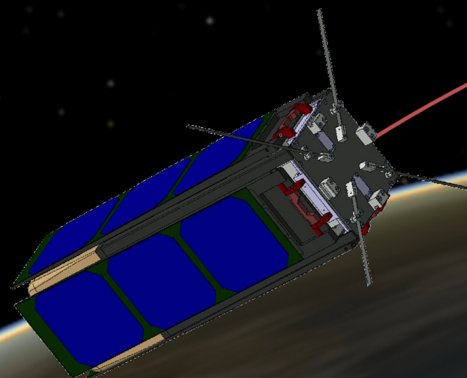
CubeSats:
Concevoir et Realiser un Satellite à l'Université

Lamberto Dell'Elce

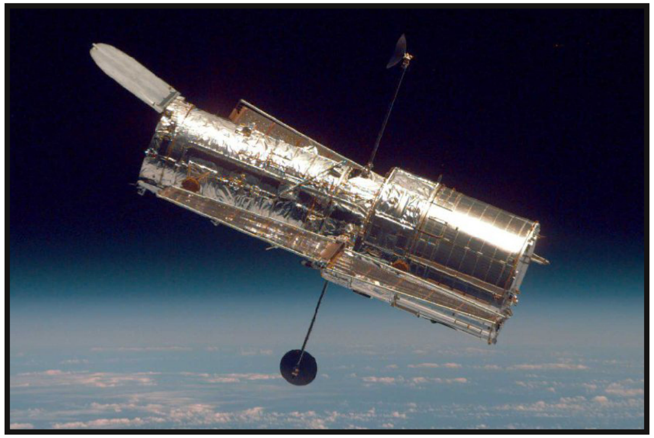
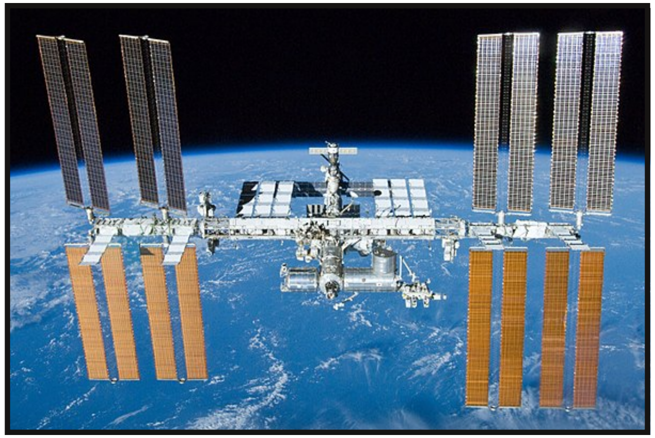
INRIA



Sophia Antipolis, 07/06/2018

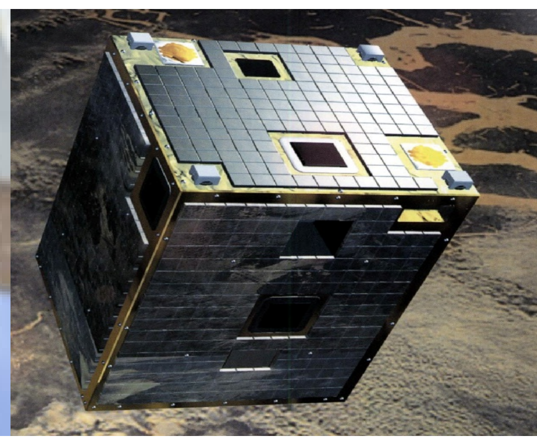
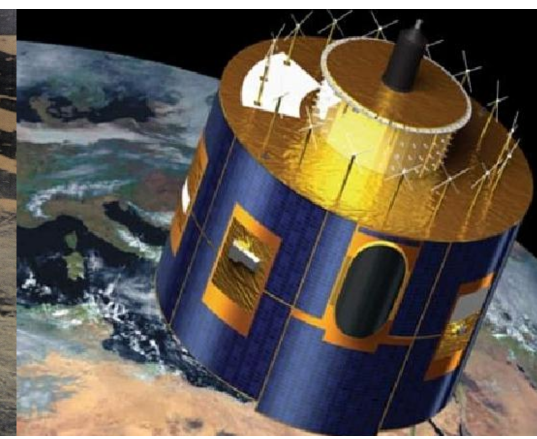
INVENTEURS DU MONDE NUMÉRIQUE

Giants in space

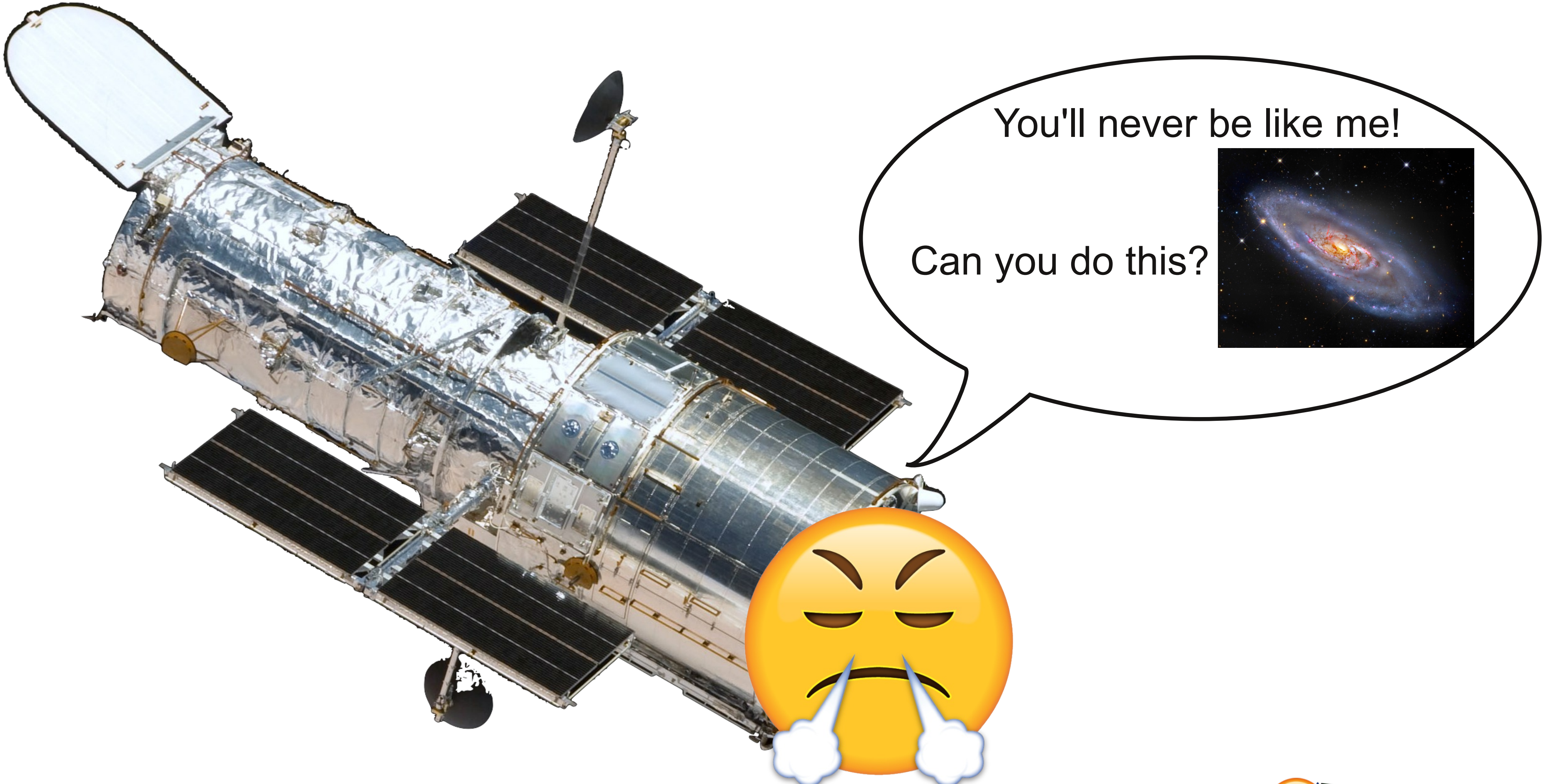
Envisat	Hubble	ISS
		
8 211 kg	11 110 kg	~420 000 kg
~ $2.9 billion	~ $4.7 billion	~ $150 billion

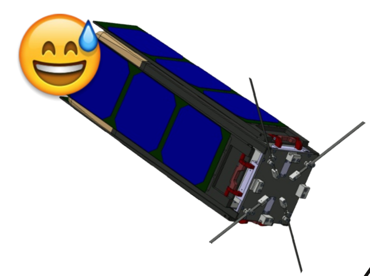
Nanosatellites (1-10 kg): the other edge of the spectrum

