# QB50

## An international network of CubeSats for scientific research and technology demonstration


***J. Muylaert, C. Asma***

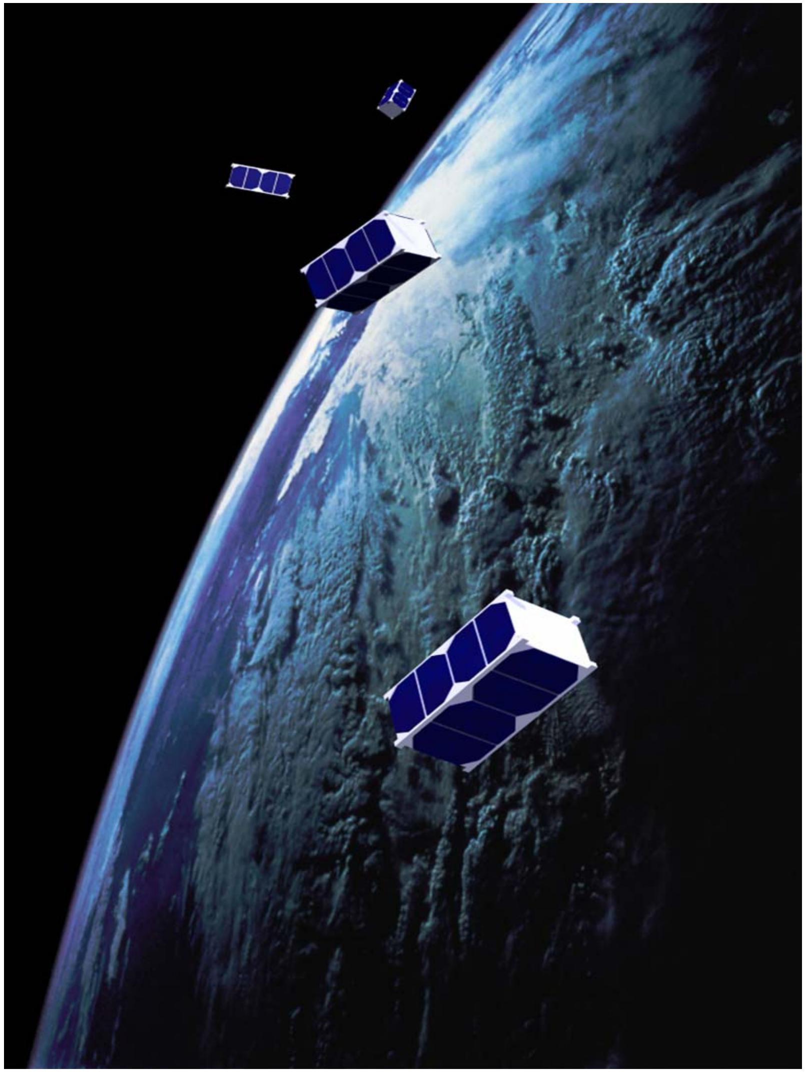
*v*on Karman Institute for Fluid Dynamics

Rhode-Saint-Genèse (Brussels)

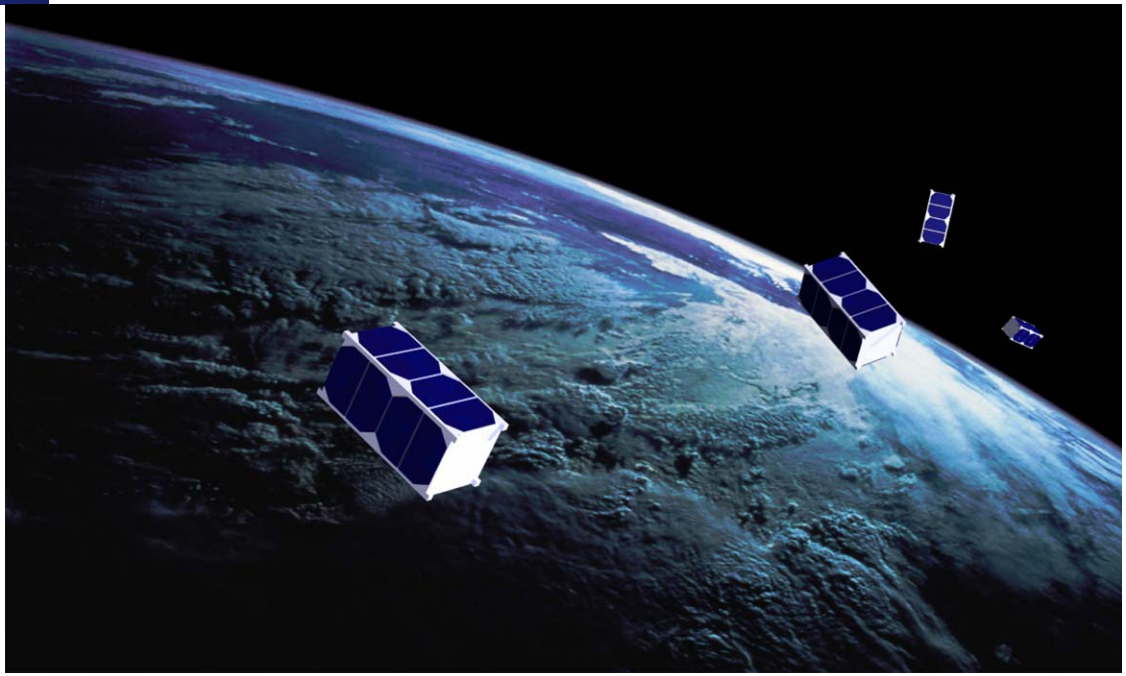

**Belgian Senate**

25 March 2013

Brussels, Belgium



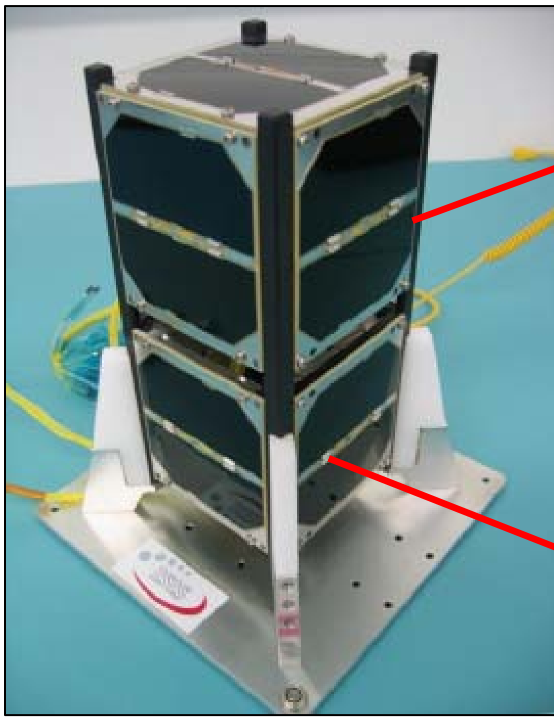
# *QB50* - THE IDEA

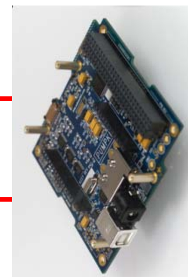


- An international network of 50 CubeSats for multi-point, in-situ, long-duration measurements and in-orbit demonstration in the lower thermosphere
- A network of *50 CubeSats* sequentially deployed
- Initial altitude: 350 km (circular orbit, high inclination)
- Downlink using the QB50 Network of Ground Stations

