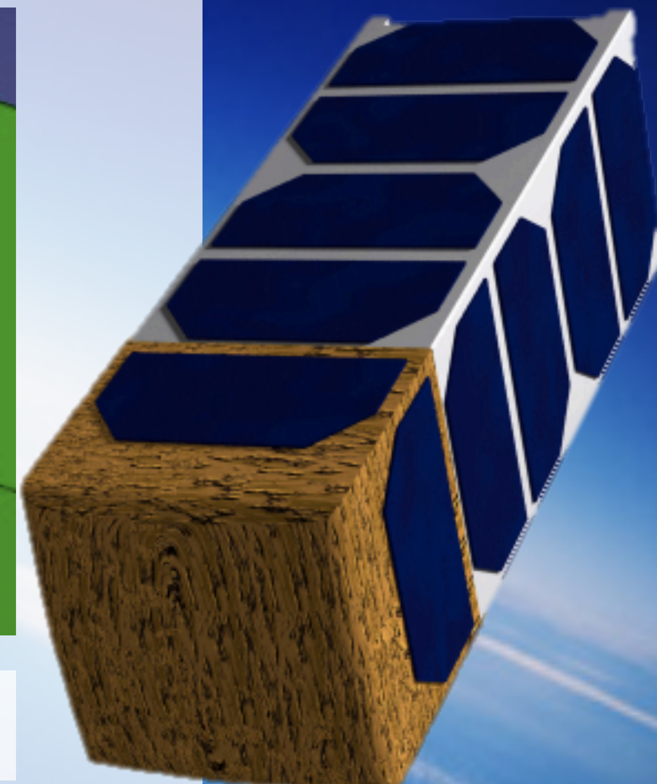


Challenges

-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))

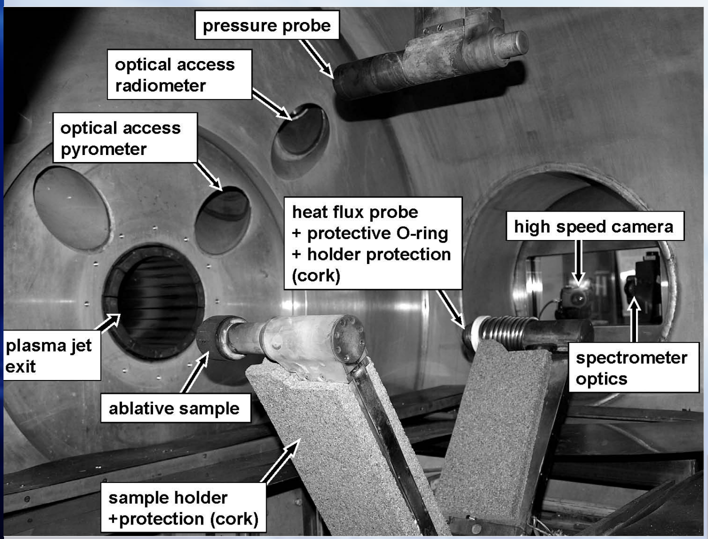


Challenges

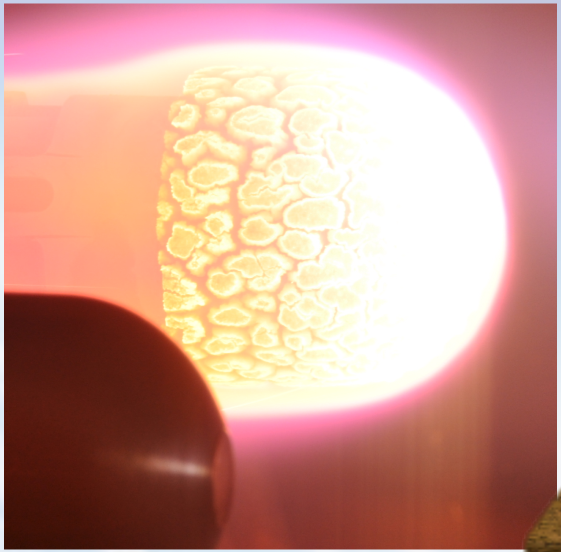
-TPS sizing-

➢ Plasmatron tests

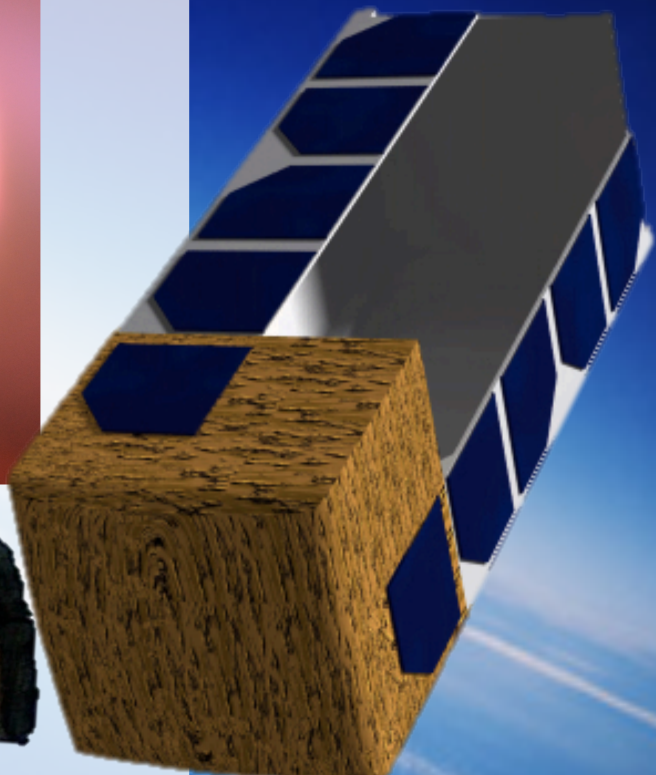
(Material characterisation)



[Asma, C. O., et al., 2010]. Infrared Thermography Measurements on Ablative Thermal Protection Systems for Interplanetary Space Vehicles. 10th QIRT, Quebec, Canada, 2010.



Cork P50 (Amorim)

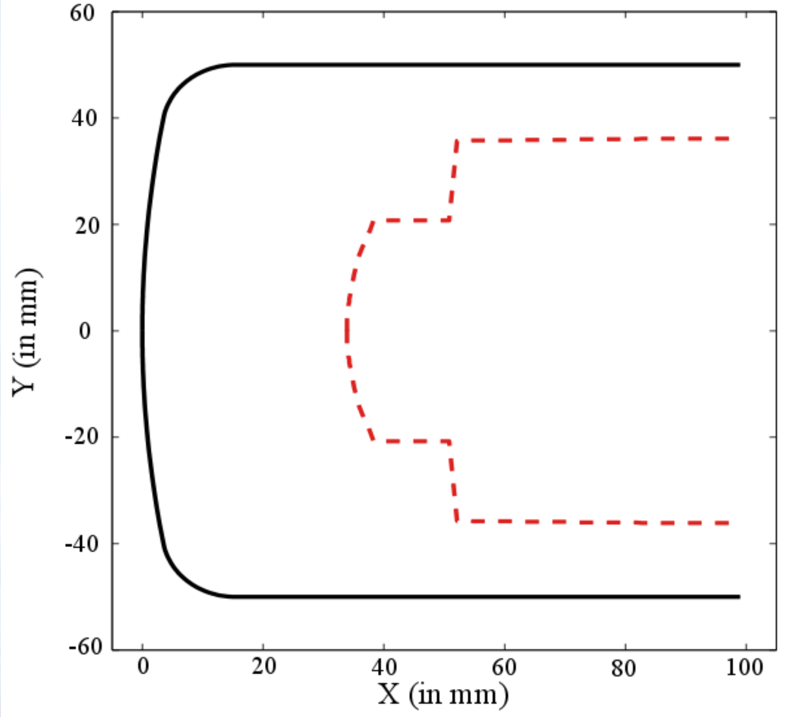


Challenges

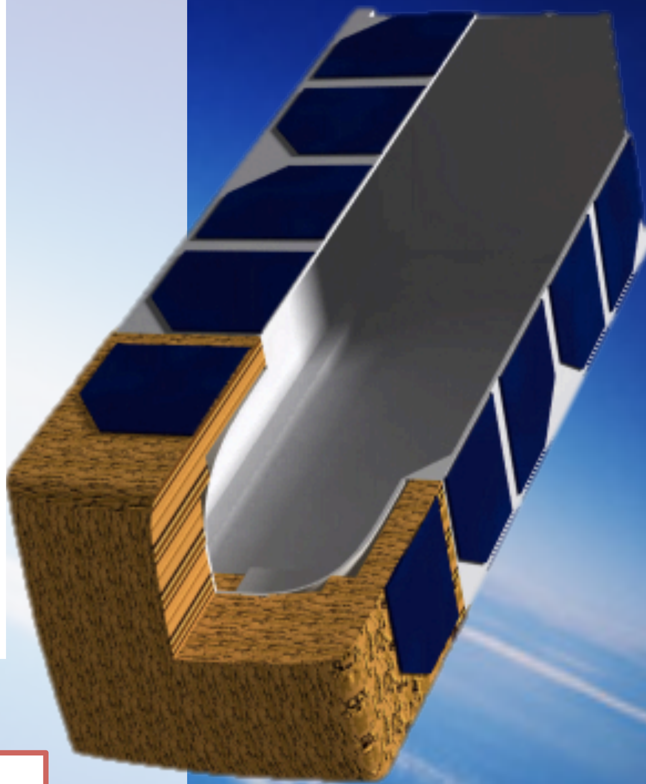
-TPS sizing-

By considering:

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



Cross section of the heat shield

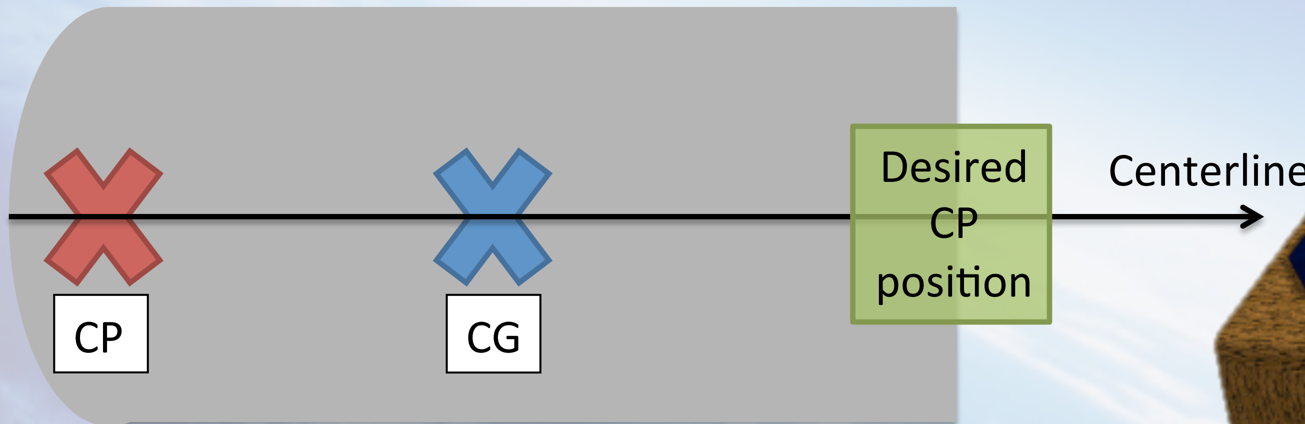


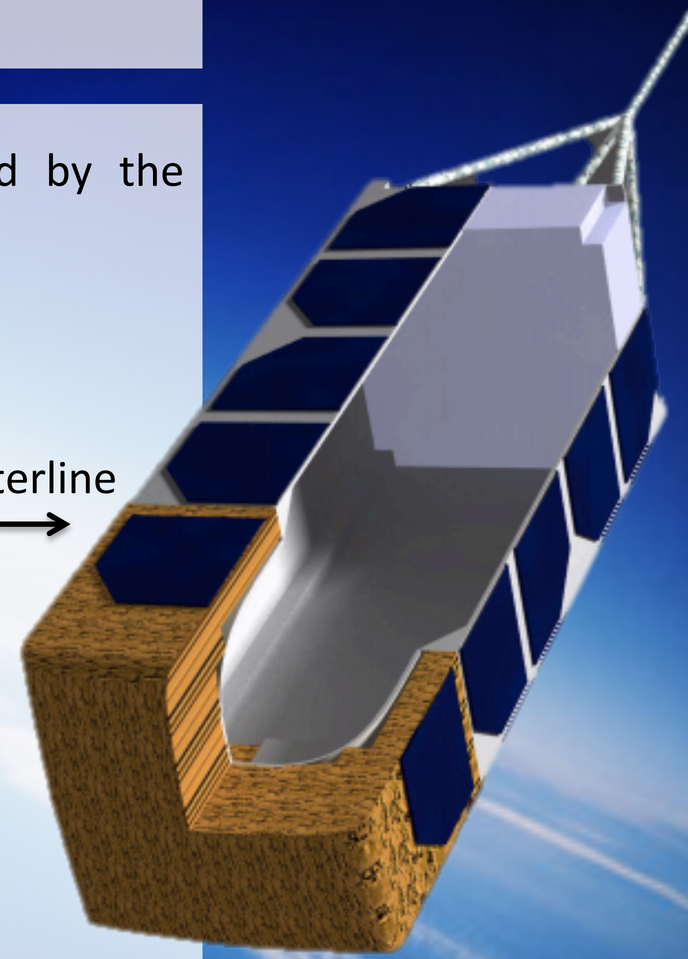
➢ Future work: use of EADS codes for more accurate sizing

Challenges

-Stability of the vehicle-

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

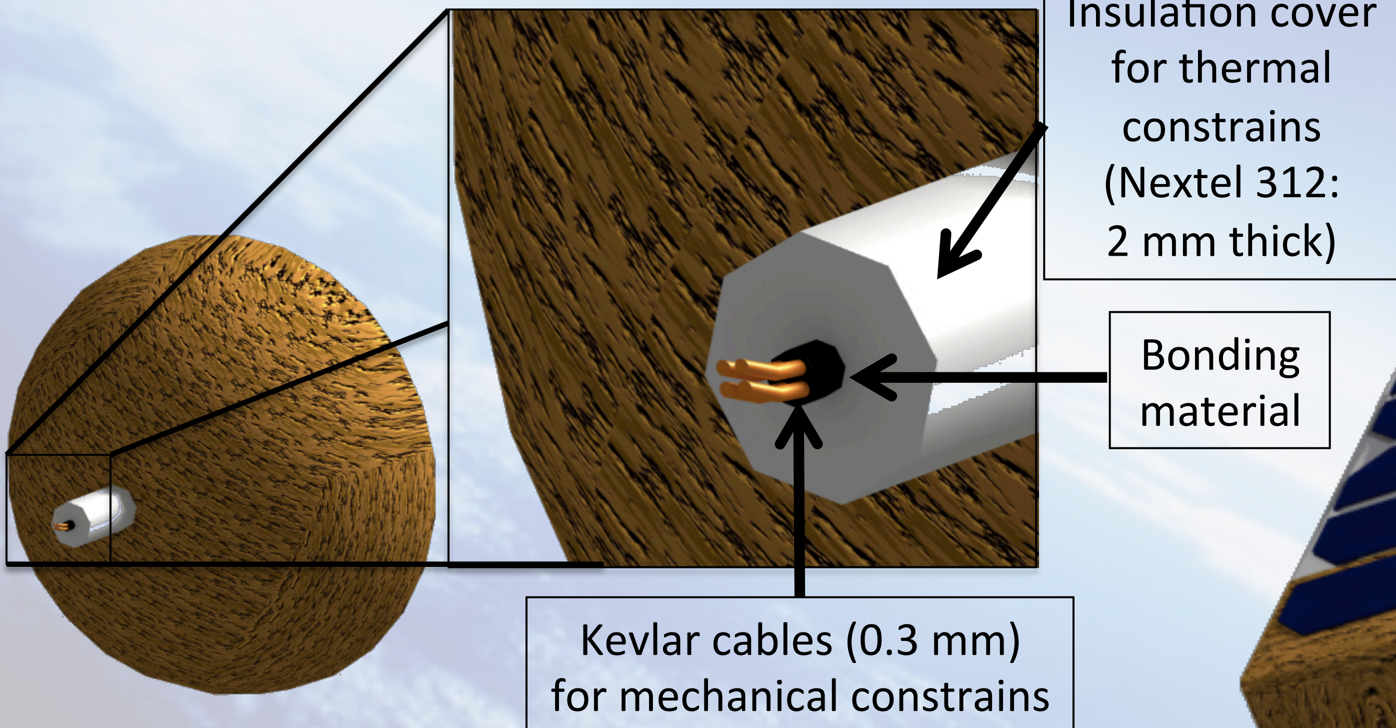


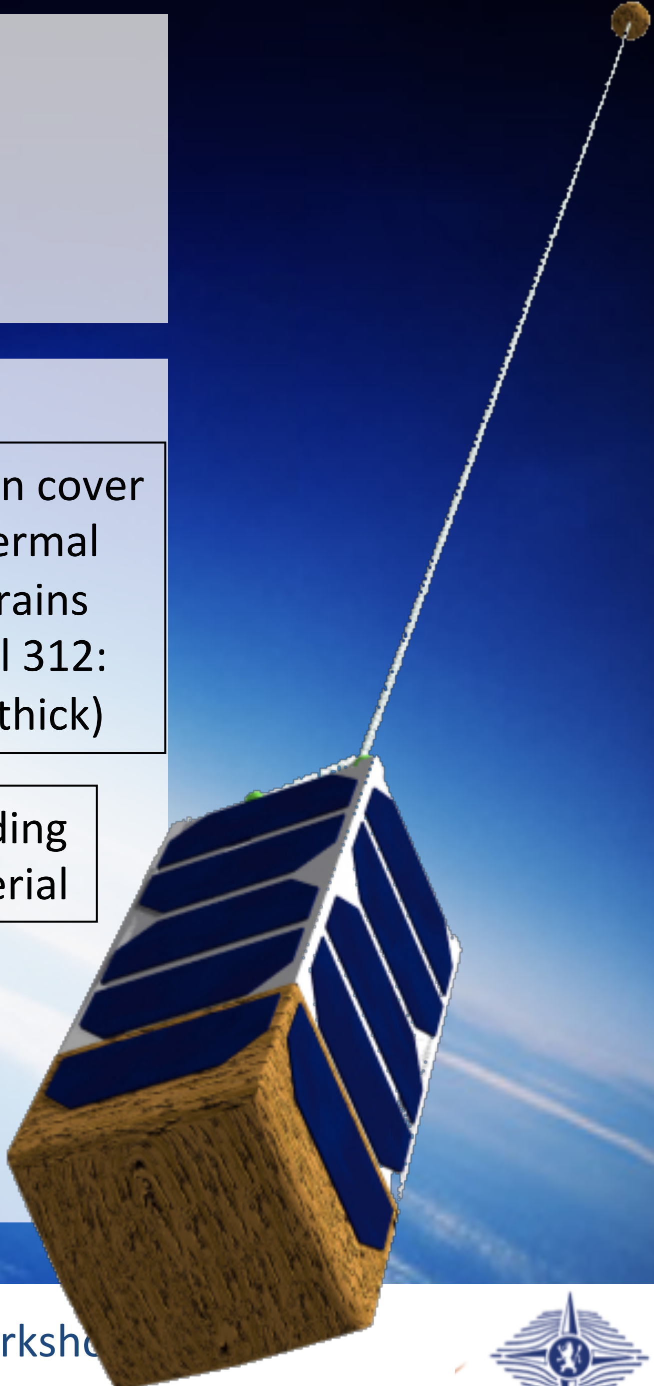


Challenges

-Stability of the vehicle-

- Stability system proposed:

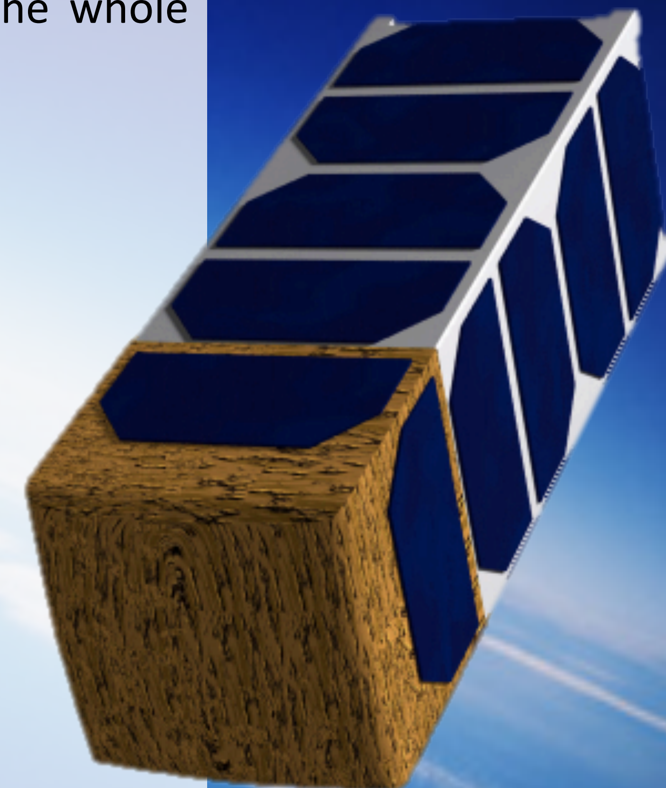




Challenges

-Deorbiting system-

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

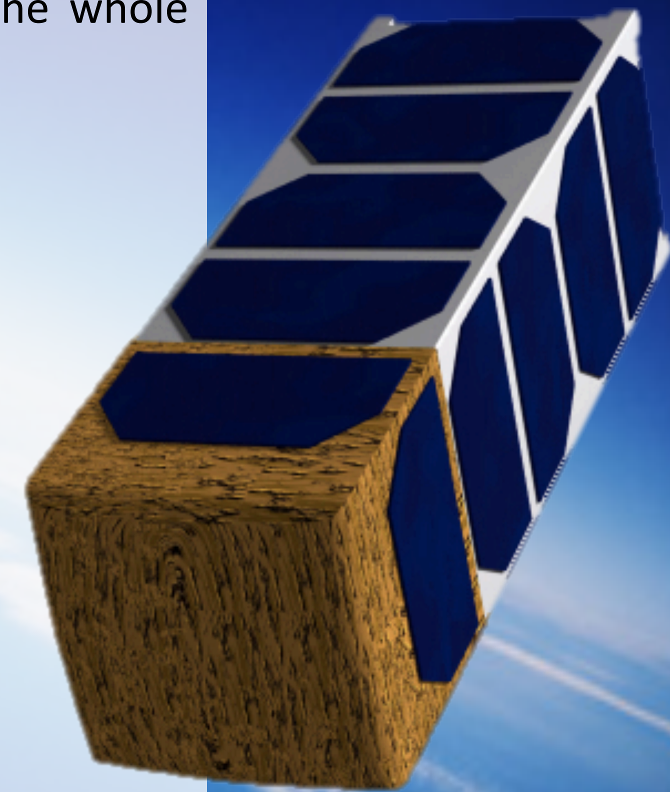


Challenges

-Deorbiting system-

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

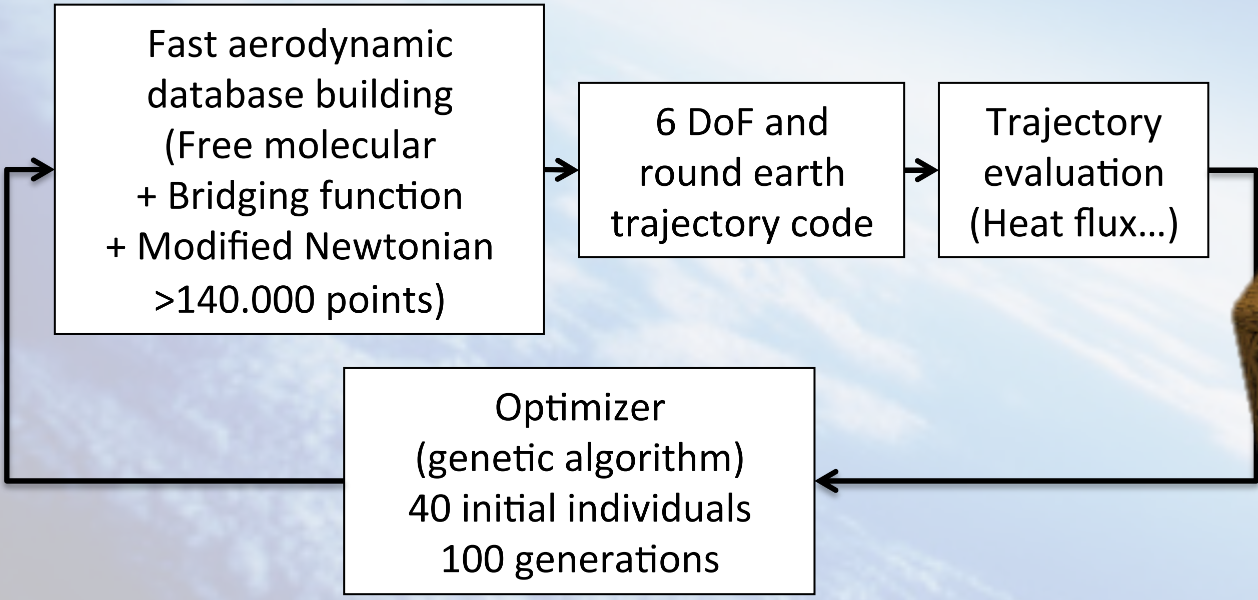
- Limit the heat load within heat flux constrains (our case)
- Collect data from a specific phenomenon or range of altitude
- Any specific mission (where you can associate an efficiency coefficient)