10 kg | 100 kg | 500 kg

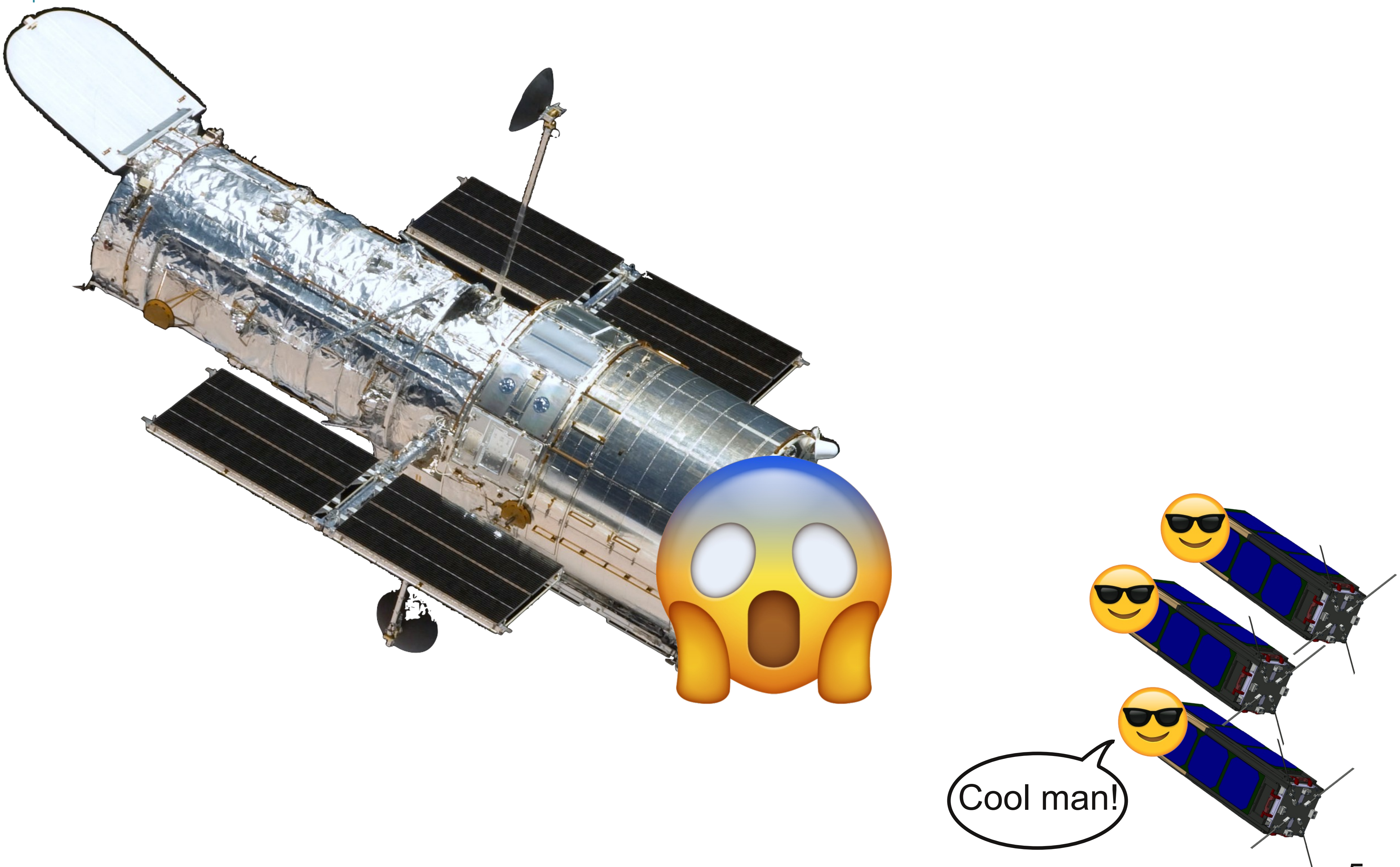
Nanosatellites "Milk brick"	Microsatellites "Washing machine"	Minisatellites "Horse"	Satellites "Truck"
			
Oufti-1	Proba 1	Meteosat	Hubble

Dimensions matter in space...





...But unity makes strength



Complementary role of nanosatellites

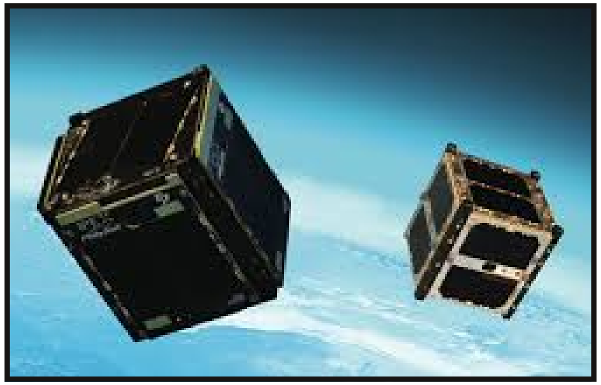
Primary objective:

- **Education**

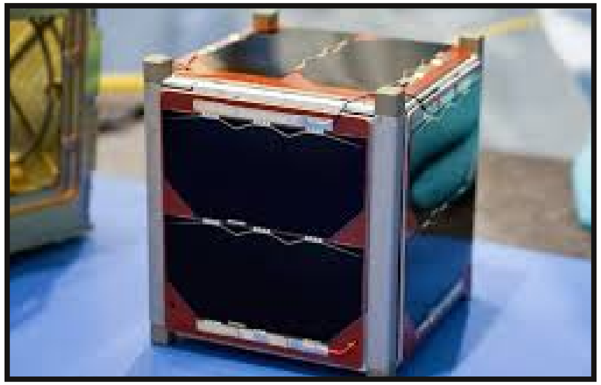
But also:

- Technological demonstrations
- Unique missions (unfeasible for big satellites!)

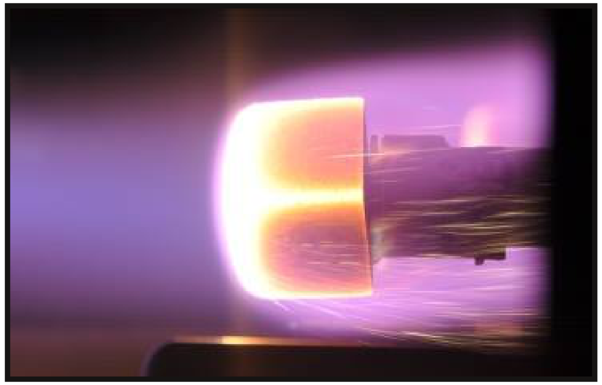
Outline



CubeSats, a tiny revolution in space

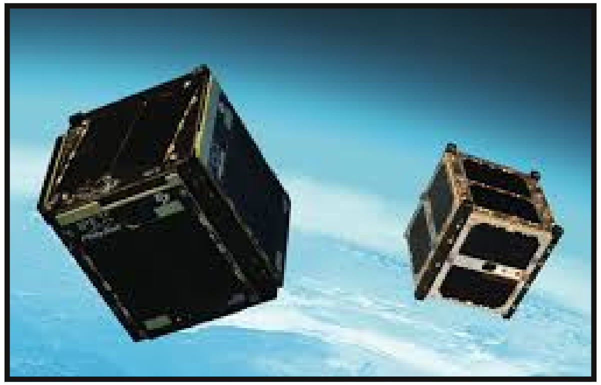


OUFTI-1, a Belgian CubeSat developed by students



Beyond education: the QB50 and QARMAN missions

Outline



CubeSats, a tiny revolution in space

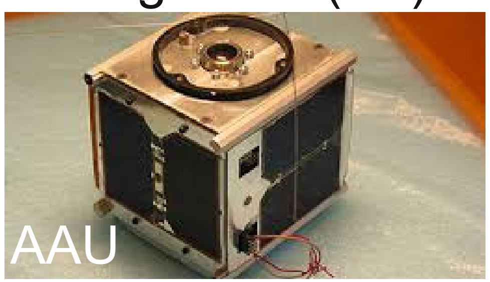
OUFTI-1, a Belgian CubeSat developed by students

Beyond education: the QB50 and QARMAN missions

What are CubeSats?

Parallelepiped-shaped **nanosatellites** made up of **multiples** of **1 dm^3** cubes

Single unit (1U)



Double unit (2U)

Triple unit (3U)

What are CubeSats?