# QB50 - The CubeSat

## On a Double CubeSat *(10 x 10 x 20 $cm^3$):*



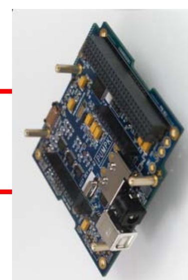


### Science Unit:

*Lower Thermosphere Measurements*

*Sensors designed by MSSL*

*Standard sensors for all CubeSats*



### Functional Unit:

*Power, CPU, Telecommunication*

*Optional Technology or Science Package*

*Universities are free to design the functional unit*

# Sensor Selection

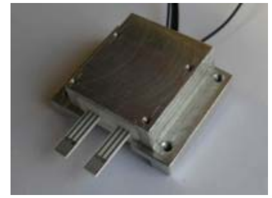
***Set 1***
Ion-Neutral Mass Spectrometer (INMS)
2 corner cube laser retroreflectors (CCR)*
Thermistors/thermocouples/RTD (TH)

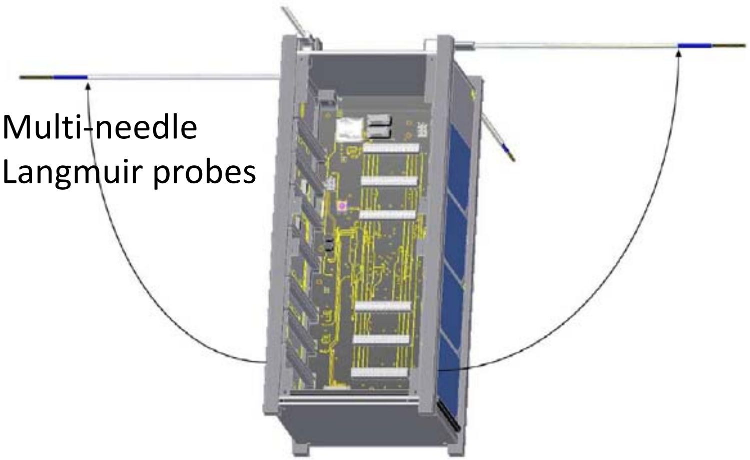
***Set 2***
Flux-Φ-Probe Experiment (FIPEX)
2 corner cube laser retroreflectors (CCR)*
Thermistors/thermocouples/RTD (TH)

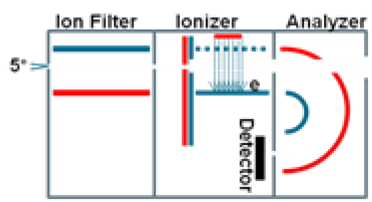
***Set 3***
A set of 4 Langmuir probes (MNLP)
2 corner cube laser retroreflectors (CCR)*
Thermistors/thermocouples/RTD (TH)

* Offered as an option

FIPEX sensor



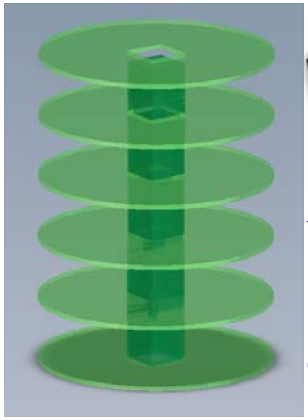



Schematic of the principle of working of the INMS

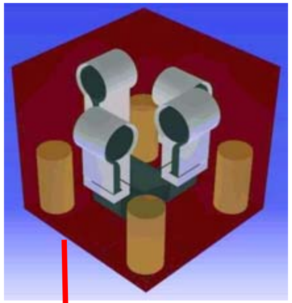
Miniaturised charged particle analyser along with the Improved Plasma Analyser