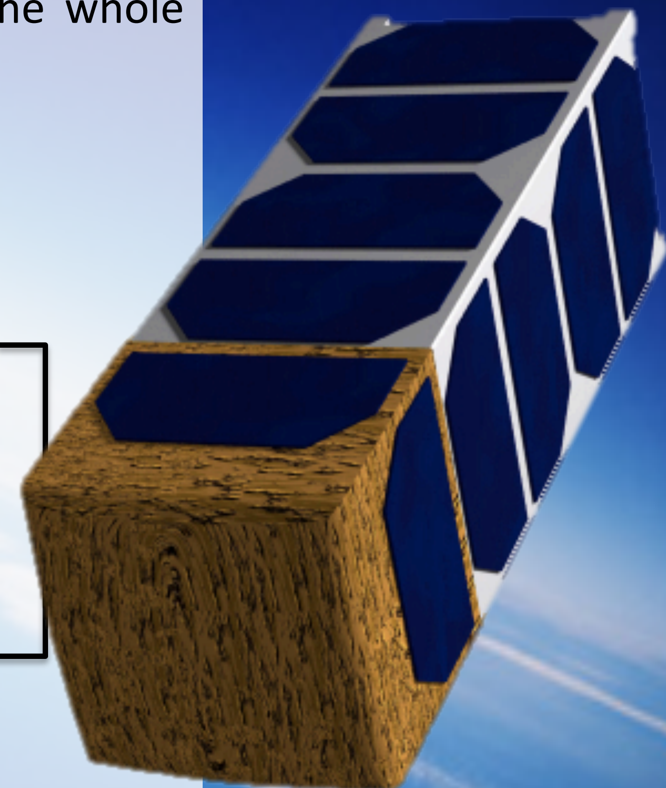
Challenges

-Deorbiting system-

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

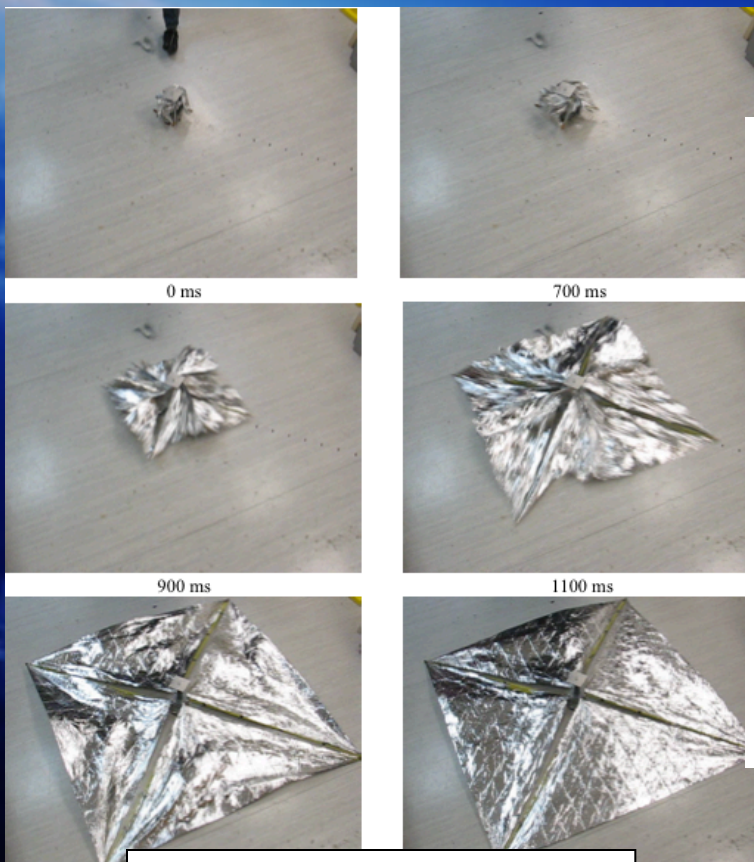


Methodology employed for the optimization

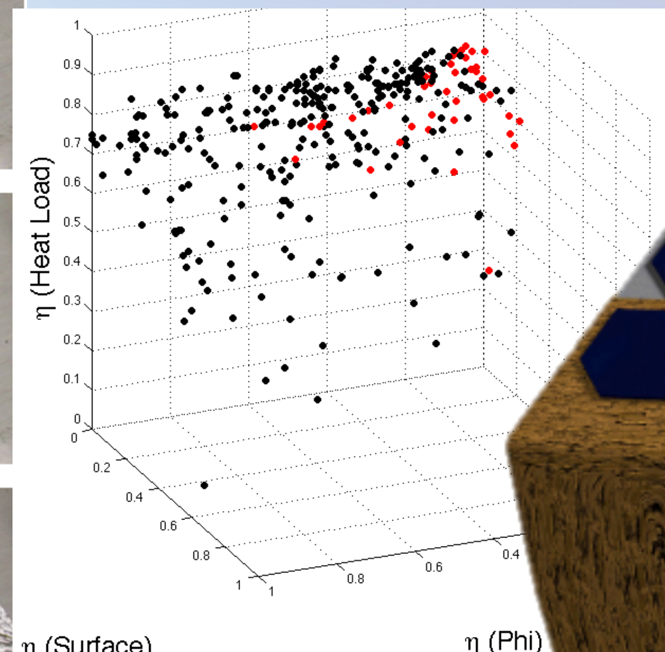


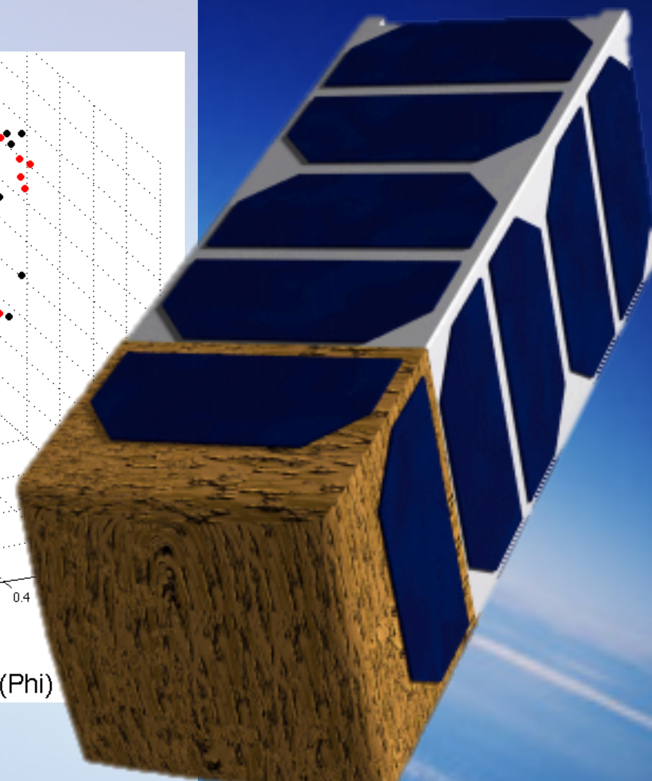
Challenges

-Deorbiting system-



Credit Surrey Space Center





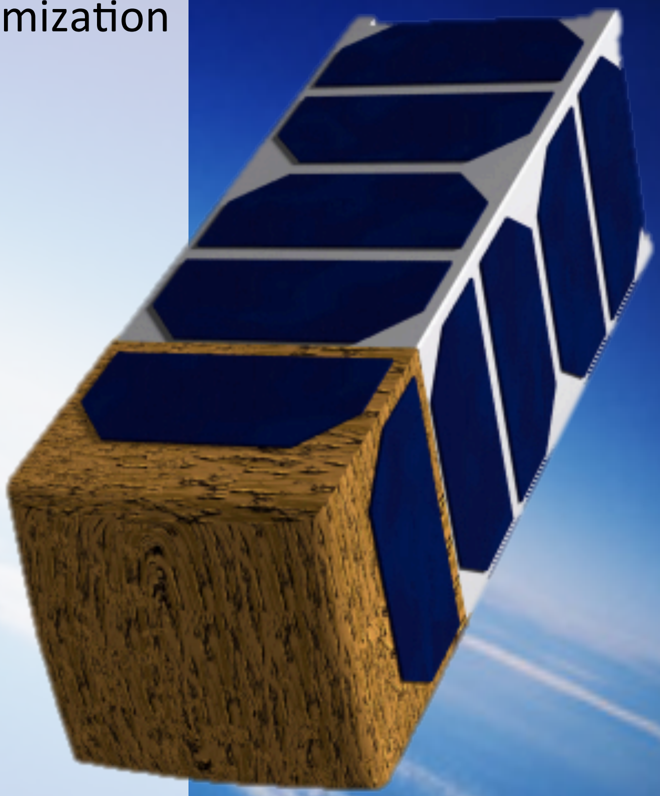
Optimum of the deorbiting system

Challenges

-Deorbitation system-

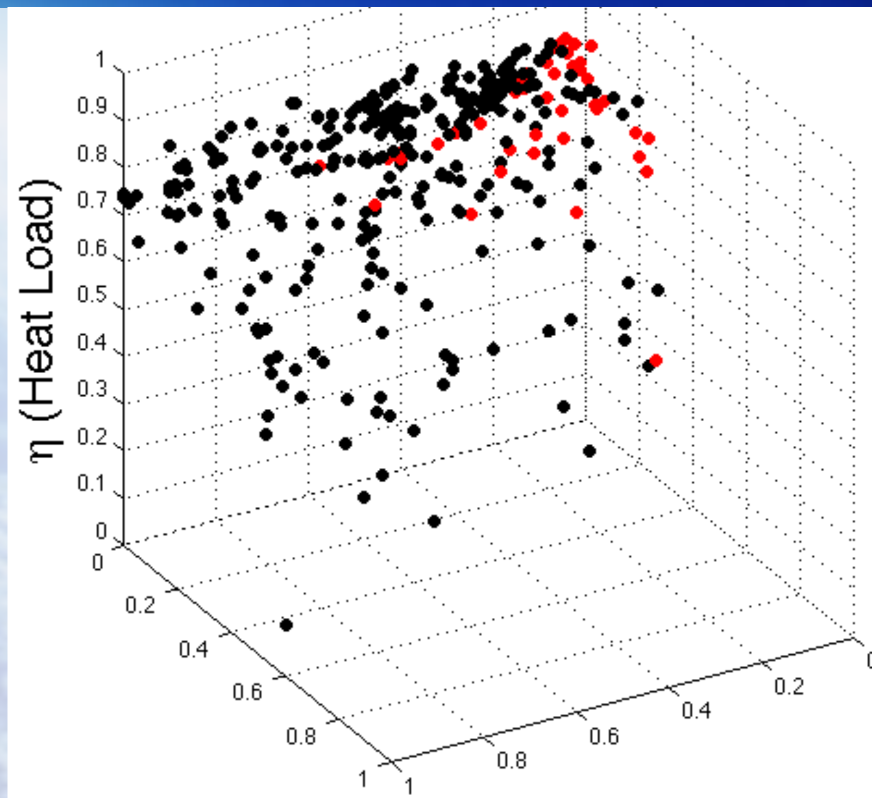
➢Several parameters are affected within the optimization process:

- Geometry of the deorbitation system
  (size, orientation of the panels)
- Altitude to deploy the deorbitation system
- Altitude to jettison the deorbitation system