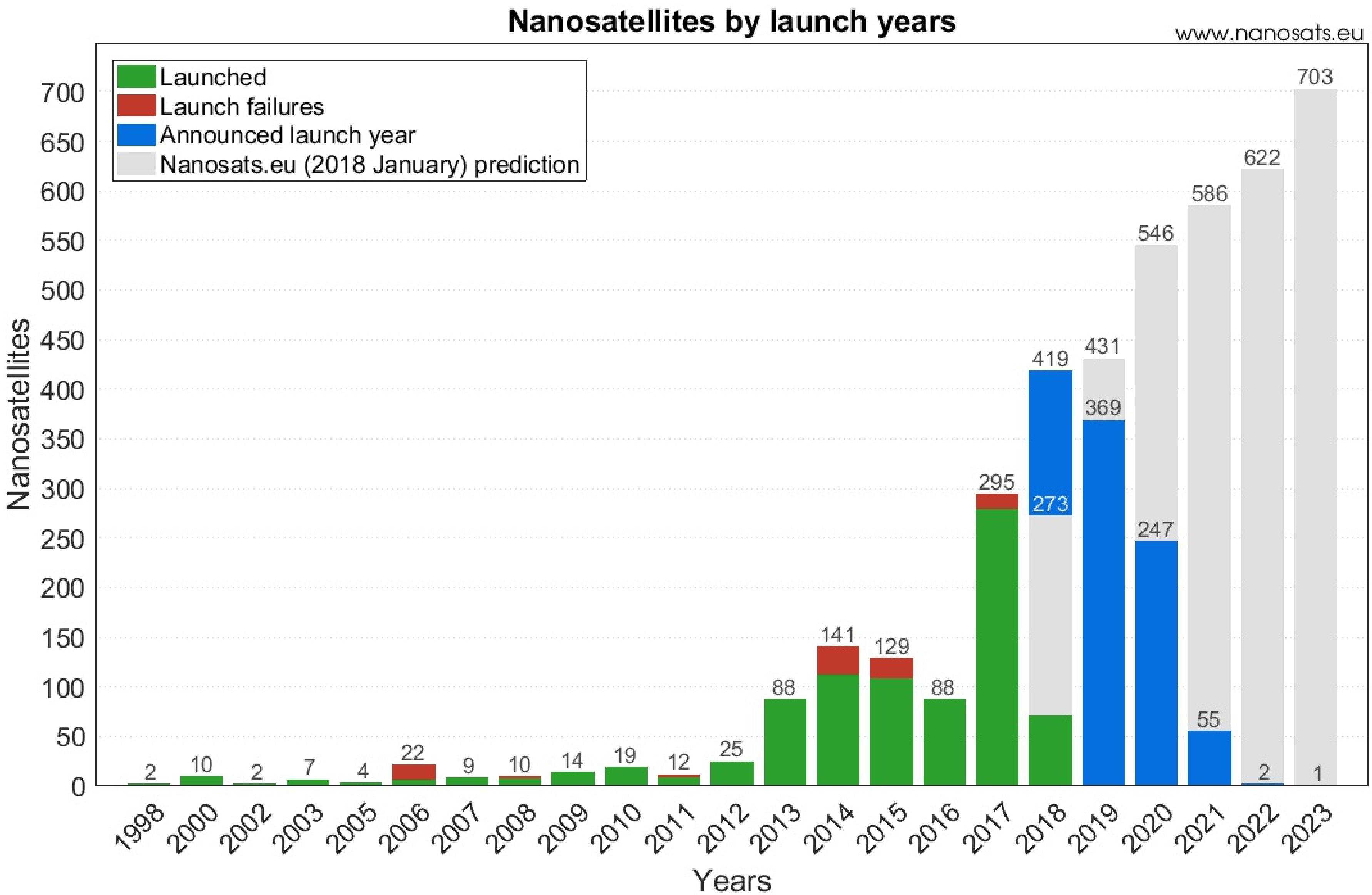
Naive idea: **1 liter X 1 kg X 1 W**

Original requirements by **Cal Poly** and **Standford** in **1999**

Unit mass was increased to 1.33 kg in 2014

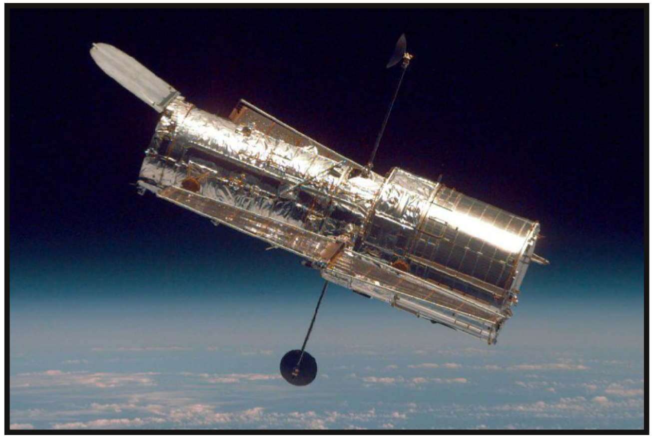
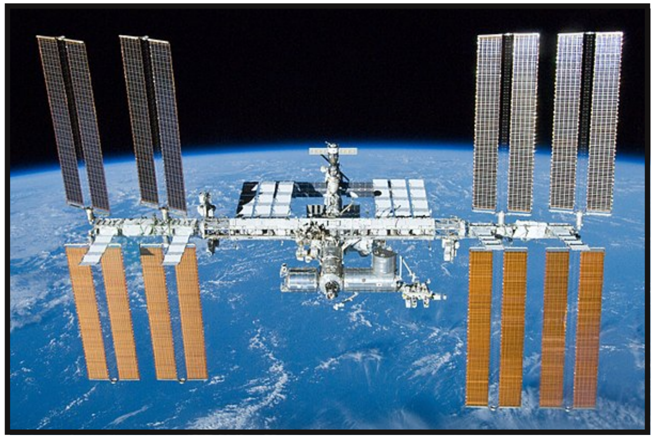
Key feature: **Interfacing requirements** (rails and springs)

A "tiny revolution" in space

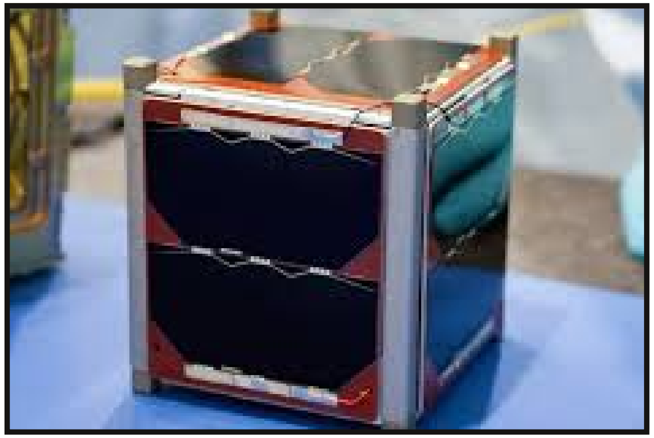
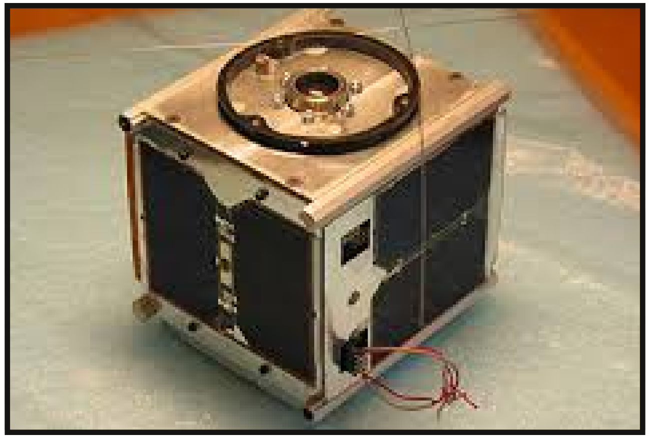
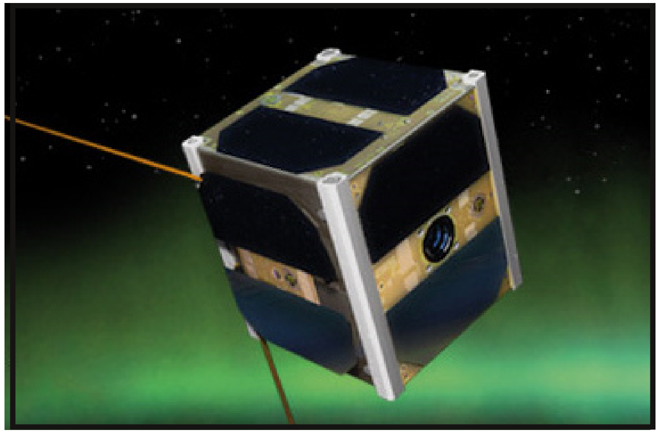


Modularity: The key of success

Big satellites

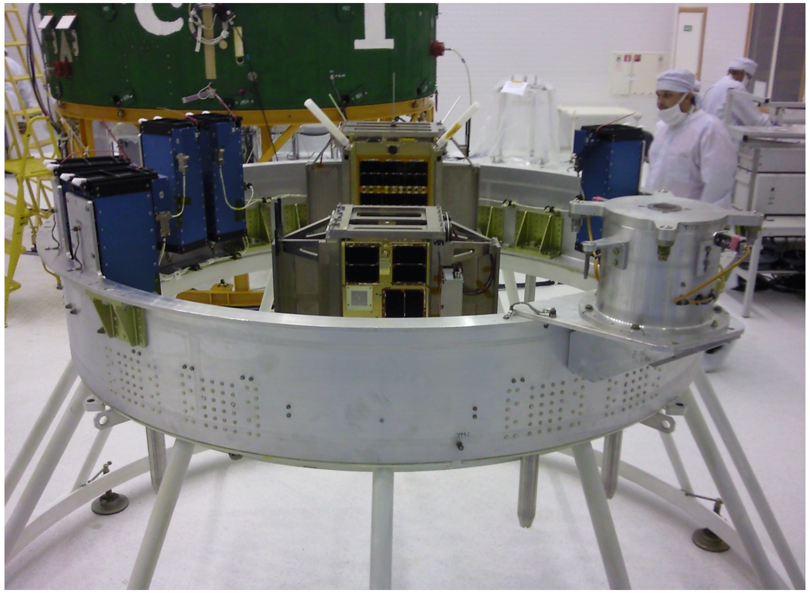




CubeSats

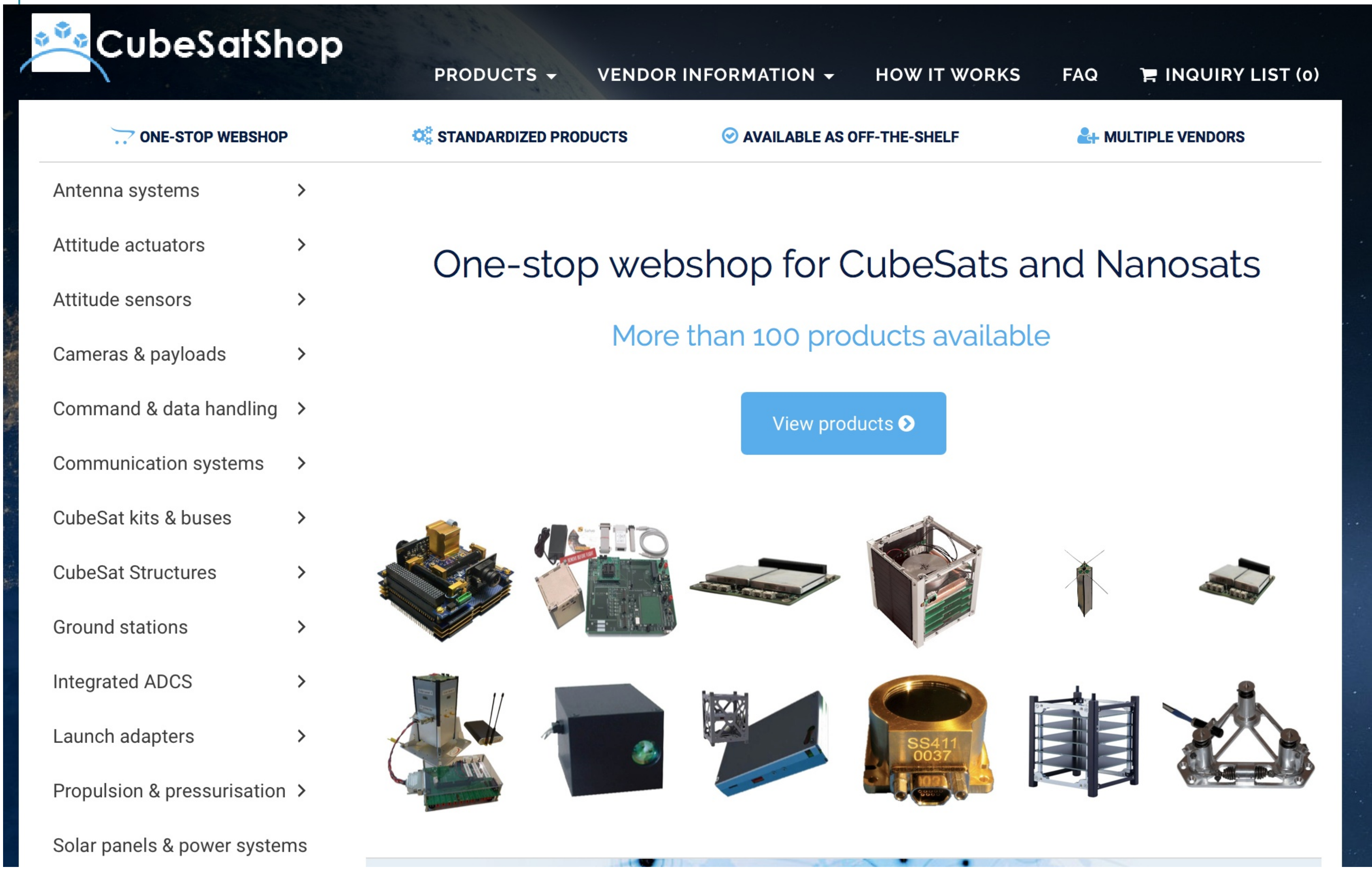




Modularity yields flexibility

P-POD (deployment box)