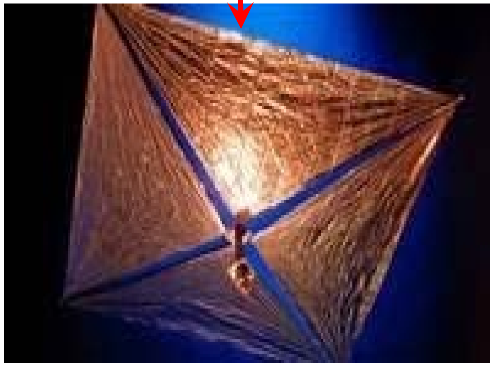
# In-Orbit Demonstration



A modular deployment system for double and triple CubeSats

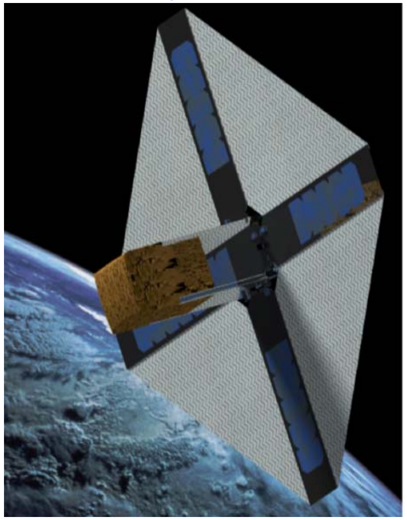

Gossamer-1 Solar Sail demonstration packagem DLR

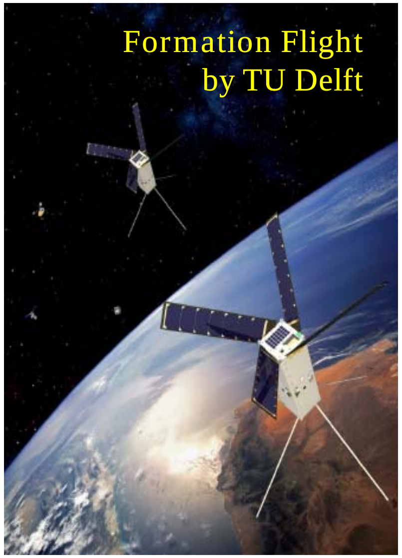


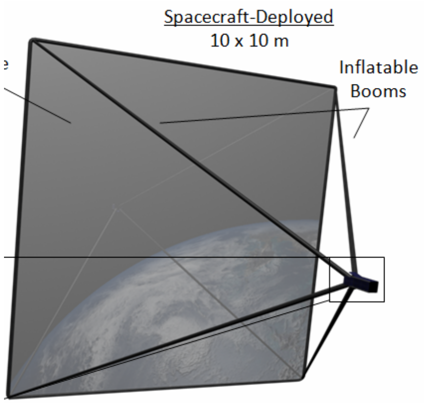


De-orbiting and aerodynamic stability

AeroSDS by VKI






InflateSail demonstration mission, SSC

**Other In-Orbit Demos:**

- End of life analysis, Debris
- Micro-propulsion systems
- Micro-g experiment

# Formation Flying

## DelFFI Project: with triple CubeSats "Delta" and "Phi"

• Delft University of Technology intends to provide two triple-unit Cubesats, both being equipped with a highly miniaturized propulsion system in addition to the standard science payload.

•This allows for a coordinated formation flying of these two satellites using baselines, which can be realized, maintained and adjusted during the mission based on scientific and technological needs.

• The position of the satellite will be determined by GPS. The inter-satellite communication will be realized by ground stations

