CubeSats: Concevoir et Realiser un Satellite à l’Université

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INRIA

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Giants in space

<table>
<thead>
<tr>
<th>Envisat</th>
<th>Hubble</th>
<th>ISS</th>
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<tbody>
<tr>
<td>8 211 kg</td>
<td>11 110 kg</td>
<td>~420 000 kg</td>
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<tr>
<td>~ $2.9 billion</td>
<td>~ $4.7 billion</td>
<td>~ $150 billion</td>
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Nanosatellites (1-10 kg): the other edge of the spectrum

- 10 kg
  - Nanosatellites "Milk brick"
  - Microsatellites "Washing machine"
  - Minisatellites "Horse"
  - Satellites "Truck"

- 100 kg
  - Oufit-1
  - Proba 1
  - Meteosat

- 500 kg
  - Hubble
Dimensions matter in space...

You'll never be like me!

Can you do this?
...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

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What are CubeSats?

Parallelepiped-shaped nanosatellites made up of multiples of 1 dm³ cubes
What are CubeSats?

Naive idea: 1 liter X 1 kg X 1 W

Original requirements by Cal Poly and Stanford 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

### CubeSatShop

#### ONE-STOP WEBSHOP

- Antenna systems
- Attitude actuators
- Attitude sensors
- Cameras & payloads
- Command & data handling
- Communication systems
- CubeSat kits & buses
- CubeSat Structures
- Ground stations
- Integrated ADCS
- Launch adapters
- Propulsion & pressurisation
- Solar panels & power systems

#### STANDARDIZED PRODUCTS

#### AVAILABLE AS OFF-THE-SHELF

#### MULTIPLE VENDORS

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**One-stop webshop for CubeSats and Nanosats**

More than 100 products available

[View products](#)
Ideal for hands-on experience on interdisciplinary project

- Orbital dynamics
- Attitude dyn & control
- Thermal control
- Science (payload)
- Structural design
- Telecommunications
- 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)
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OUFTI-1 the first Belgian nanosatellite
Project milestones

- **2007**: Project Kick off
- **2008**: First three students: mission objectives and scenario
- **2009**: Subsystems design
- **2010**: 
- **2011**: 
- **2012**: 
- **2013**: Chosen 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.
My contribution: prevent batteries from freezing
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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The QB50 constellation

An International Network of Double and Triple CubeSats
in a string-of-pearls configuration for multi-point, in-situ, long-duration exploration of the lower thermosphere (200-380 km), for re-entry research and for in-orbit demonstration of technologies and miniaturised sensors.

We kindly acknowledge the QB50 UNSW-EC0 Team for the CubeSat picture

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 $380 \text{ km}$
near-circular
inclination 98 deg
Succesful deployment in 2017

**QB50-ISS**
- 28 CubeSats
- Altitude 415km
- Inclination 51.6deg
- Launched on 18th April 2017
- Atlas-V Rocket from Cape Canaveral (USA)
- Deployed from the ISS in May 2017

**QB50-PL**
- 8 CubeSats
- Altitude 500km
- Sun Synchronous Orbit 97.1deg
- Part of the Science Campaign
- Launched on 23rd June 2017
- PSLV Rocket from Satish Dhawan Space Centre
QARMAN, a 3U CubeSat of the QB50 constellation

- Commissioning
  - Université de Liège
  - 2 days

- Differential drag
  - von Karman Institute
  - 1 month

- Aerodynamic stabilization
  - von Karman Institute
  - ~2 months

- Reentry
  - ~15 min

- Disposal

Time line: 2 days to ~15 min
My PhD: Propellantless maneuvers with differential drag

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

**Idea:** Turn drag into an opportunity

$$ \text{Control force} = f^A_{\text{drag}}(u) - f^B_{\text{drag}} $$
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**
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