Modularity allows to develop COTS components



Ideal for hands-on experience on interdisciplinary project

Science (payload)

Orbital dynamics

Structural design

Attitude dyn & control

Telecommunications

Thermal control

Data handling

Electrical power supply

However, the way to orbit can be very long

Managemental issues:

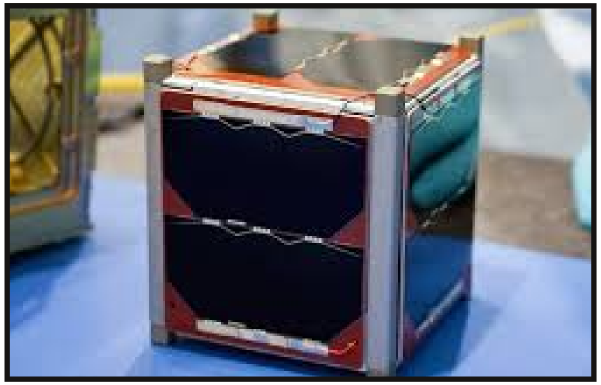
- Students team change mostly yearly
- Need of permanent members to efficiently progress
- Small budget compared to regular space missions but not for universities

Real-life issues:

- Tertiary payload: no authority on orbit design
- Not everybody is enthusiast of nanosatellites (debris problem)

Outline

CubeSats, a tiny revolution in space



OUFTI-1, a Belgian CubeSat developed by students

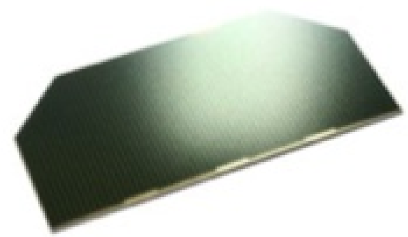
Beyond education: the QB50 and QARMAN missions

OUFTI-1 the first Belgian nanosatellite

D-STAR

ThalesAlenia Space

AZURSPACE
SOLAR POWER GMBH



Université de Liège ULg

isil

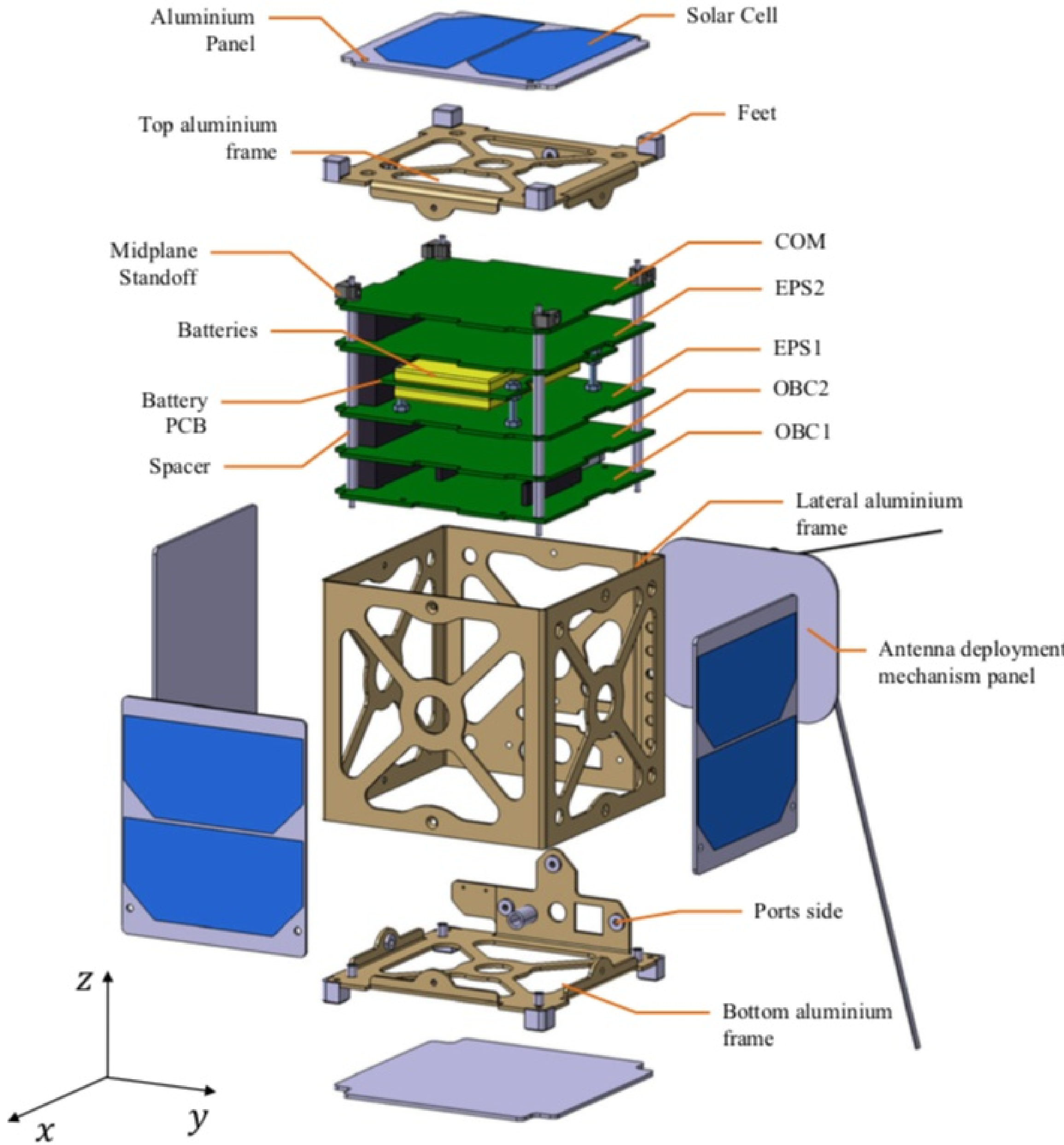
UCL Université catholique de Louvain

Haute Ecole Province de Liège

Project milestones

2007	Project Kick off
2008	First three students: mission objectives and scenario
2009	
2010	
2011	Subsystems design
2012	
2013	Choosen by ESA for the "Fly Your Satellite" program
2014	Test campaign
2015	
2016	Launch

Conceived by students from scratch



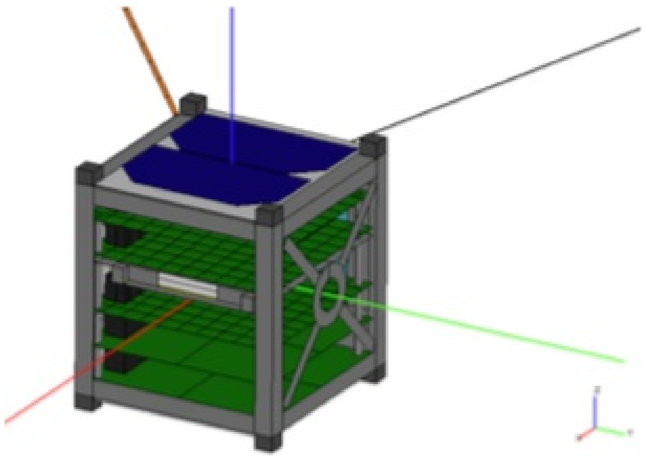
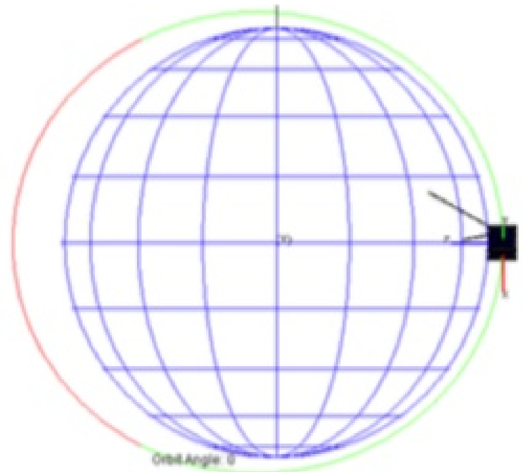
Different backgrounds for a common goal

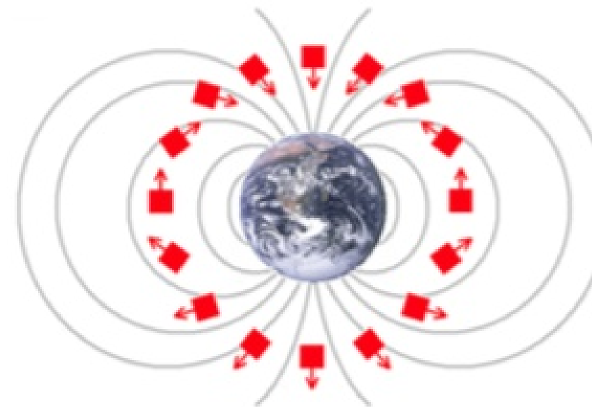
2 Universities + 3 Engineering schools

> 50 students (Aerospace, Mechanical, Telecom, Electrical, Computer Sciences)

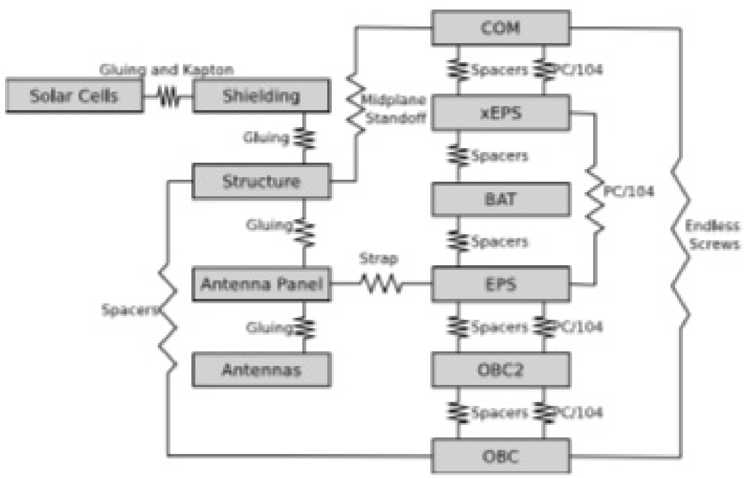
I was in charge of the thermal protection system in 2011