•Therefore, formation flight will be possible at any distance

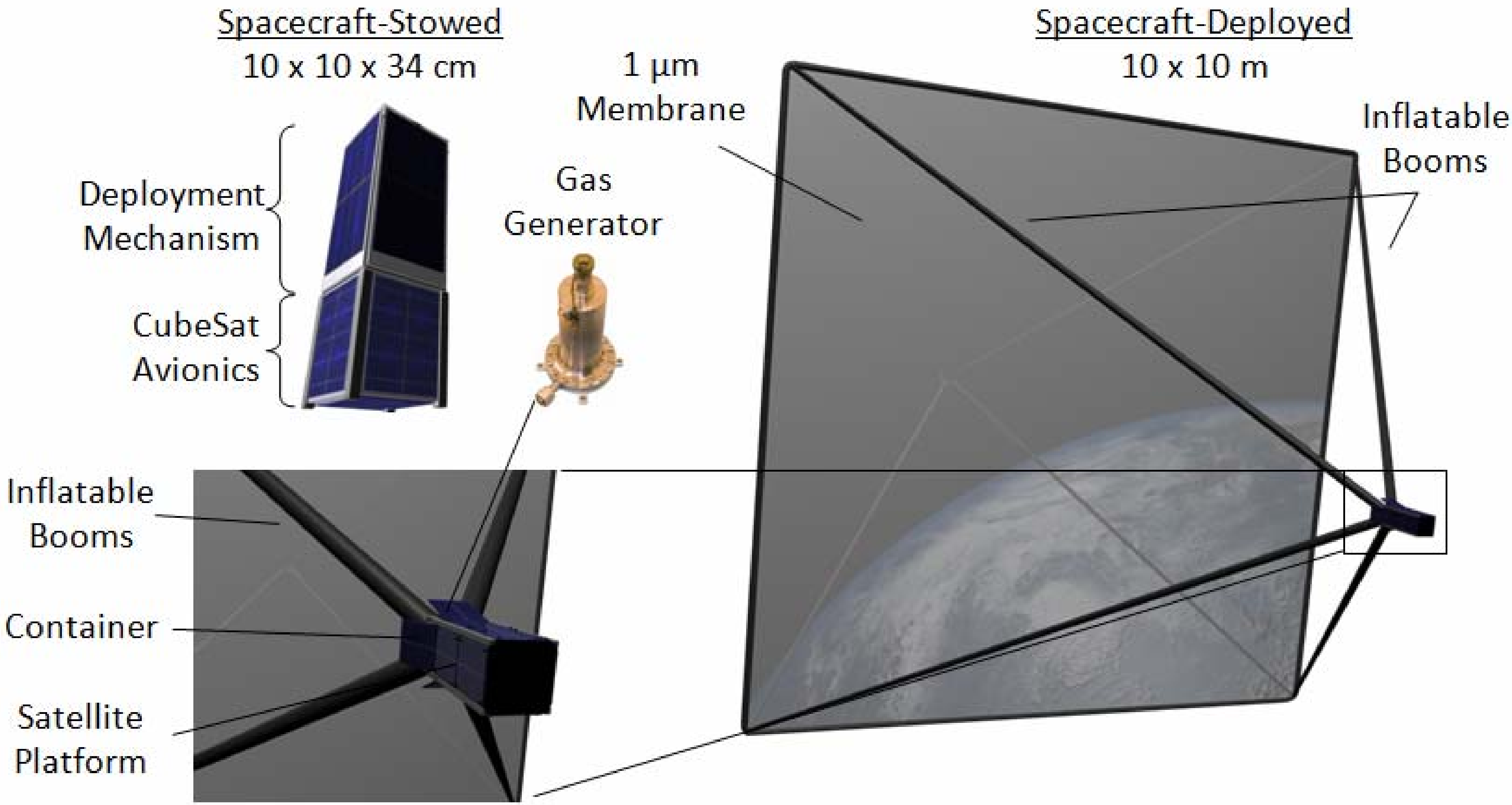


von Karman Institute for Fluid Dynamics

TU Delft Delft University of Technology

# Inflate-Sail

## for testing a solar sail with inflatable booms





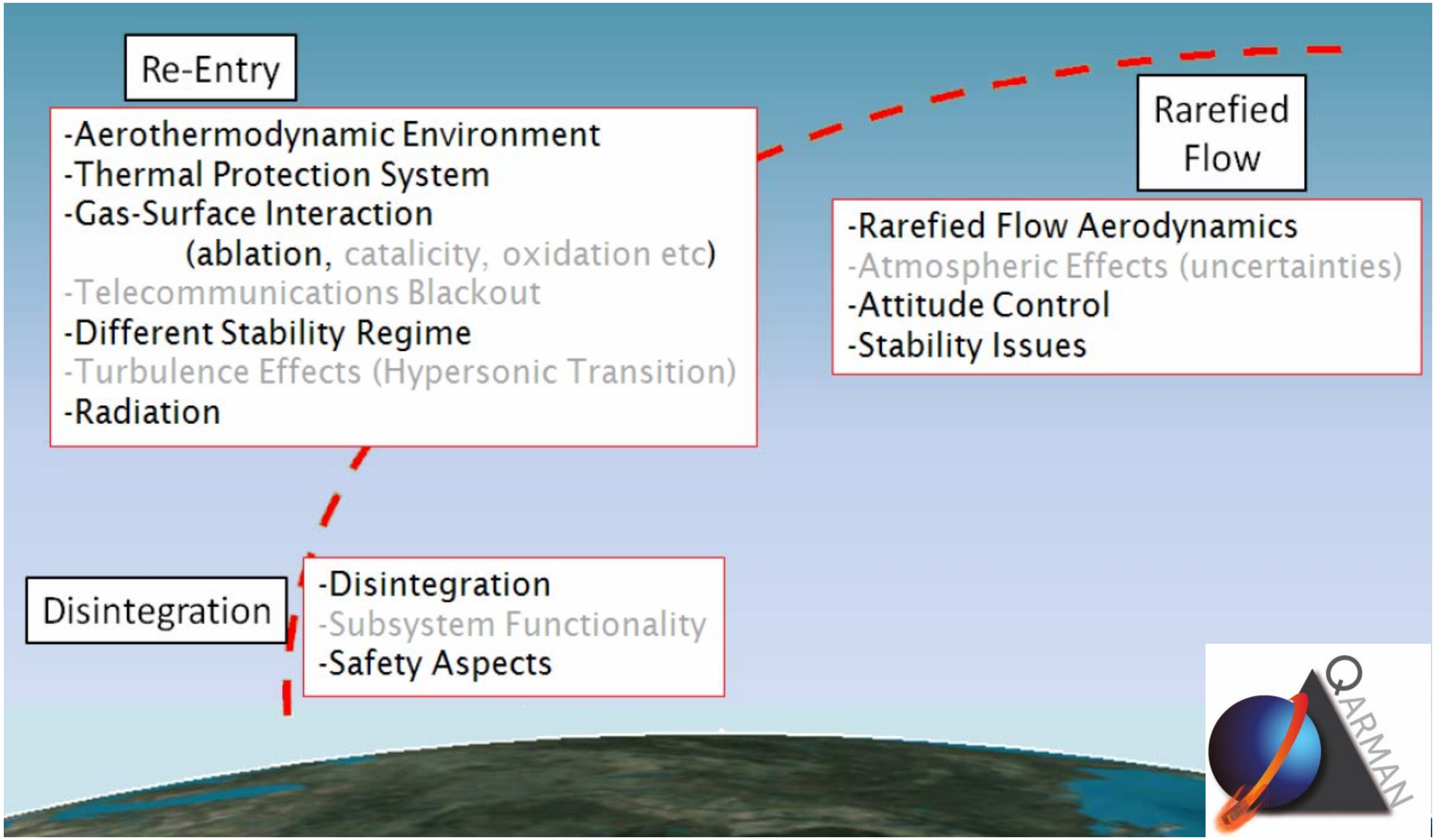

von Karman Institute for Fluid Dynamics

UNIVERSITY OF SURREY

www.QB50.eu

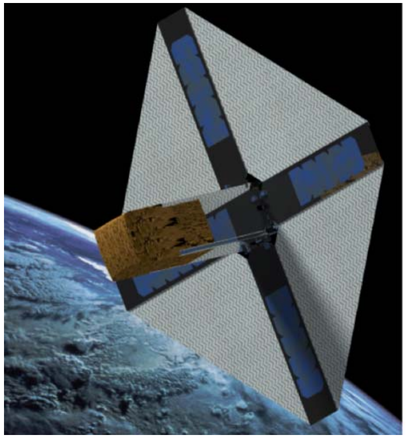
# QARMAN: Re-entry Demonstrator

- Low Cost Flight Test: Low altitudes and re-entry conditions



# QARMAN: AeroSDS

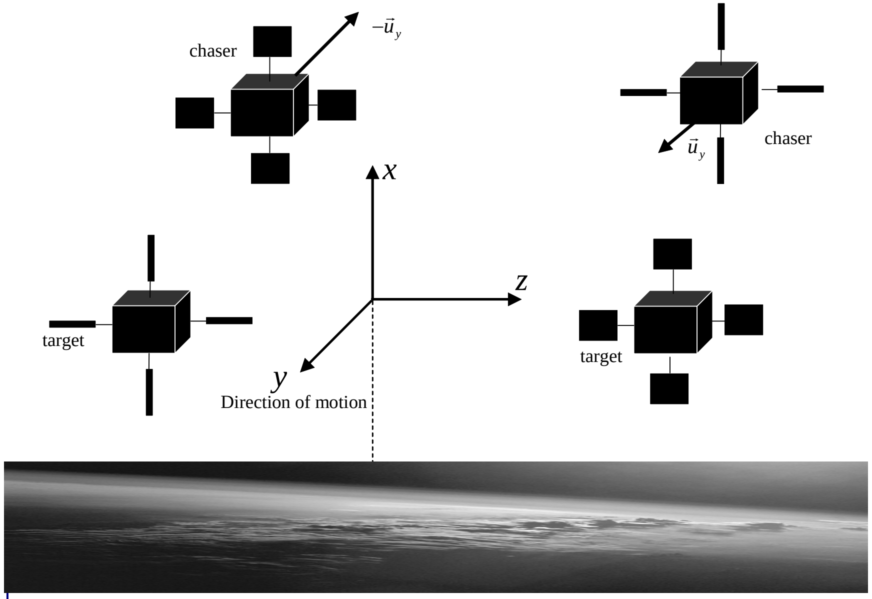
- low-cost, passive and permanent stability
  -powered only during deployment
  -standard COTS systems
- two modes for rarefied & entry phase



- flexible sizing according to desired entry conditions and lifetime

# QARMAN: Differential Drag

By *controlling* (increasing and decreasing) the surface exposed to the residual atmosphere it is possible to change the magnitude of the atmospheric drag and therefore create a (differential) acceleration, in the plane of the orbit), between one spacecraft and either another spacecraft or a desired target point.