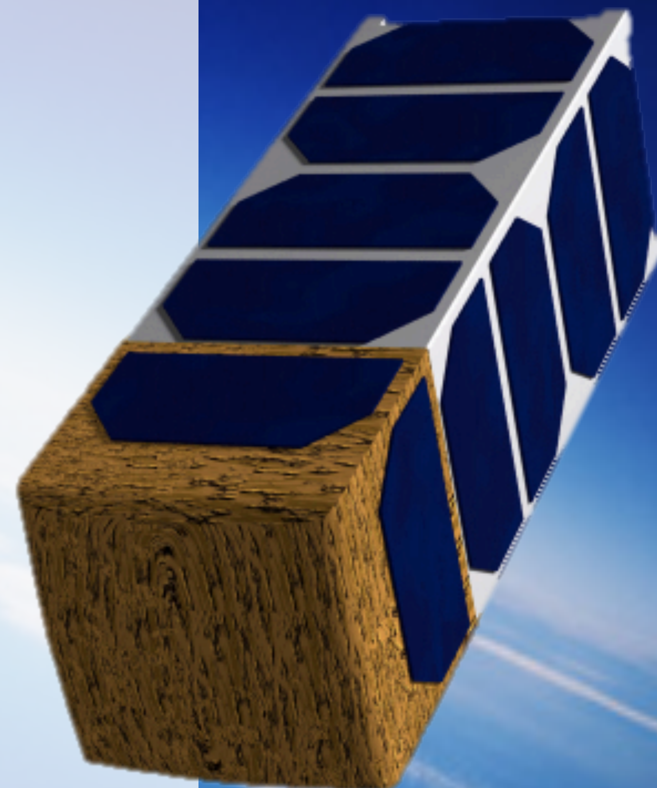


Challenges

-Deorbiting system-

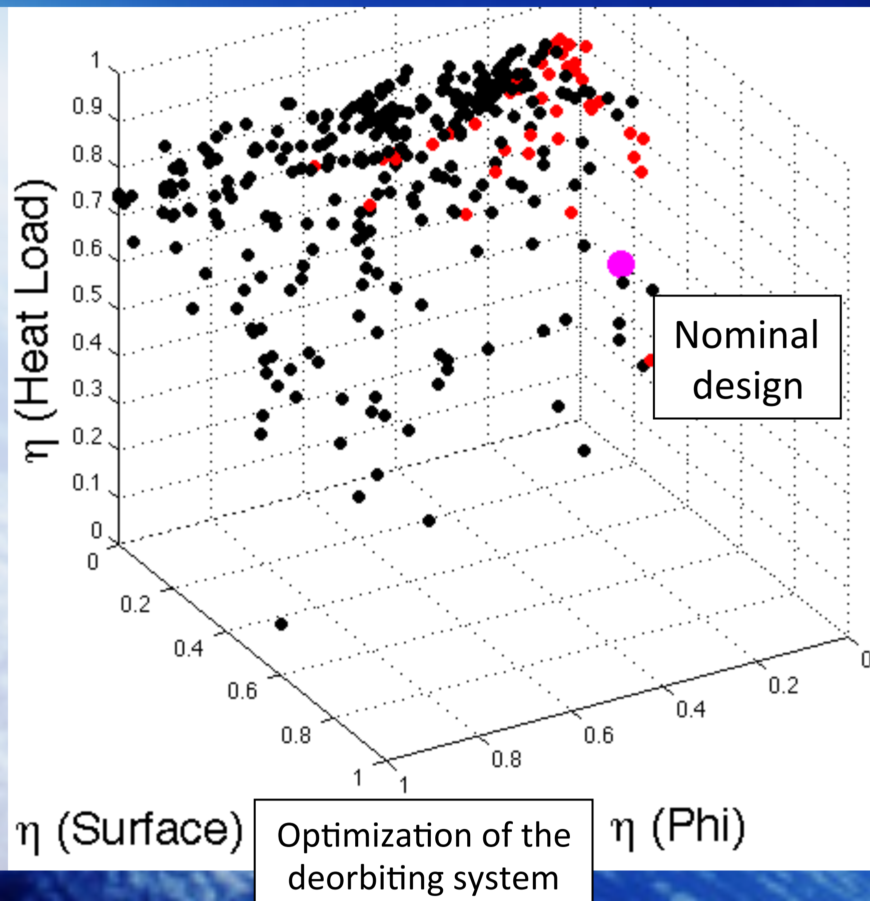


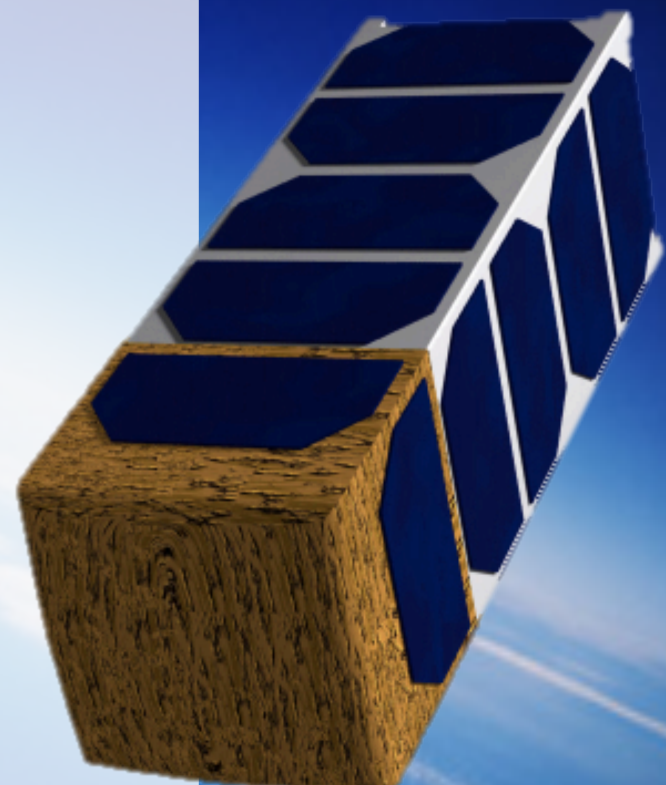
Optimization of the deorbiting system



Challenges

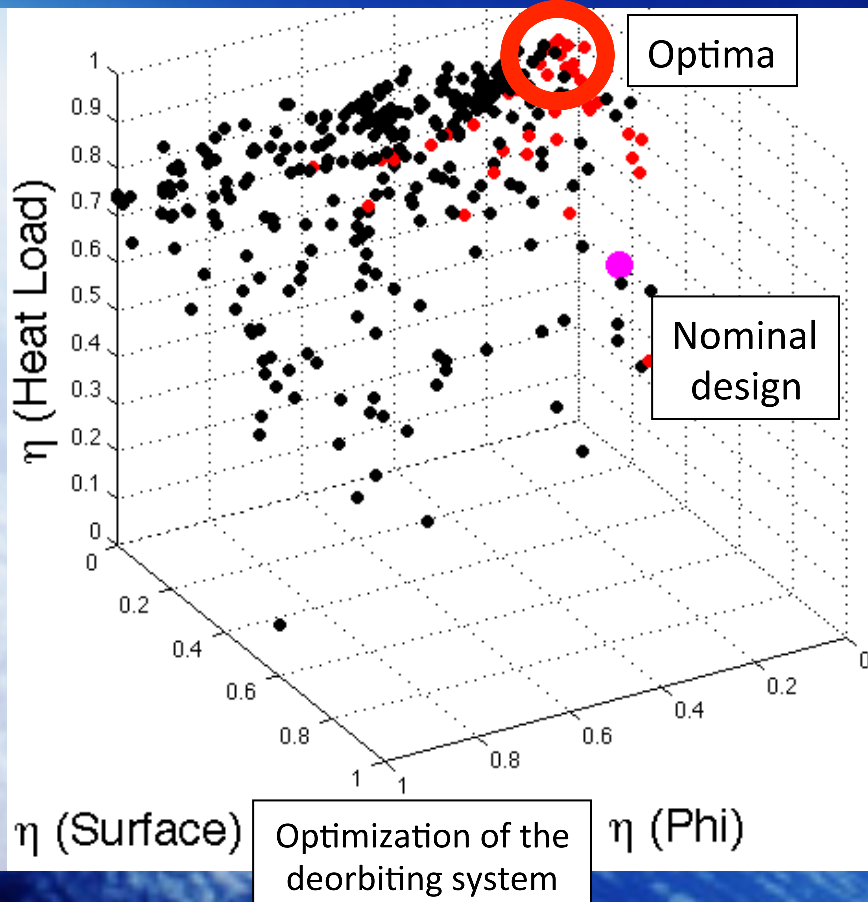
-Deorbiting system-

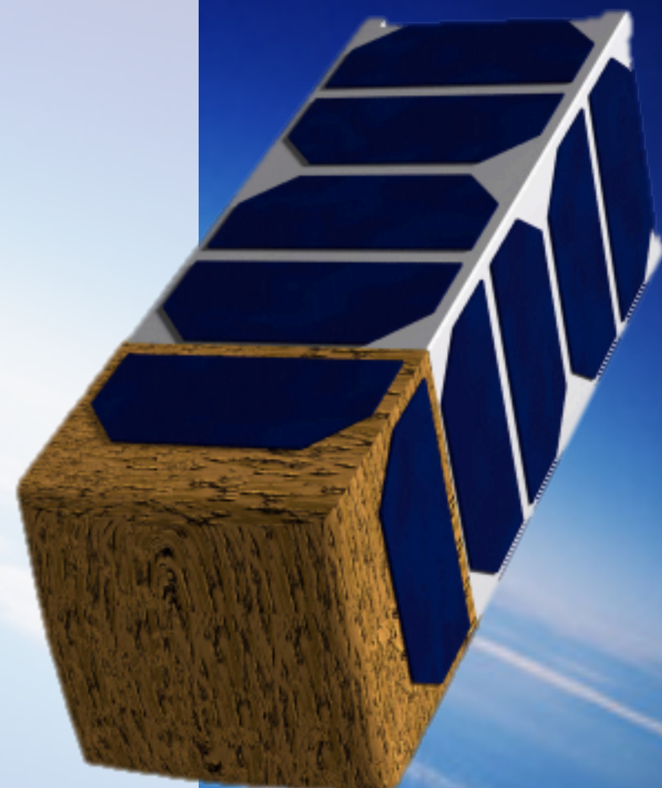




Challenges

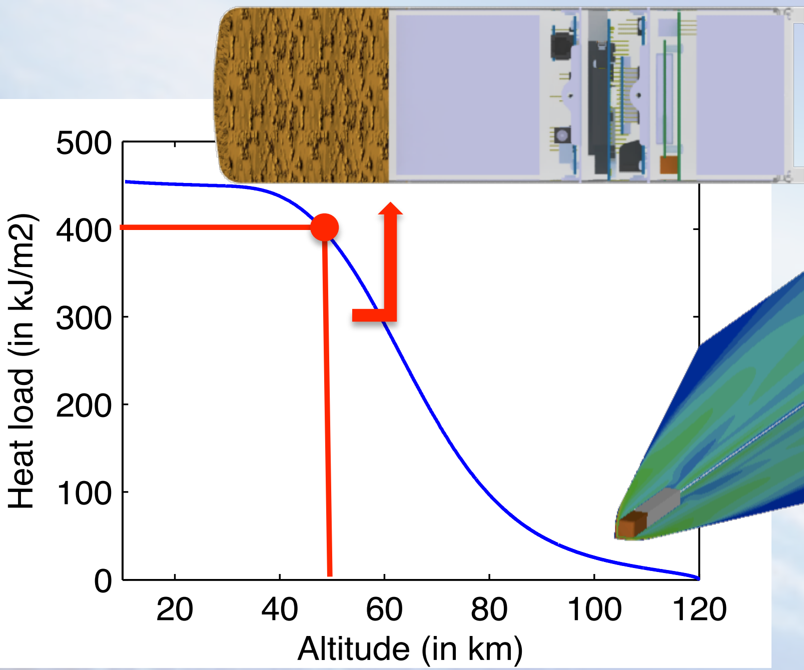
-Deorbiting system-



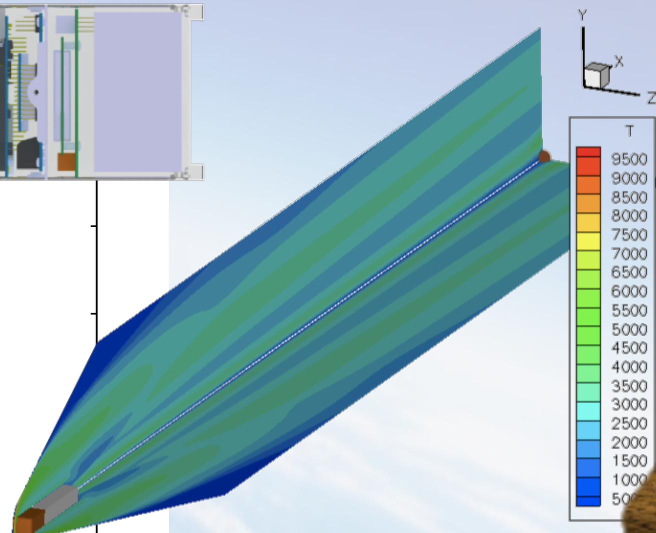


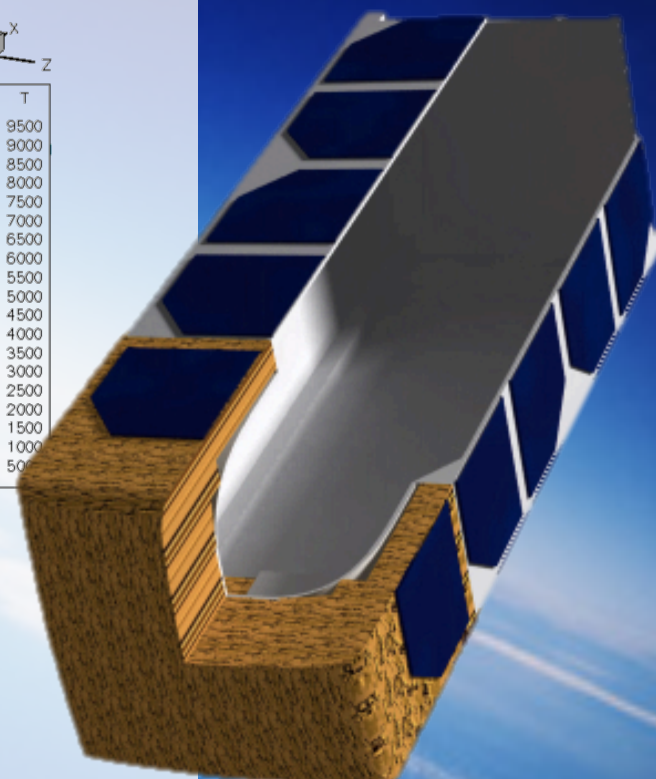
Challenges

-Thermal management-



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





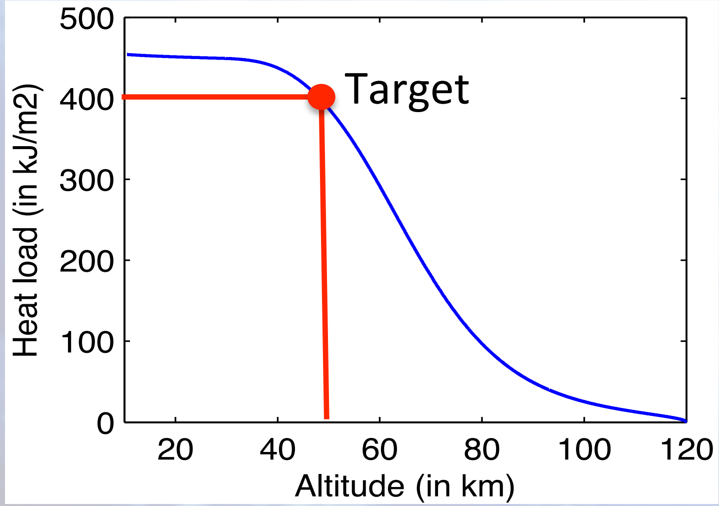