- Geometrical Mathematical Model (GMM)

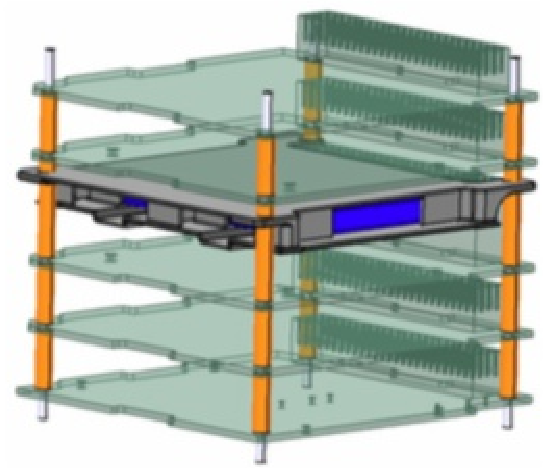


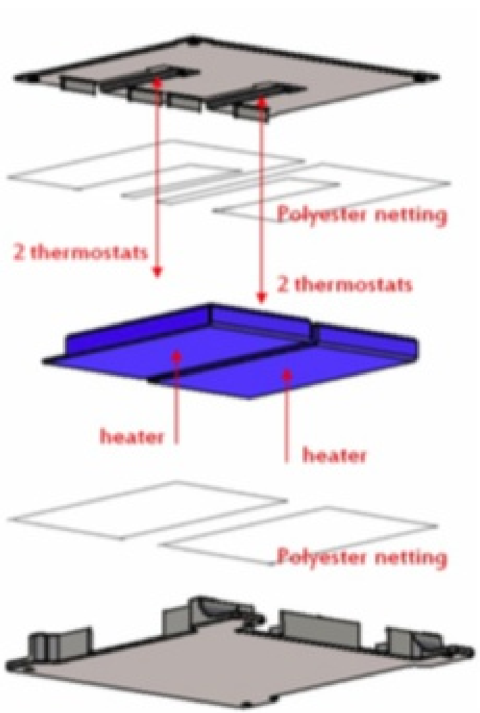
- Thermal Mathematical Model (TMM)