The *control of the exposed surface* can be achieved in essentially two ways:

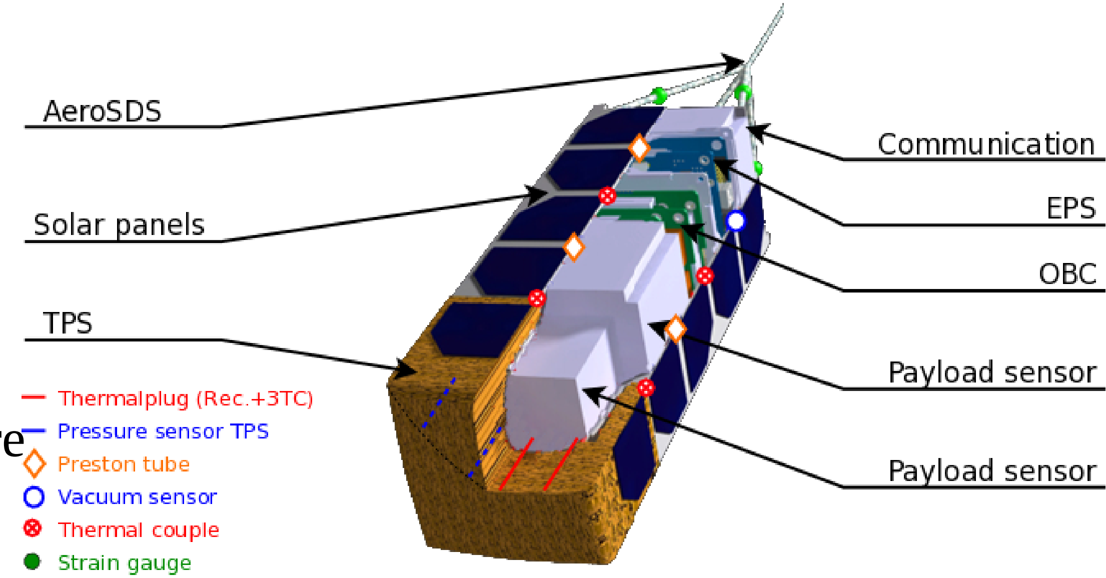
1) by opening/closing "drag vanes" [see figure on the left]

2) by changing the orientation of the spacecraft (offering a larger or smaller front area to the relative wind) [method preferred for this proposed effort]


von Karman Institute for Fluid Dynamics
Université de Liège
www.QB50.eu

# QARMAN Subsystems

- Measurements for Satellite Re-Entry Trajectory Rebuilding:
  - Ablation
  - Radiation
  - TPS Efficiency
  - Shear Force & Transition
  - Off-Stagnation Temperature
  - Rarefied Flow
  - Stability



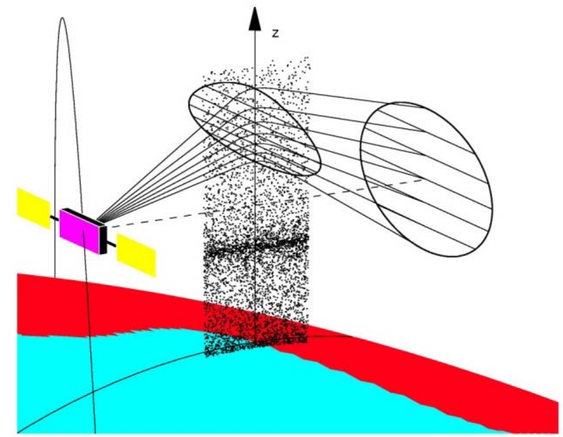

- Feasible Off-the-Shelf Subsystems: IRIDIUM Downlink
- Models for extrapolation of data: **Ground ⇔ Flight**

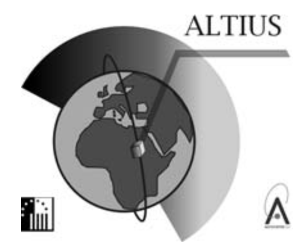
# PICASSO CubeSat

*(BIRA/ROB)*

## Module 1 (BISA): A spectro-imager in the visible range

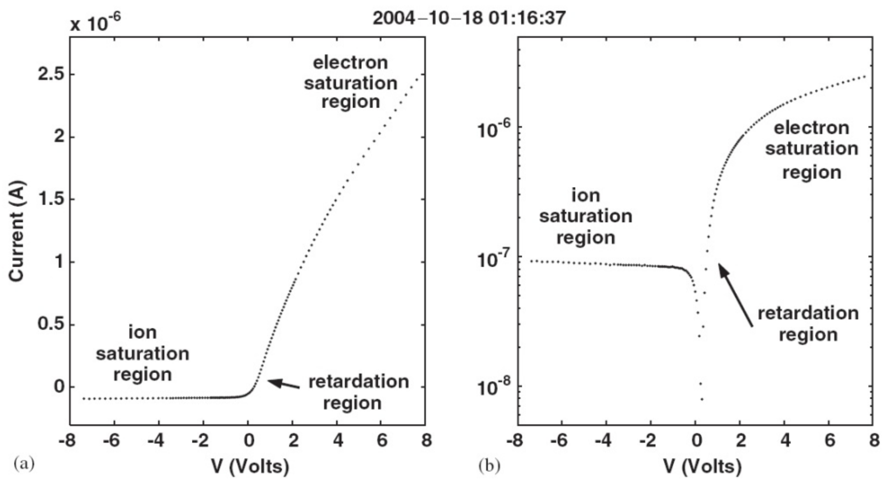
- Atmospheric remote sounding by solar occultation
- Observation of airglow and auroral emissions



# PICASSO CubeSat

## Module 2 (BISA): Langmuir Probe




Goal: to measure electron density and temperature (or s/c potential)

A typical I-V characteristic of a Langmuir probe (Bekkeng 2009)

Two types of LP:

- swept bias: $N_e$, $T_e$, $N_i$ but $\Delta t \cong 1$ sec $\Rightarrow$ poor spatial resolution

to resolve ionospheric plasma structures of ~ 10m

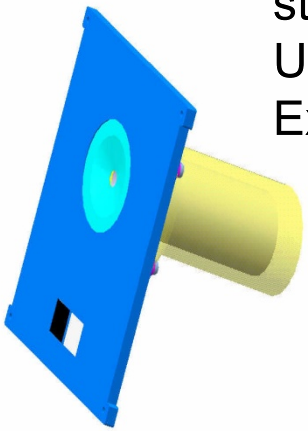
- fixed bias: used when high sample rates are needed. Cannot make absolute measurements of $N_e$ with only one probe

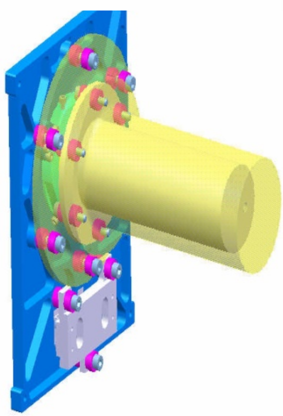
2 cylindrical LPs with different fixed bias