Challenges

-Thermal management-

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

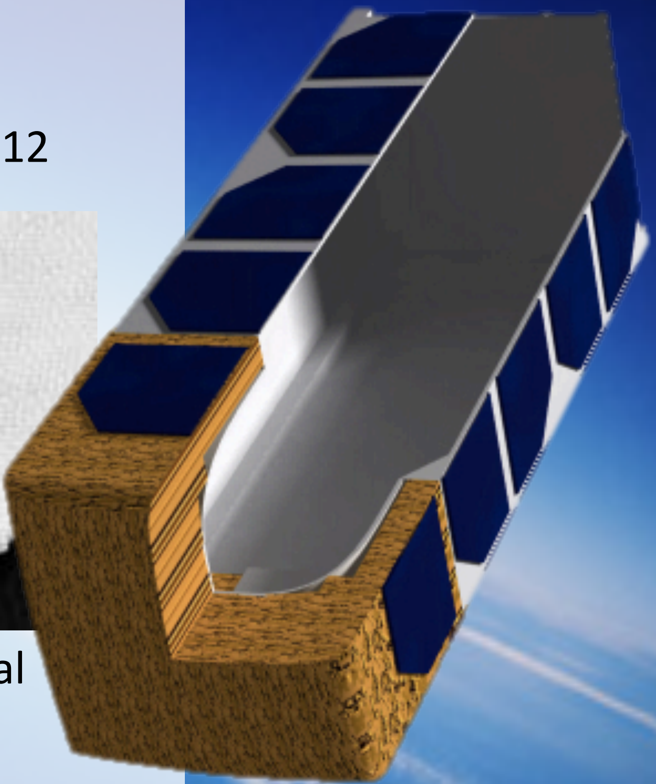
- Standard Aluminium panel (thickness of 1.5 mm)

+ 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

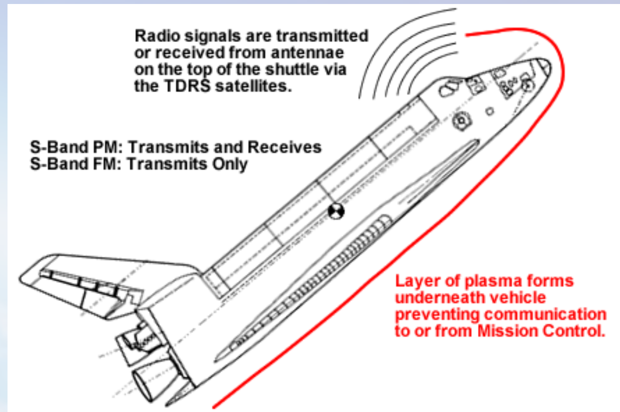
-Telecommunication system-

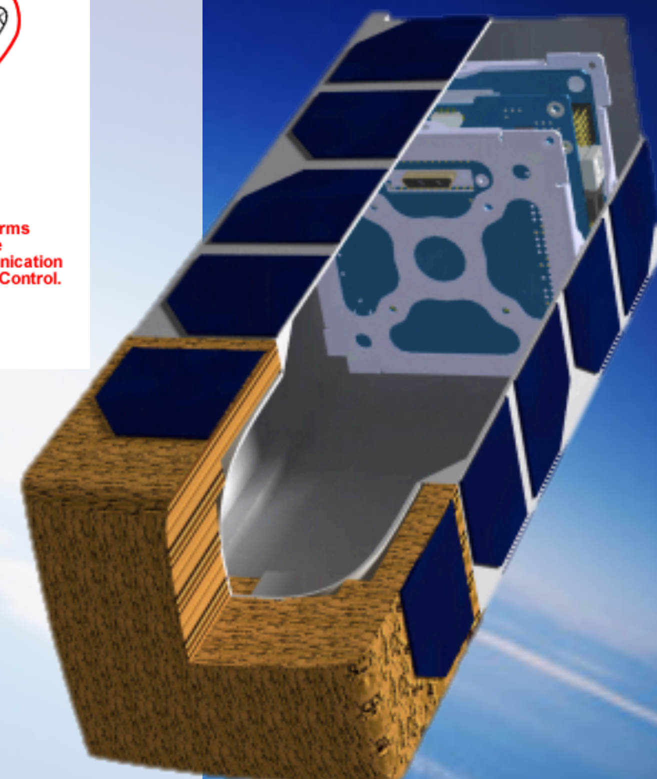
Maximum of 10 minutes for the Re-entry and the vehicle will not survive:

➢Needs to transmit the data before disintegration

Utilization of the Iridium constellation:

➢ Permanent coverage of all the trajectory
(by 4-6 satellites)