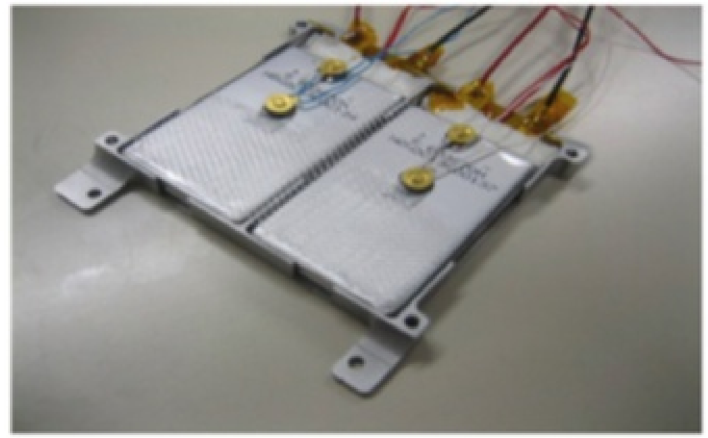
- 1 cold case
- 2 hot cases

My contribution: prevent batteries from freezing

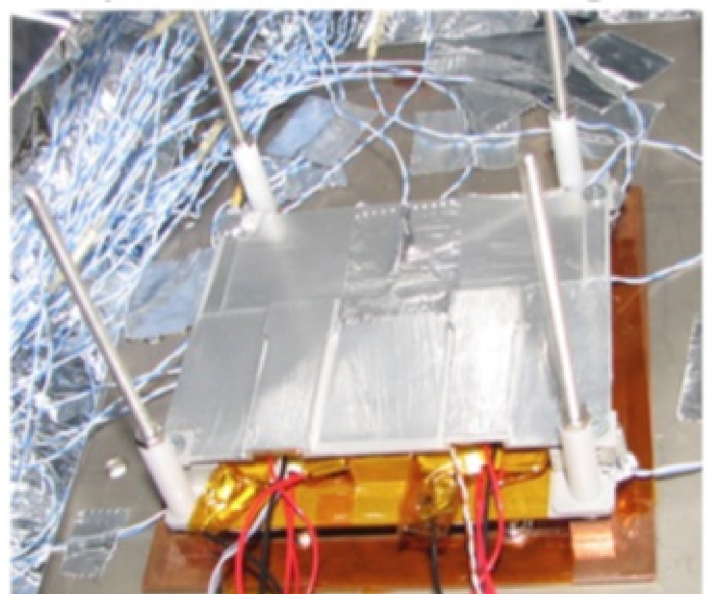




Thermostats

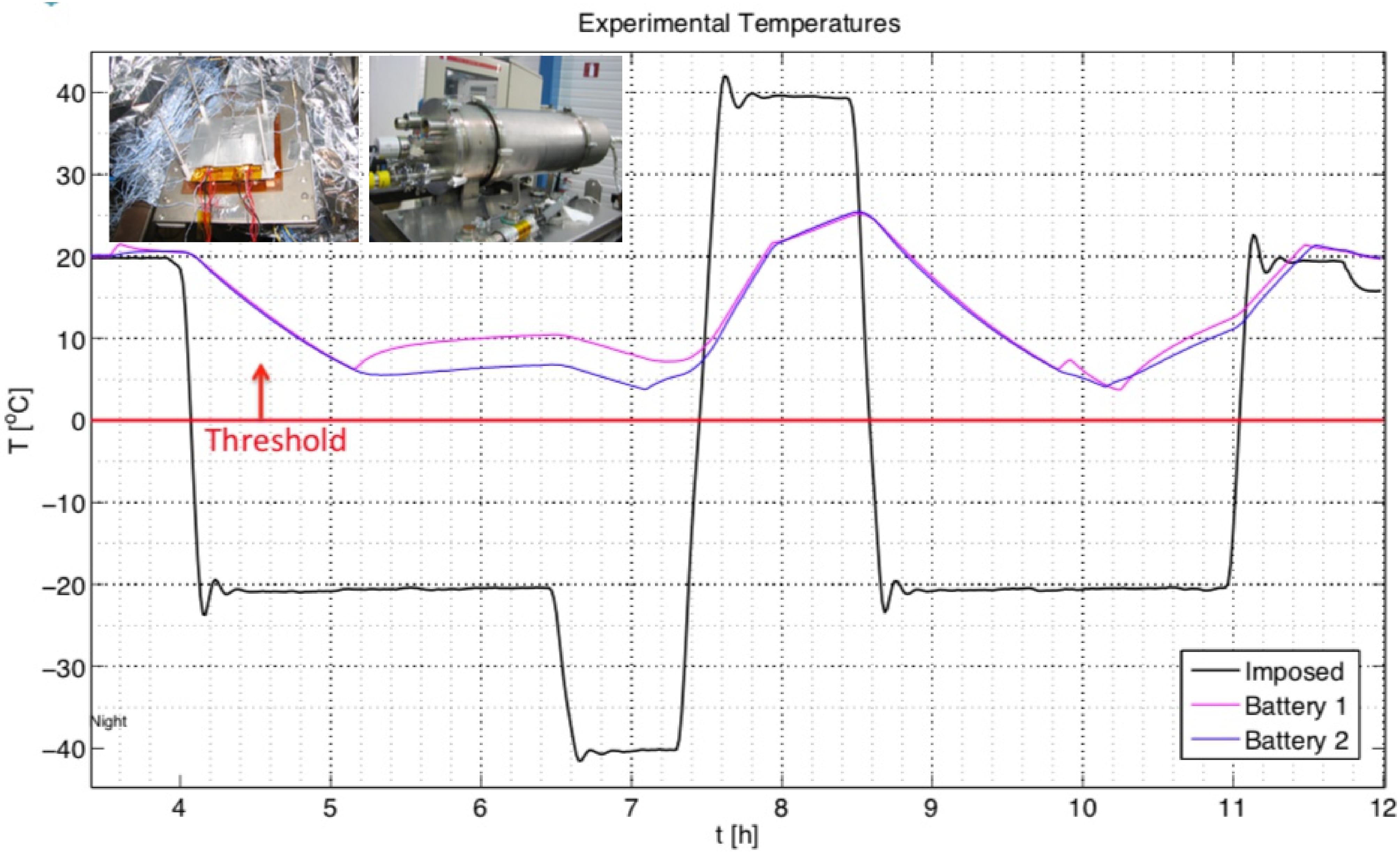


Spacers & Al coating



Heater

Experimental validation at the Centre Spatial de Liege



My personal take away

Use of ESATAN and ESARAD **softwares**

Thermal **testing** of satellite subsystems

Interactions with other subsystems

Outline

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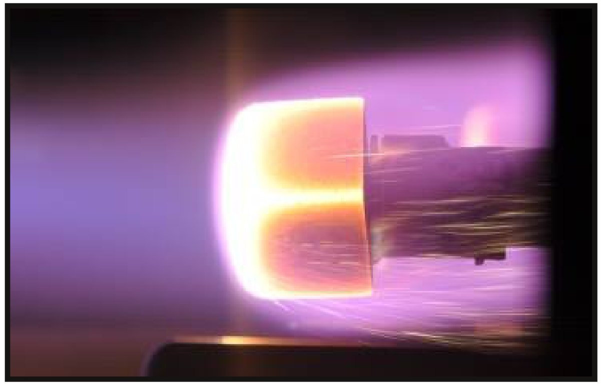
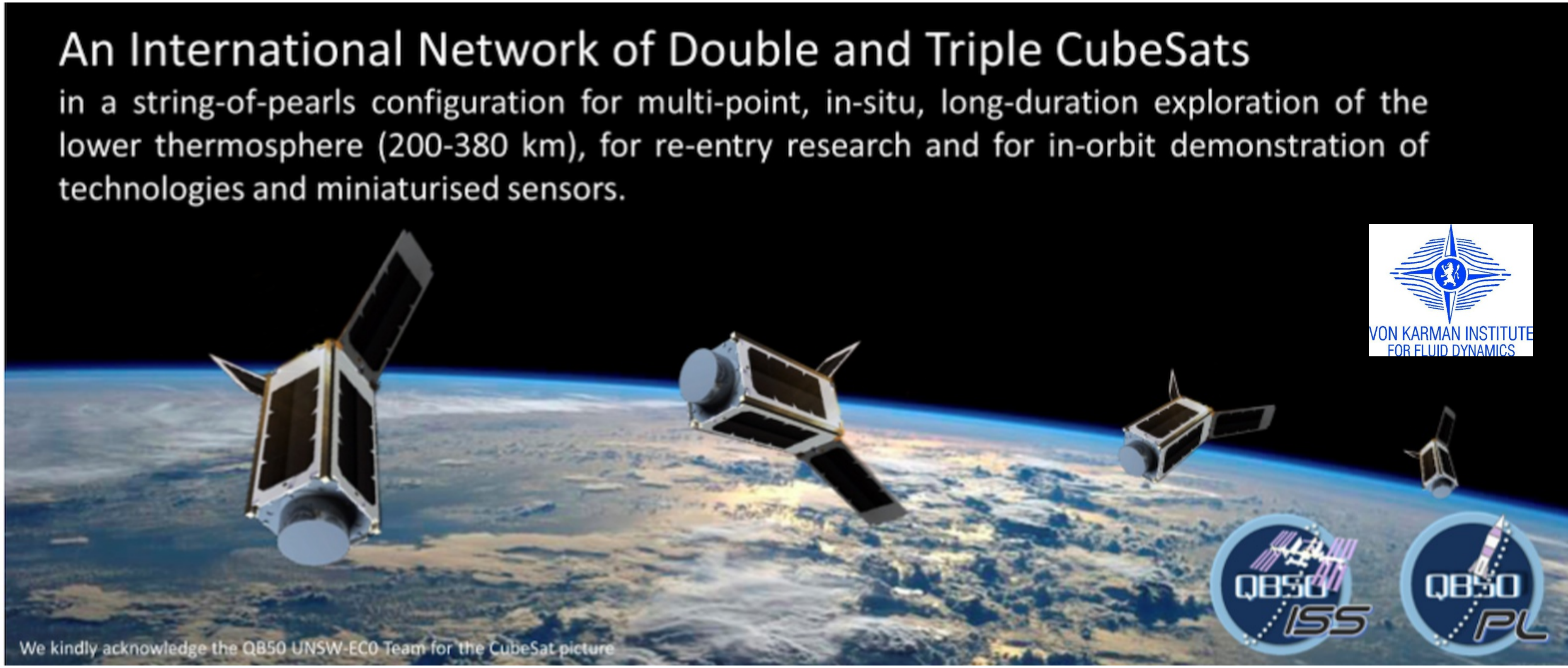
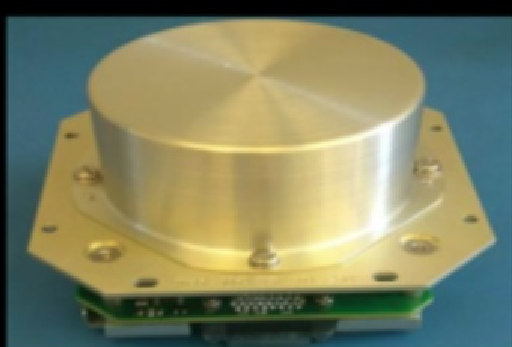
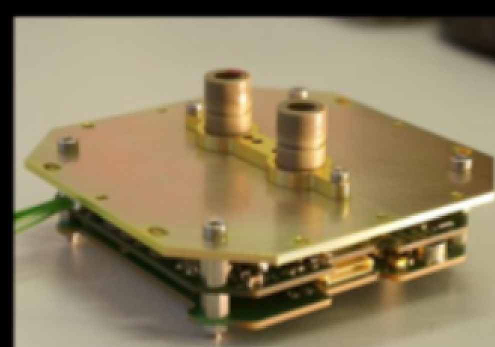


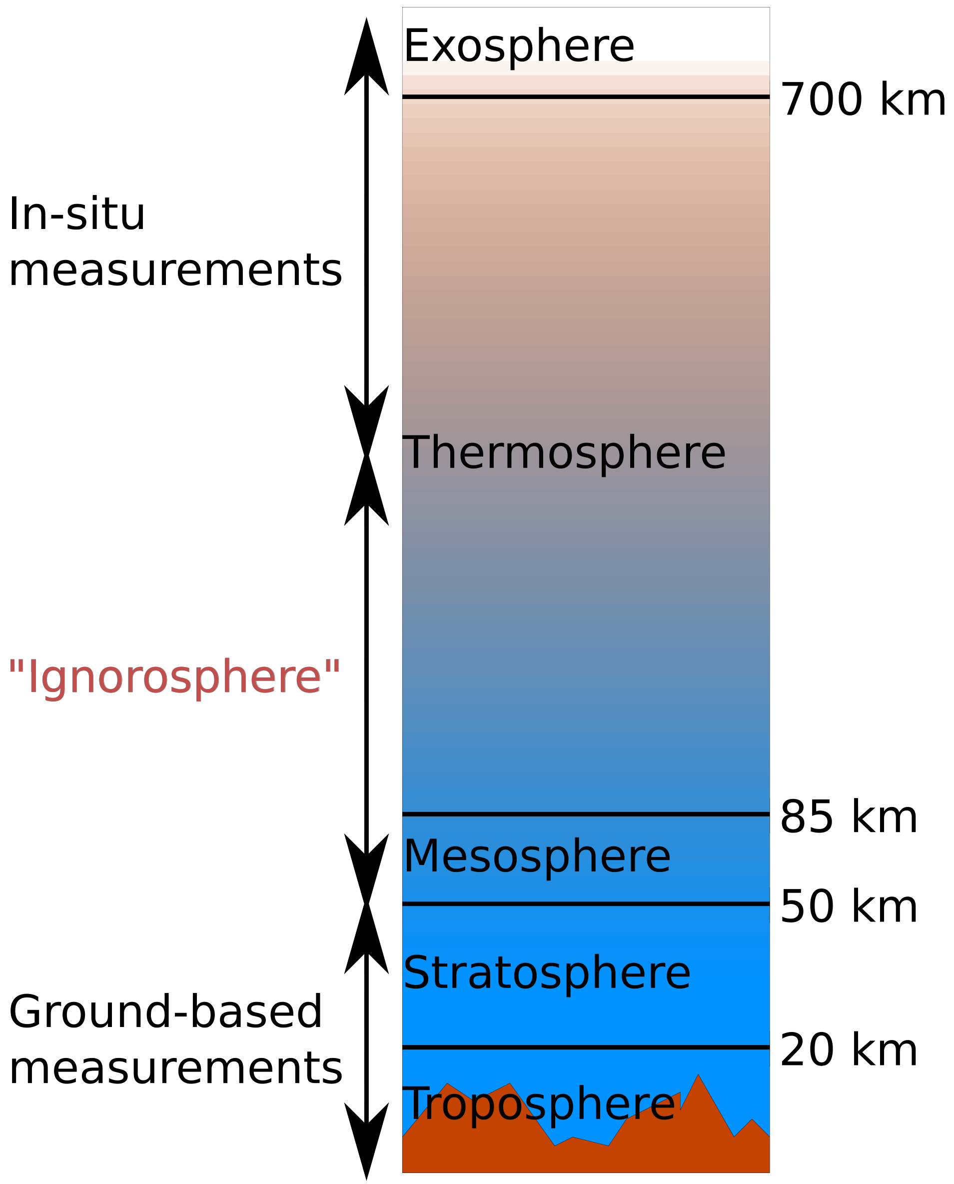
Beyond education: the QB50 and QARMAN missions

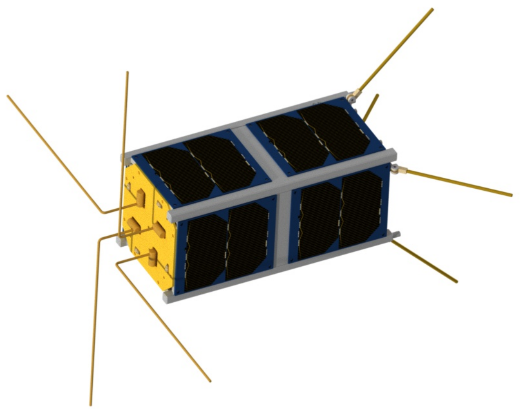
The QB50 constellation



10 INMS – Ion/Neutral Mass Spectrometer	14 FiPEX – Flux Probe EXperiment	10 mNLP – multi Needle Langmuir Probe
		

Only nanosatellites can do it!