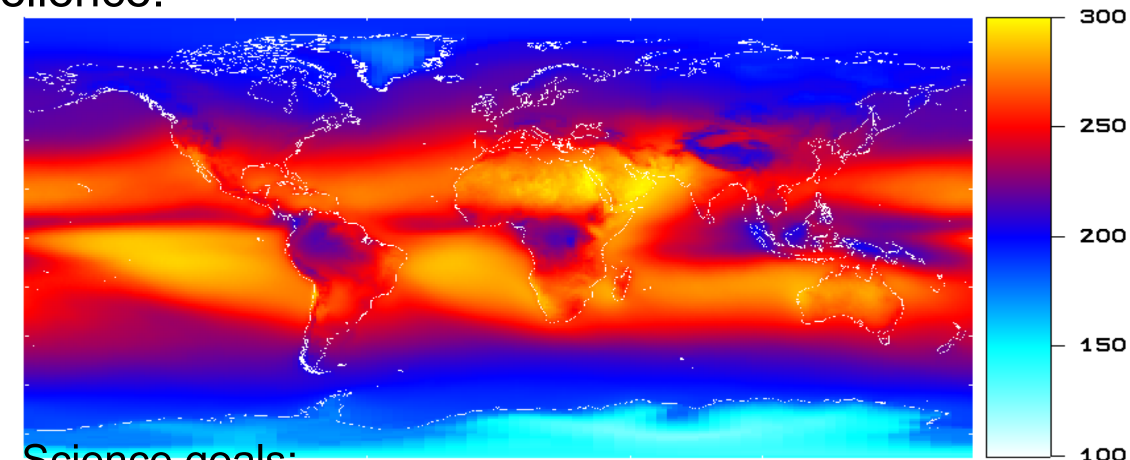
Bekkeng (2009)

# SIMBA CubeSat
## (BIRA/ROB)

The Sun-earth Imbalance (SIMBA) radiometer is an innovative instrument concept for the simultaneous measurement of the Total Solar Irradiance (TSI) and the Earth Radiation Budget (ERB) that has been studied by the Royal Meteorological Institute of Belgium and the University of Liege in the framework of the Solar Terrestrial Center of Excellence.








*Annual mean thermal radiation flux (W/m²) emitted by the earth measured by the CERES Terra instrument.*

Science goals:

- Continue and improve the measurement of the absolute value of the TSI
- Continue and improve the ERB measurements
- Understand and explain the Sun – Earth Radiation Imbalance problem

# Selection of CubeSat Teams

- More than 70 proposals received
- Selection of the 50 CubeSats
  - about 40 double CubeSats for atmospheric research to be selected from 50 proposals,
  - about 10 double and triple In-Orbit-Demonstration CubeSats to be selected from 20 proposals, 4 of them already pre-selected (Delta, Phi, QARMAN, Inflatesail)
  - The two other Belgian CubeSats PICASSO and SIMBA are also approved.
- Contractual Agreement between the QB50 Consortium and the proposing universities
- Availability of funding and readiness at the PDR are critical issues in the selection process,
- There will be backup CubeSat teams as well

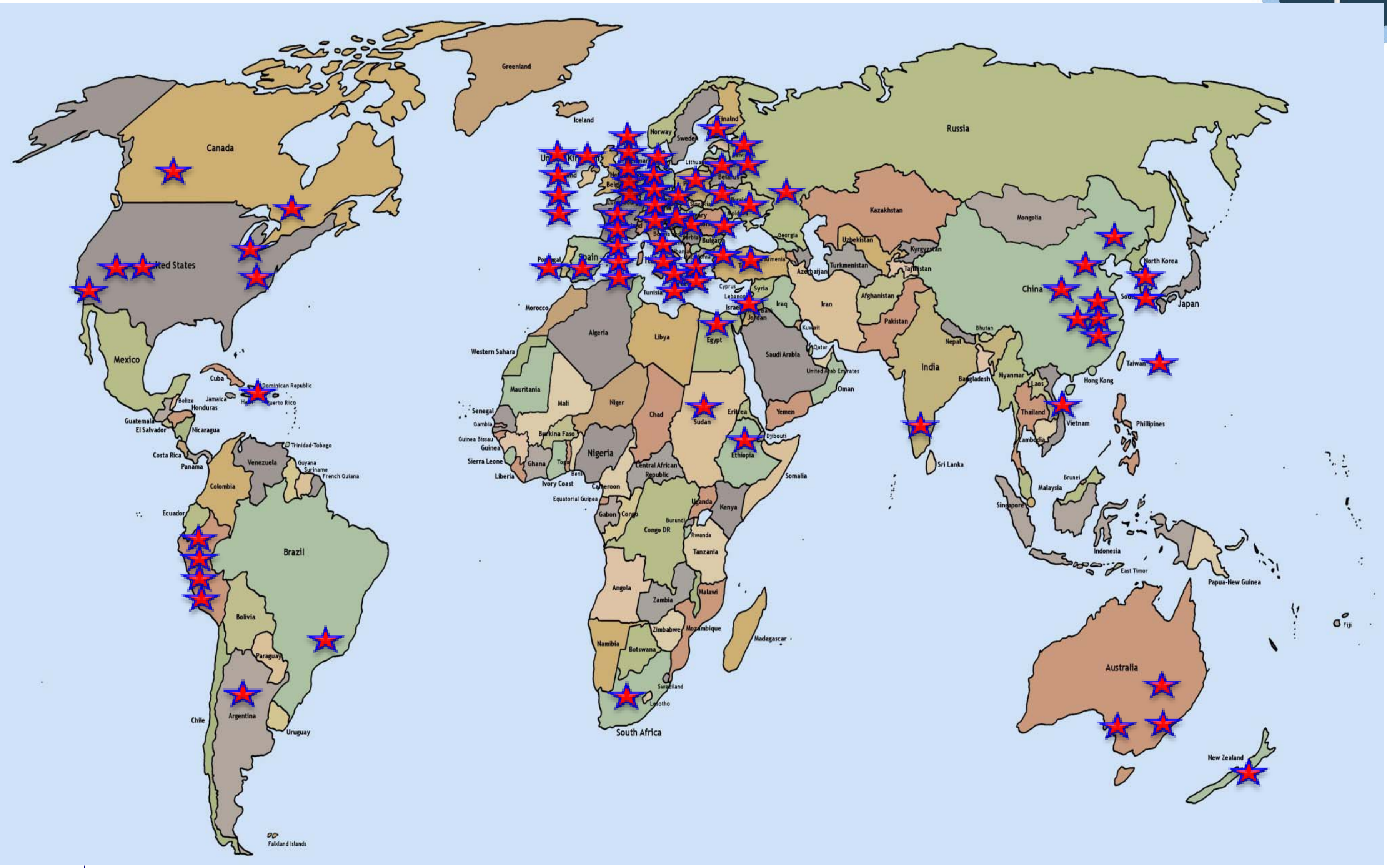
# European CubeSat Teams


16

von Karman Institute
for Fluid Dynamics

www.QB50.eu

# *QB50* – CubeSat Teams






von Karman Institute
for Fluid Dynamics

www.QB50.eu

# QB50 – Educational Impact

- European Union funds 15 industrial/research partners to prepare the infrastructure of QB50 and similar future missions. The total cost is estimated to be ~11 M€ with a reimbursement of 8 M€ from the EU.