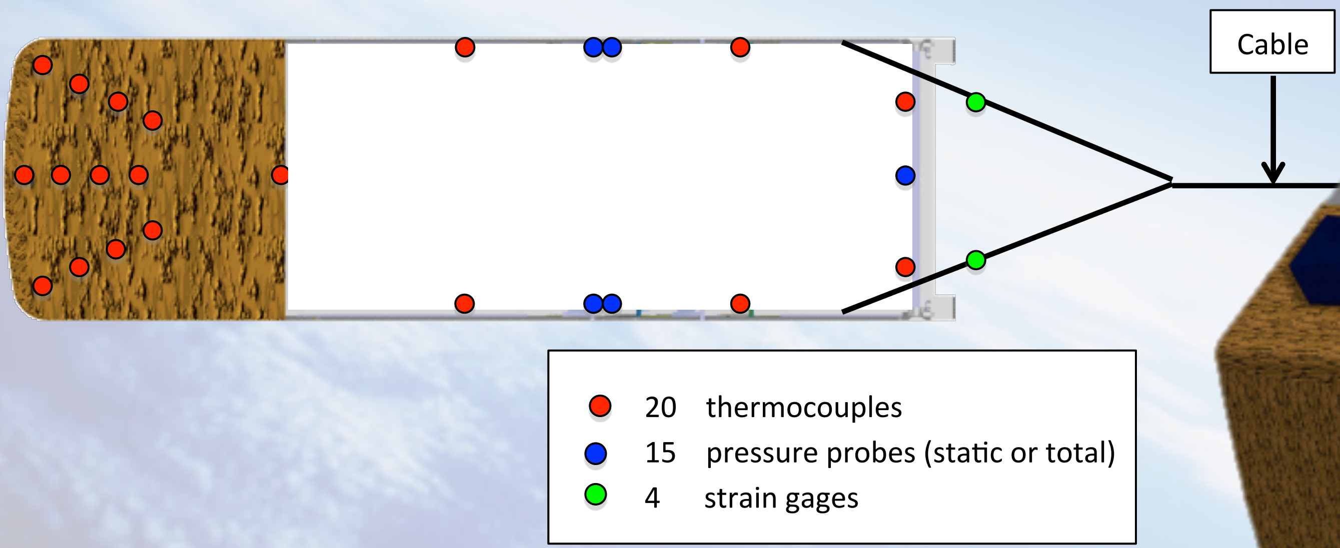


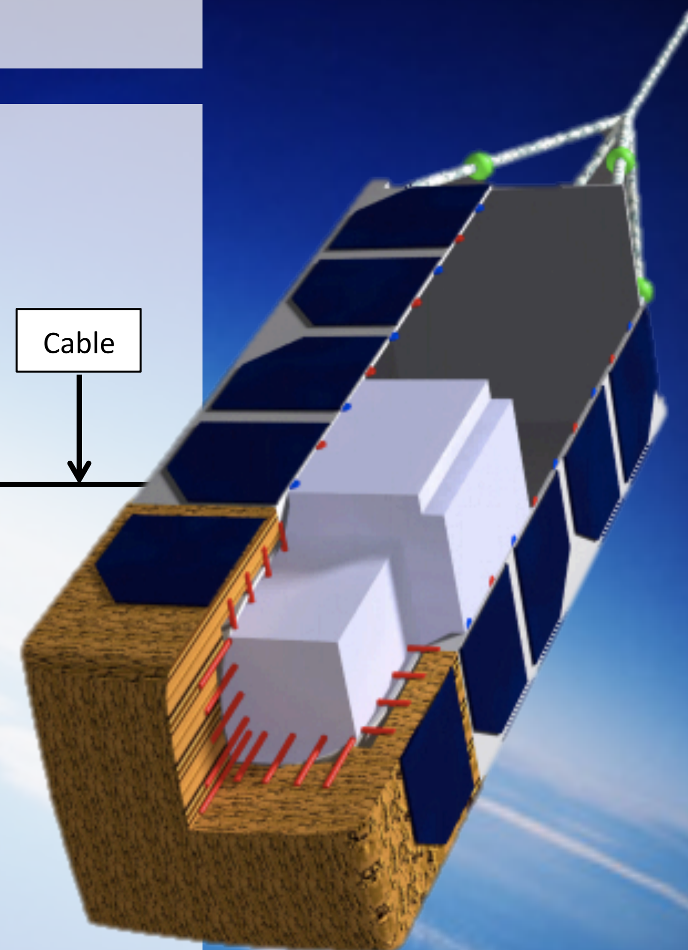


Payloads

-minimal configuration-

- Minimal payload



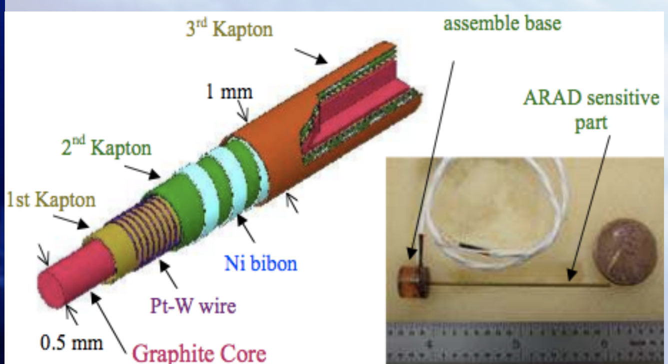


Payloads

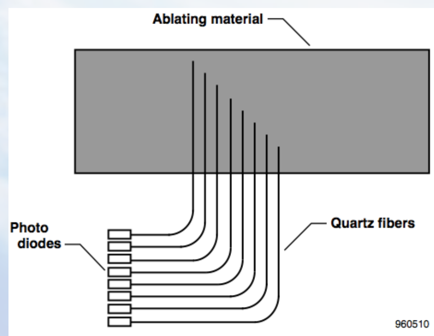
-Ablation characterization: example of a recession sensor-

Ultrasound recession sensor

McGunigle, Richard D. and Michael Jennings, “Ultrasonic Ablation Recession Measurement System,” *Proceedings of the 21st International Instrumentation Symposium*, Philadelphia, Penn- sylvania, 1975.

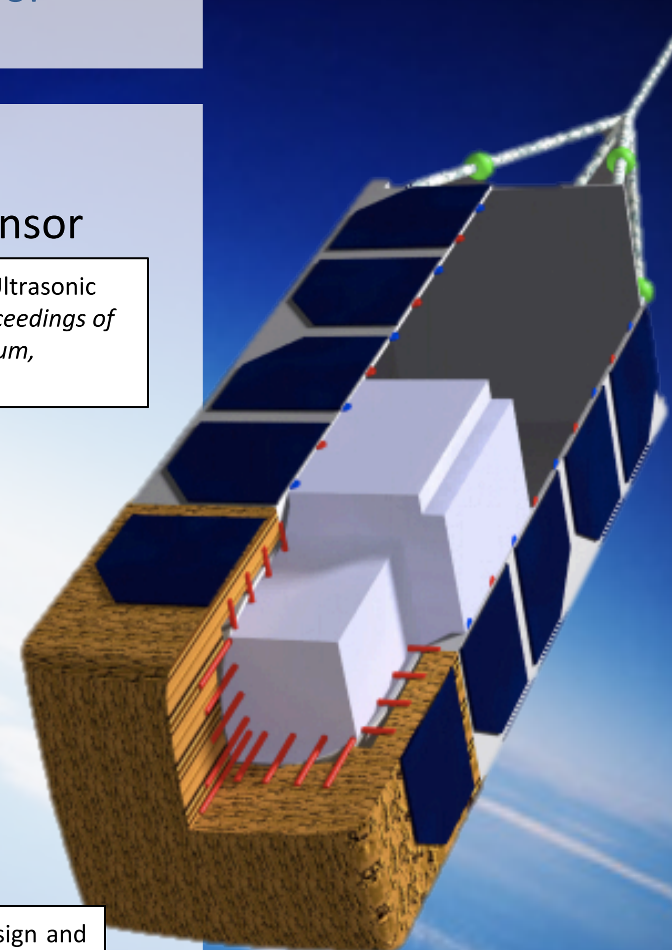


ARAD recession sensor
(NASA Ames)



Light pipe gage

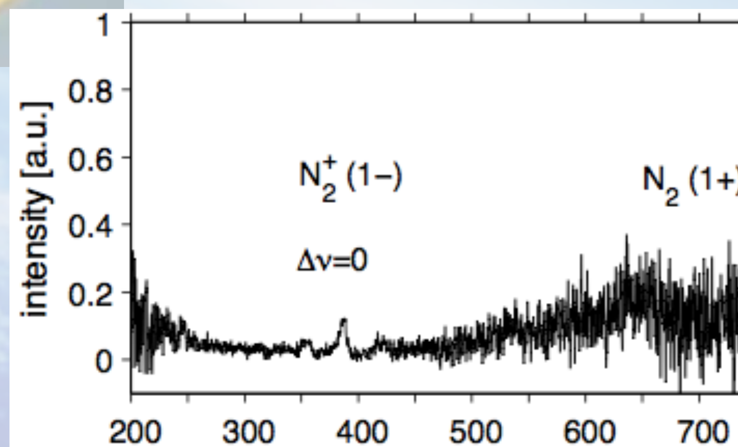
Ref: G.K. Noffz and M. P. Bowman, 1996, “Design and Laboratory Validation of a Capacitive Sensor for Measuring the Recession of a Thin-Layered Ablator” NASA TM 4777



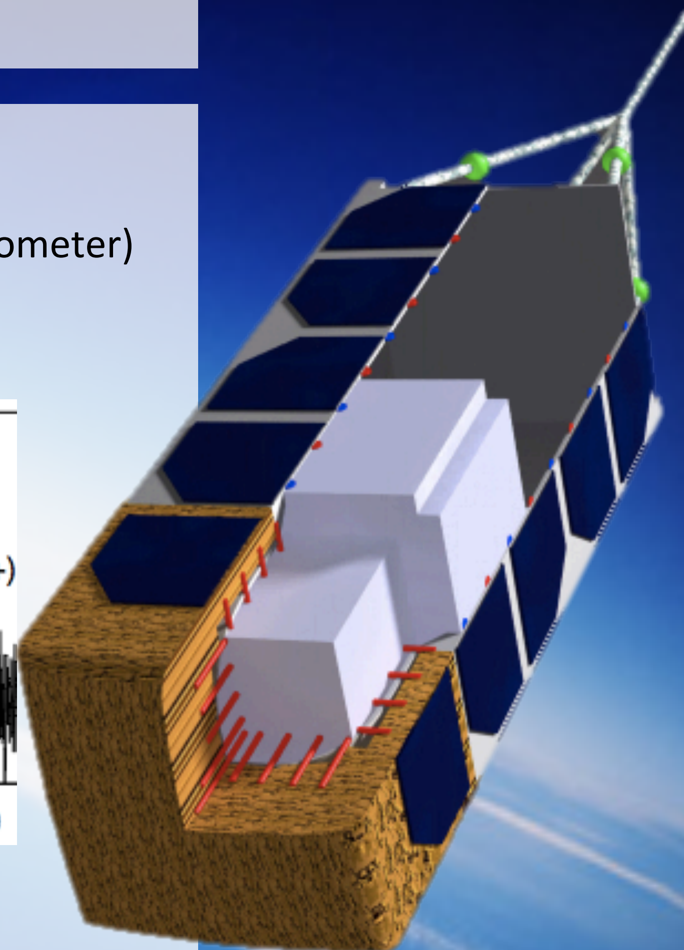
Payloads

-Emission spectroscopy-

Qmini (highly integrated spectrometer)
range 200-700 nm
from www.rgblasersystem.com