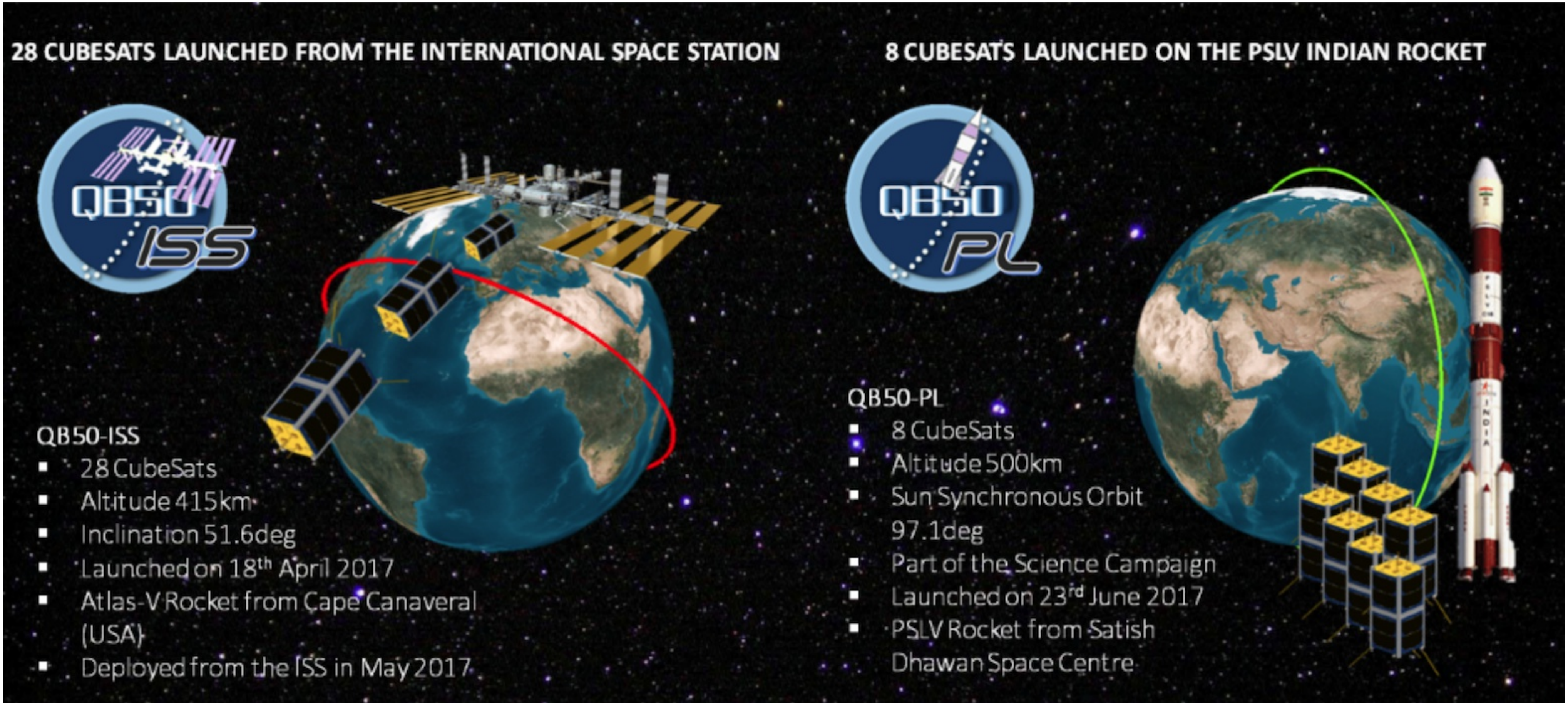


Initial baseline

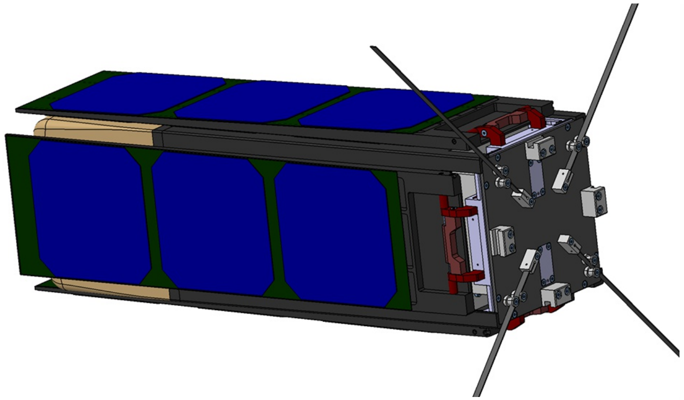
Constellation of 50 CubeSats
40 double-unit
10 triple-unit

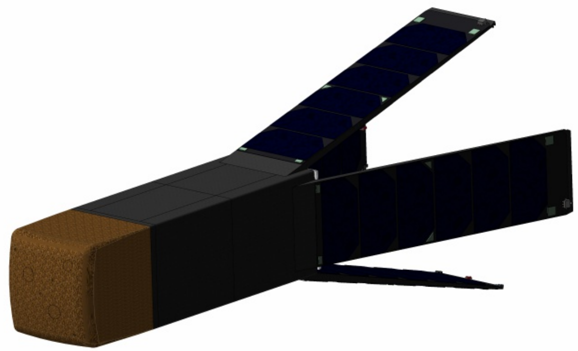
Initial orbit
altitude **380 km**
near-circular
inclination 98 deg

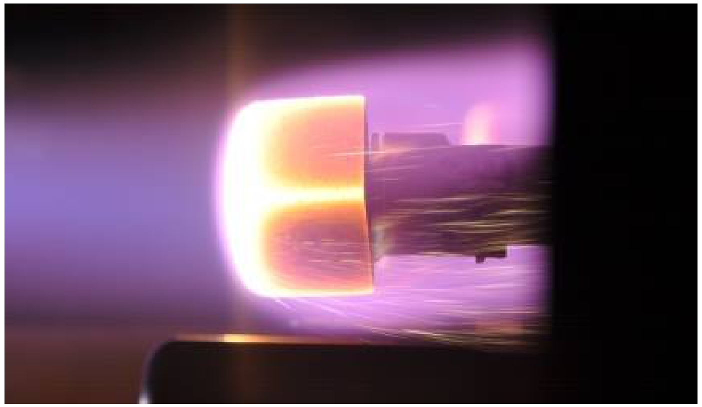
Succesful deployment in 2017



QARMAN, a 3U CubeSat of the QB50 constellation







Commissioning → **Differential drag** → Aerodynamic stabilization → Reentry → Disposal

Commissioning	Differential drag	Aerodynamic stabilization	Reentry	Disposal
	Université de Liège	von Karman Institute	von Karman Institute	
2 days	1 month	~ 2 months	~15 min	

time

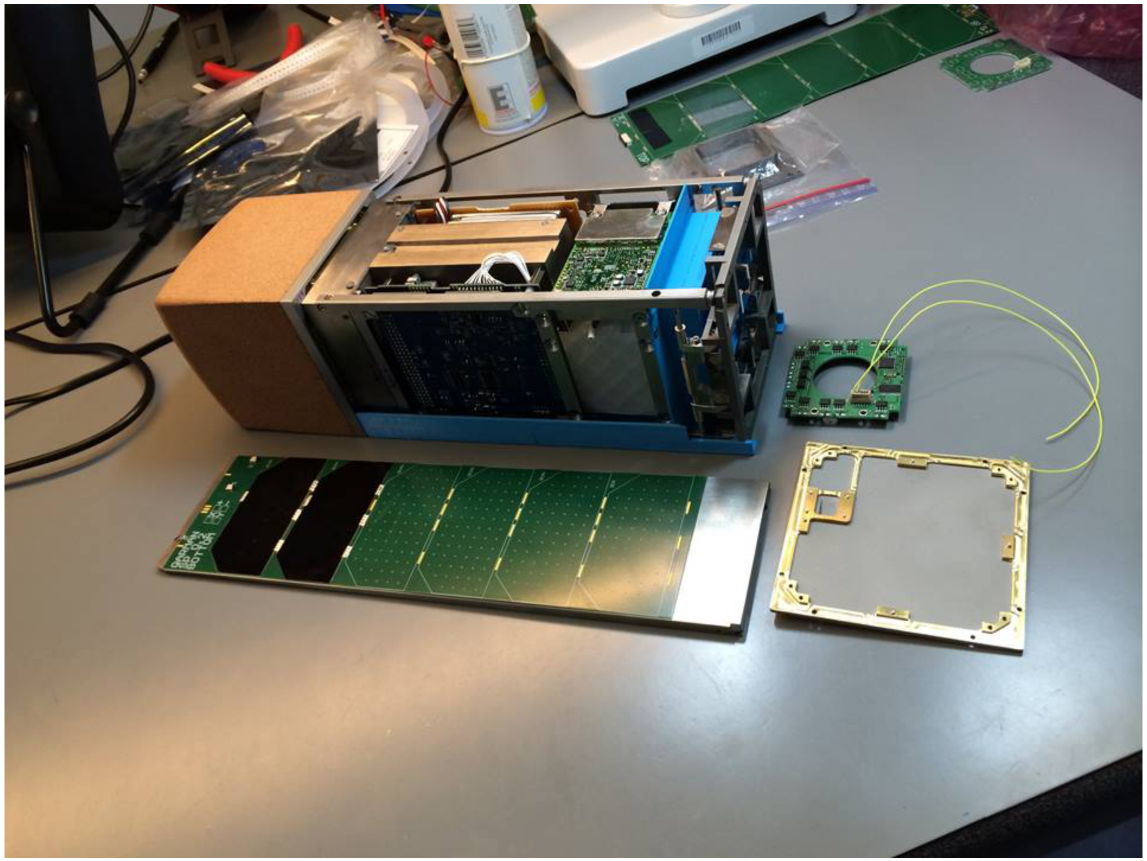
My PhD: Propellantless maneuvers with differential drag

Can we achieve a rendez-vous **without propulsive means**?

Idea: Turn drag into an opportunity

Control force = $\boldsymbol{f}^{A}_{drag}(\boldsymbol{u}) - \boldsymbol{f}^{B}_{drag}$