- The Call for proposals has attracted more than 70 CubeSat teams worldwide, almost all of them being universities. Assuming an average CubeSat hardware and lab cost of 500 k€, this corresponds to 35 M€.

- Besides, a total of 1000 students and faculty members are expected to work for QB50 worldwide.

- This is a HUGE worldwide educational impact. Only at VKI and only in 2 years, more than 15 Belgian students have assumed active roles.

- In 2012, the Best Wallonia Space Project award was given to a UCL student who worked on QB50; this was a first for UCL in its history.

- QB50 is an international innovative and pioneering project, driven by Europe. In Europe, the major partner is Belgium.

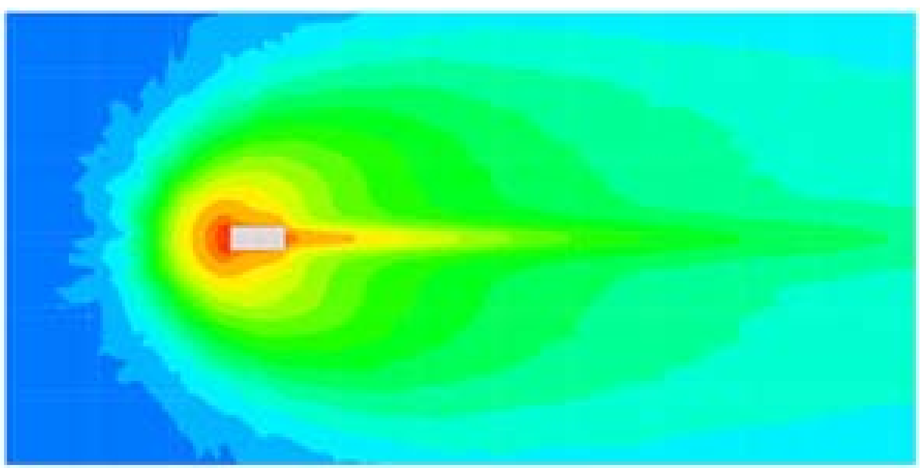
# Status of QB50 Project

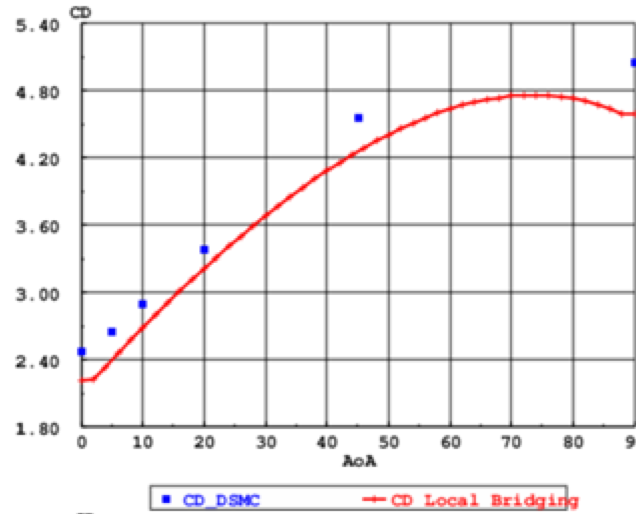
- Started working on the Project as of Nov 2011
- Kick-off was held at 22 Nov 2011

- The Call for Proposals issued on the QB50 web site
- More than 70 proposals were received
- Major technical work accomplished on
  - Orbital dynamics
  - Sensitivity analysis on interaction with the atmosphere
  - Deployment strategy
  - Deployment system
  - Science payload design

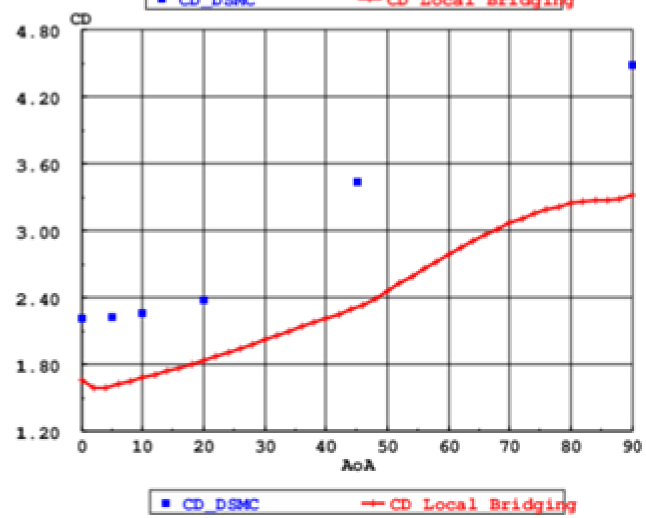
# DSMC simulations for CubeSat – Atmosphere interaction

Preliminary computations for selected amount of points of re-entry trajectory were performed and aerothermodynamic characteristics of CubeSat were obtained in free-molecular, transitional, and near-continuum flow regimes and accuracy of the engineering methods was assessed by comparison with the results obtained by the DSMC SMILE code (ITAM & VKI)