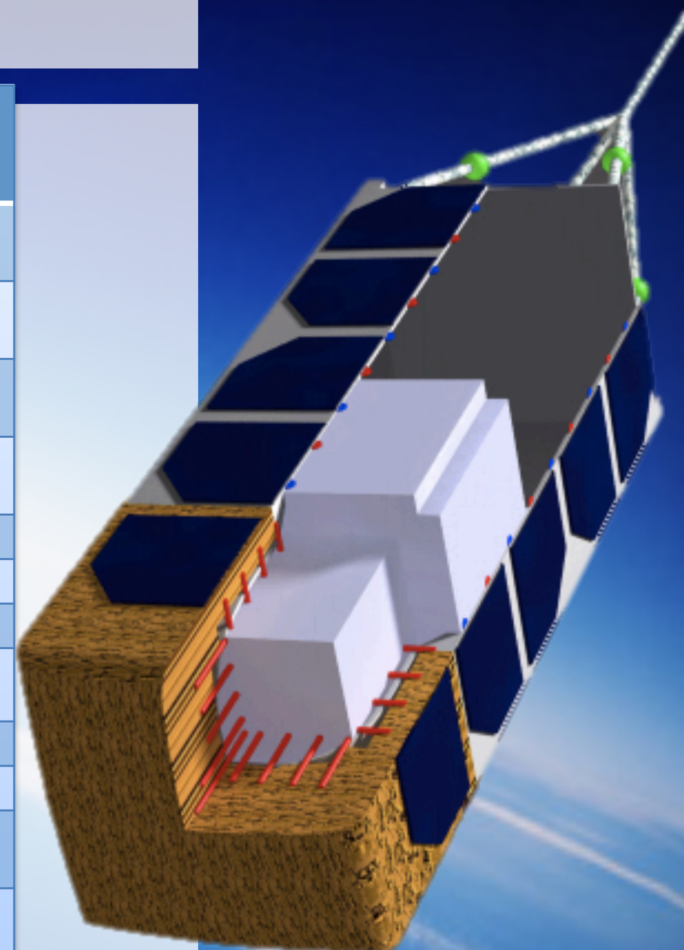


Example of Nitrogen diagnostic
in an Air plasma



Payloads

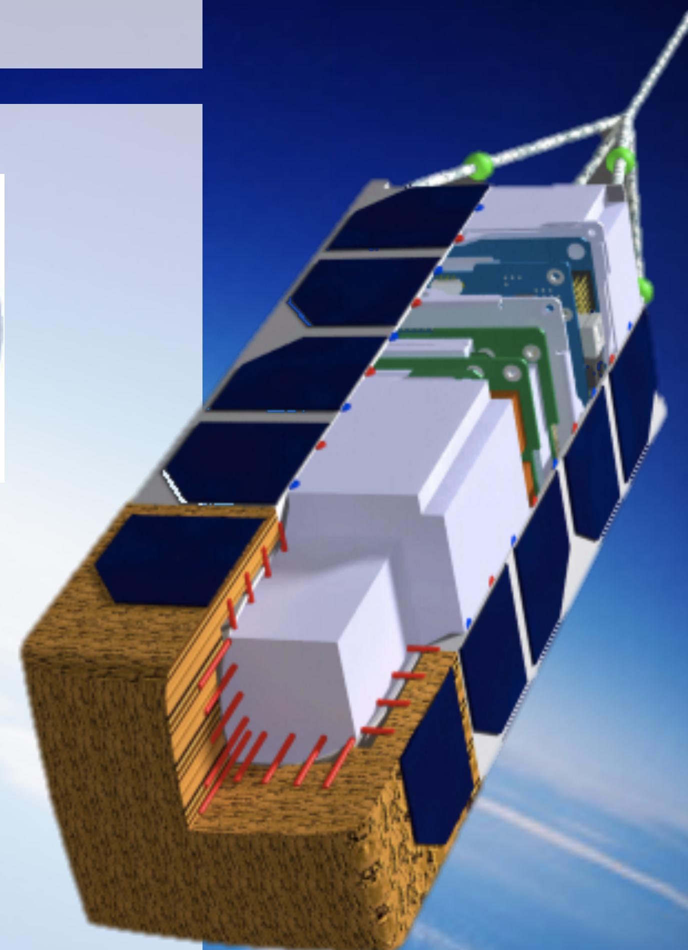
Investigated Challenge	Parameter to measure	Sensor	Total Mass [kg]	Power [mW h]	Data Size / Meas. [bit]	Phase	Total Data Size [KB/ Phase]
TPS Ablation	Recession	2 x Recession Sensor	0,004	1.67	10	3	3.0
TPS Efficiency	Temperature Distribution	8 x TC	0,031	1.67	14	3	16.8
TPS & Environment	Pressure	2 x Pressure Sensor	0.060	8.33	10	3	3.0
Stability	Pressure	4 x Pressure Sensor	0,060	840	10	2	302.4
Rarified Flow Conditions	Low Pressure / Vacuum	1 x Vacuum Sensor	0,011	756	10	1	151.2
				756		2	151.2
Shear Force, Laminar to Turbulence Transition	Skin Friction	2 x Preston Tube	0.120	2520	10	2	907.2
				16.67		3	3.0
Off-Stagnation Temperature Evolution	Temperature	10 x TC	0,021	16.8	14	2	211.68
				1.67		3	21.0
Aerothermodynamic Environment	Species	1 x Spectrometer	0,084	6250	28	3	3.5
Total			**0.391**	**6250**	**338**		



Acknowledgement

SEVENTH FRAMEWORK PROGRAMME

The research leading to these results has received funding from the European Community's Seventh Framework Program ([FP7/2007-2013]) under grant agreement n◦ 284427 for the QB50 Project



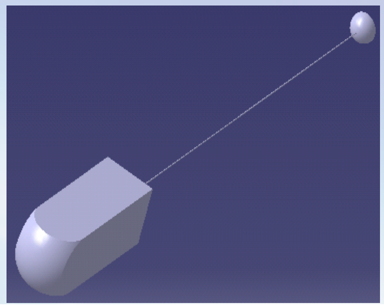
VON KARMAN INSTITUTE

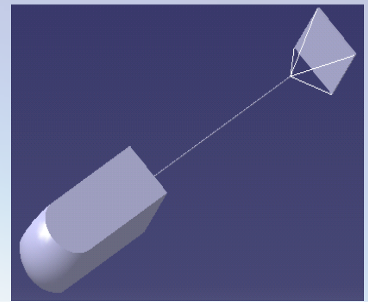
Thank you for your attention

-gilles.bailet@vki.ac.be-

Stability system

-How can a brick fly?-





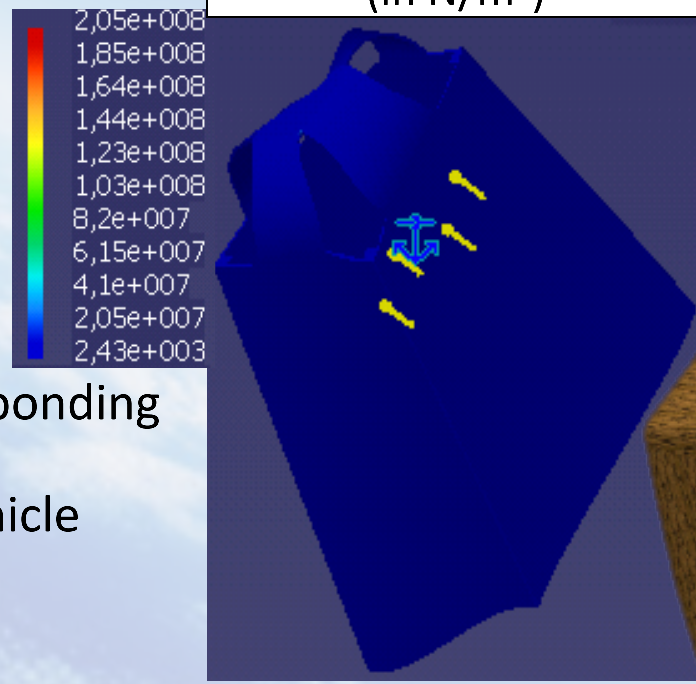
	Low drag increment (hemisphere)	High drag increment (flat plate)
Surface area (in cm^2)	42.25	100
Position downstream the vehicle (in m)	1.3	0.32
Drag coefficient increment	0.38	2

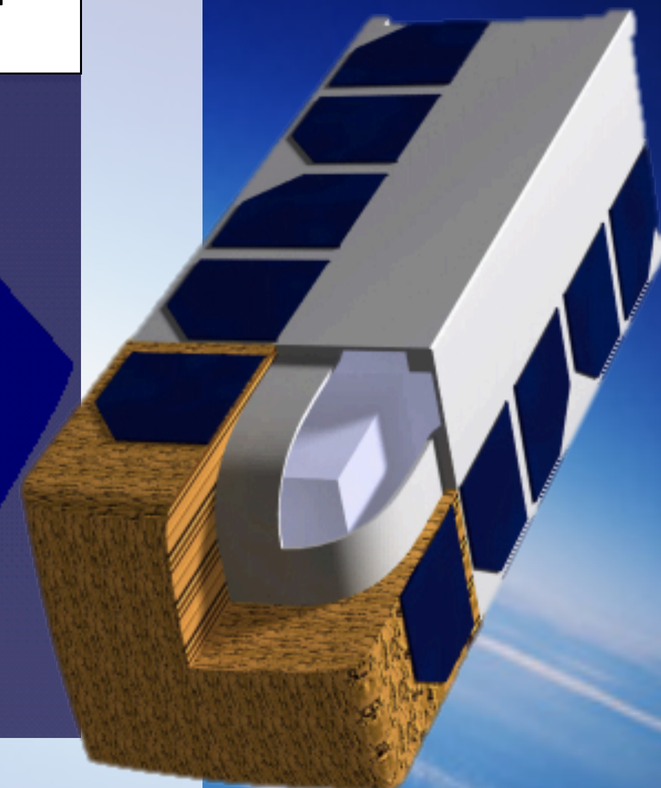
- Future work: PASDA code (Parachute System Design and Analysis Tool)

Structural consideration

-CATIA FEM module-

von Mises criteria
(in N/m²)





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

  (safety factor of 5)