In-orbit validation with QARMAN

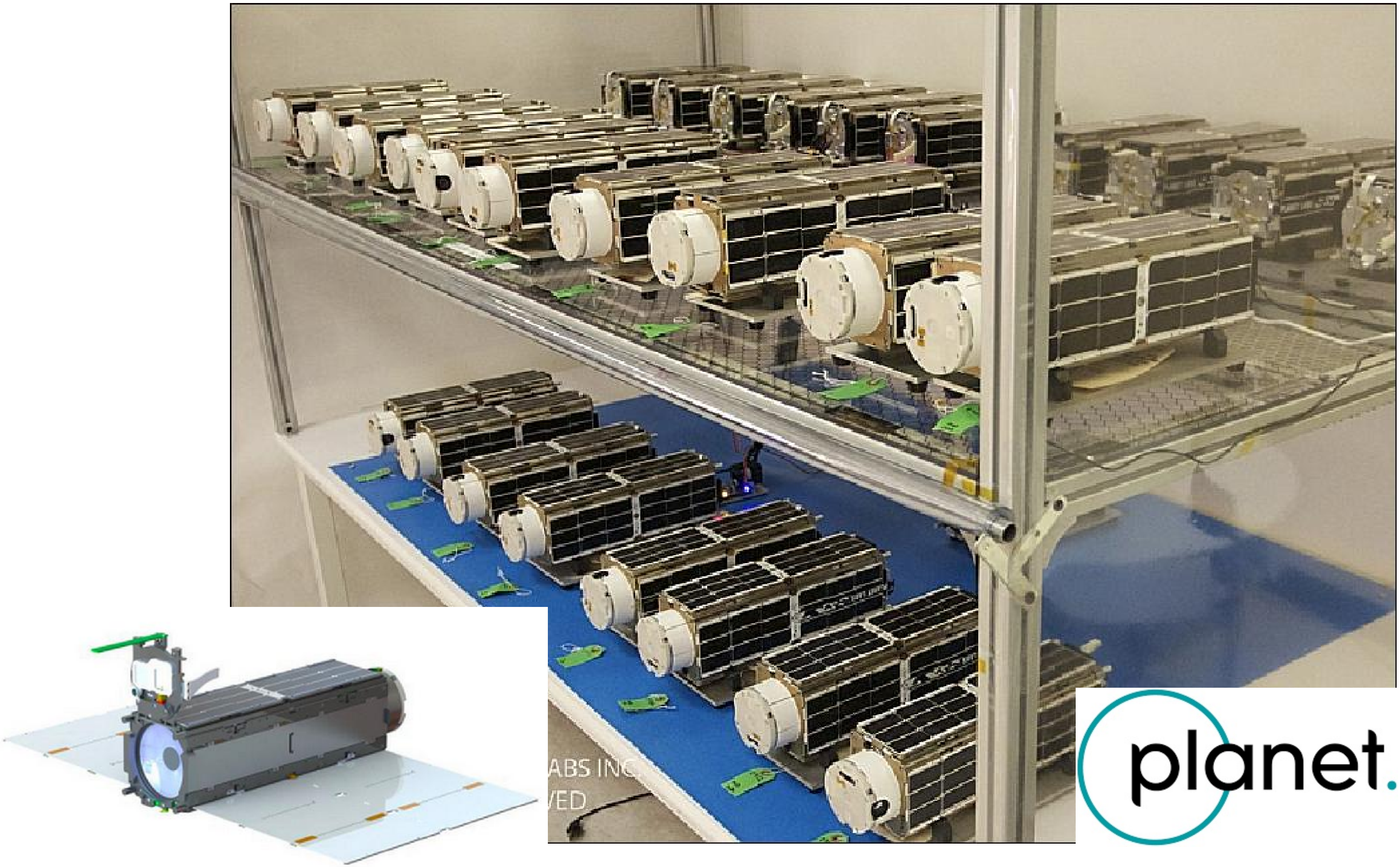


Microprocessor

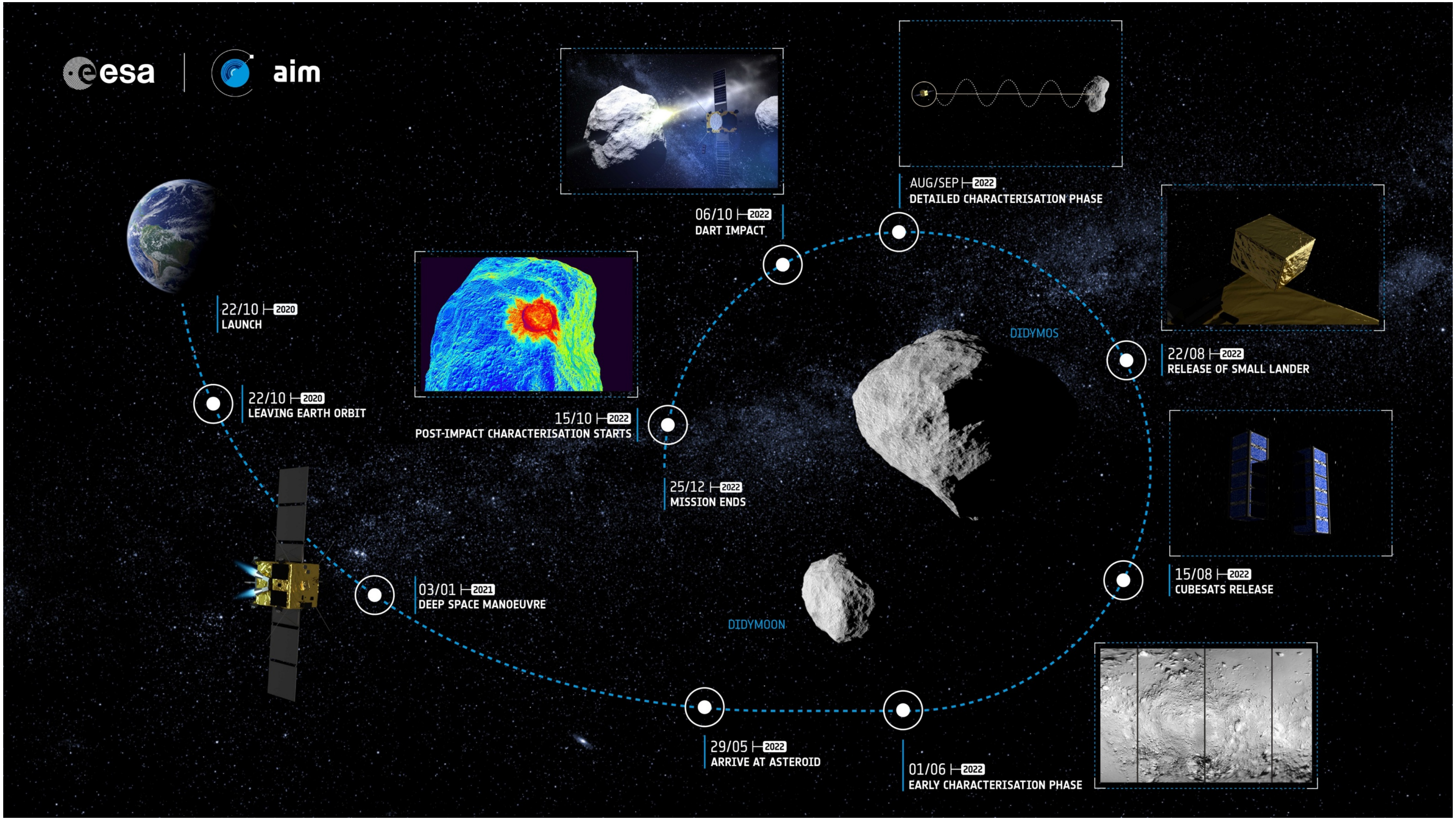
MSP430 FR5969
64 kB FRAM
16 MHz

Launch in 2018

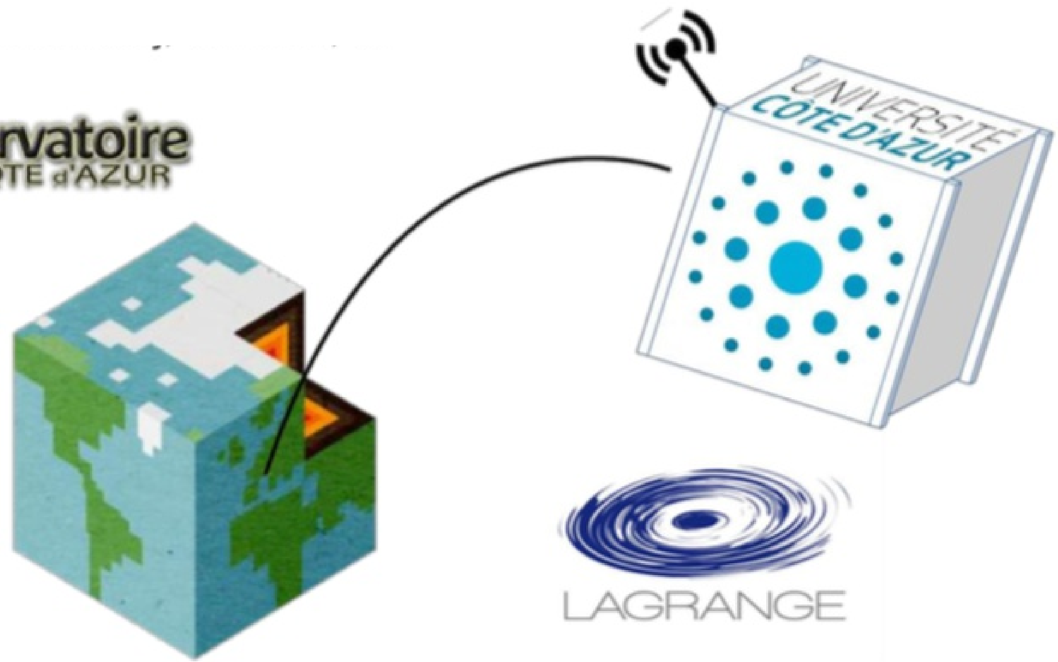
Not only science: business with CubeSats



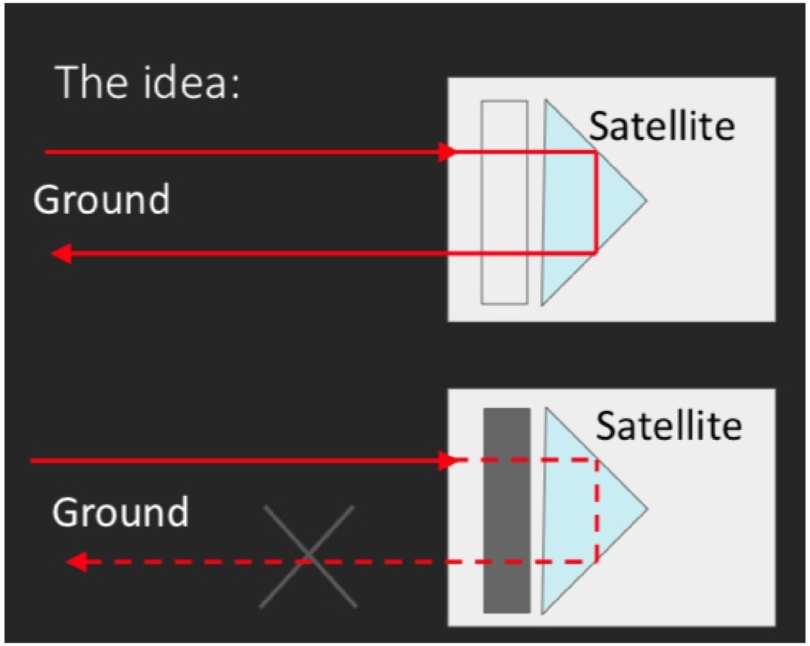
Way forward: interplanetary CubeSat missions



Local initiatives: Centre Spatial UCA



Demonstrator of data transmission with optical link



Conclusions

CubeSats are ideal to provide **hands-on experience** to students

Basically as any satellite... but small: **interdisciplinary** projects

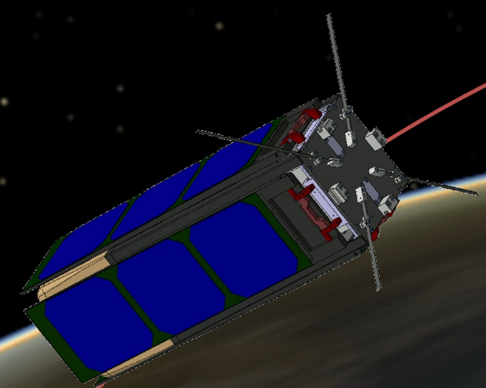
Allow **unique missions** unfeasible for big satellites

Novel activity in the center: **CS-UCA**

CubeSats: Concevoir et Realiser un Satellite à l’Université

Lamberto Dell'Elce

INRIA



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