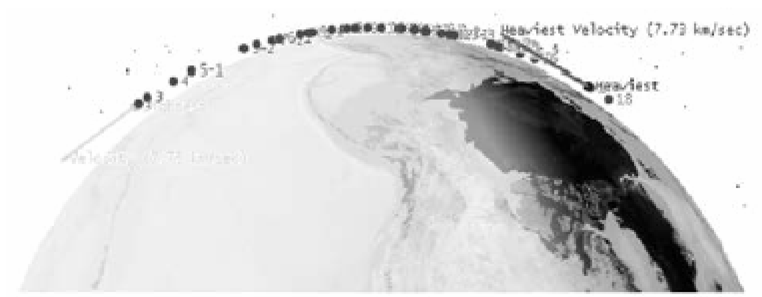

> 100 km



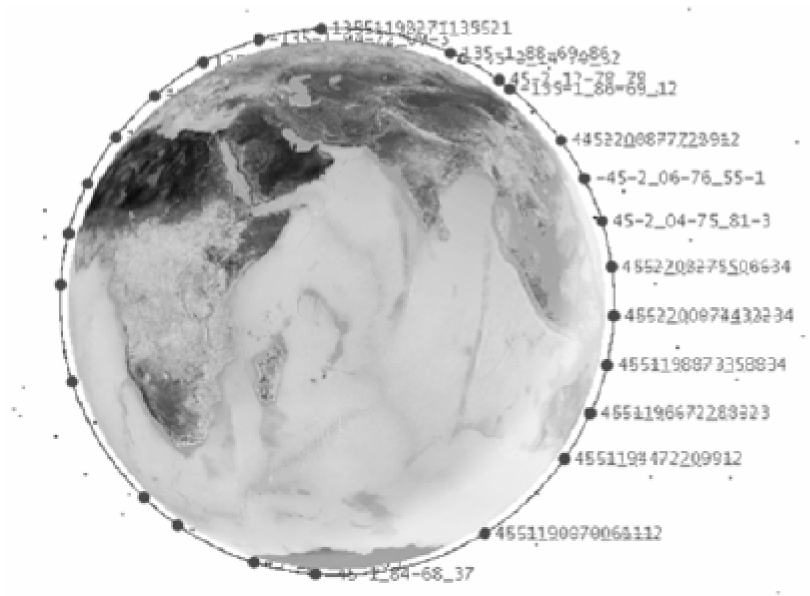

< 80 km

# Deployment Strategy

- How to deploy the 50 CubeSats with minimal collision risk and optimised distribution ?
- Detailed analysis covering ballistic coefficient, deployment direction, deployment frequency
- Best scenario to minimize risk in the first 8 hours, and to optimise a uniform network distribution – the developed strategy can be used directly with the ballistic coefficient database of the selected CubeSats.




After 20 days



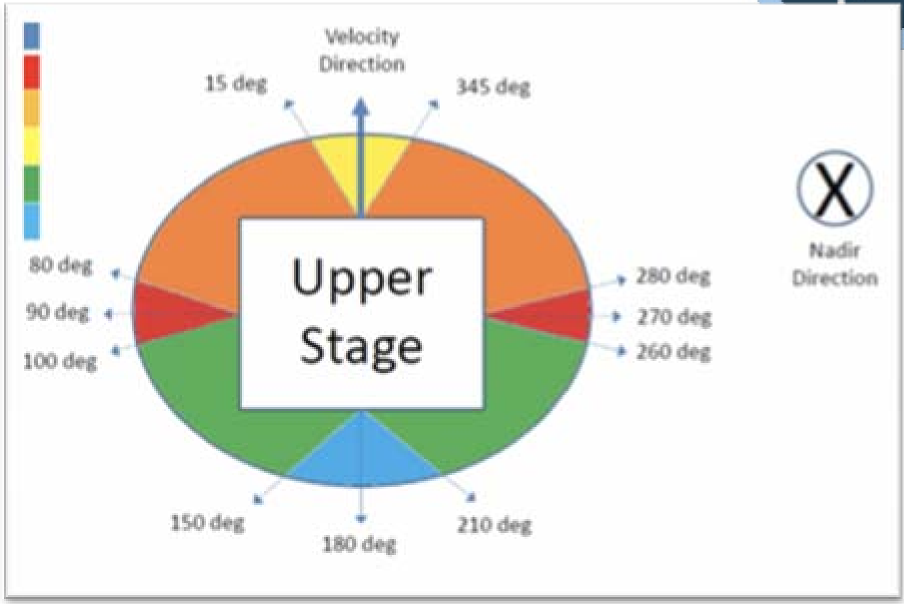

After 30 days



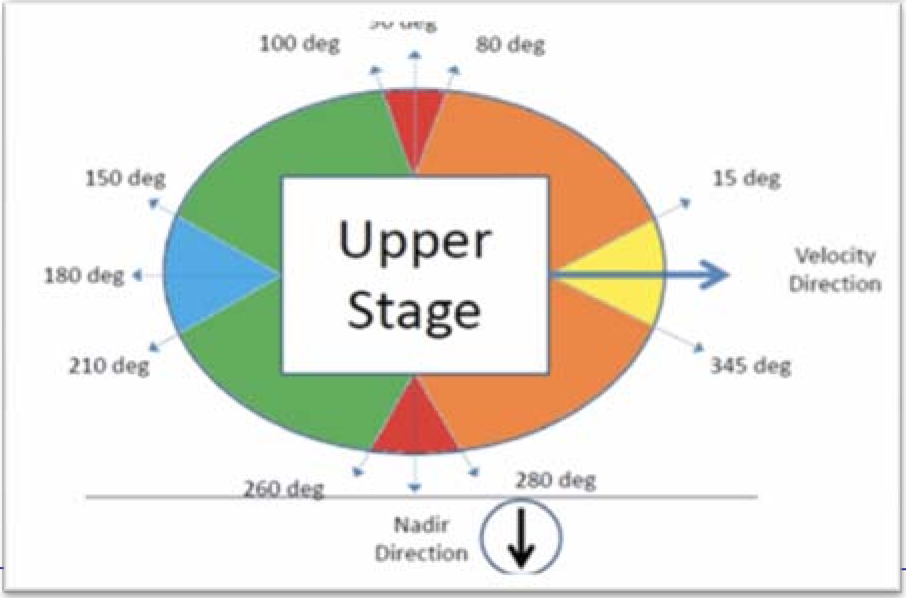
von Karman Institute
for Fluid Dynamics

# Deployment Strategy

TopView

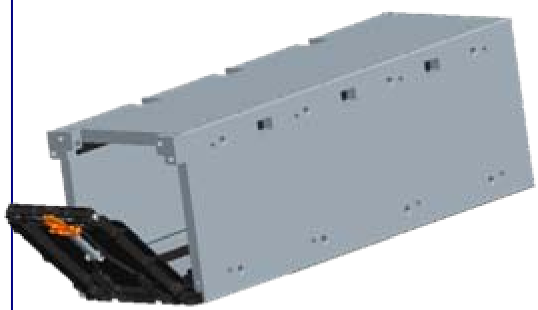



| Risk Colors | |
|---|---|
| High | |
| High-Medium | |
| Medium | |
| Medium-Low | |
| Low | |

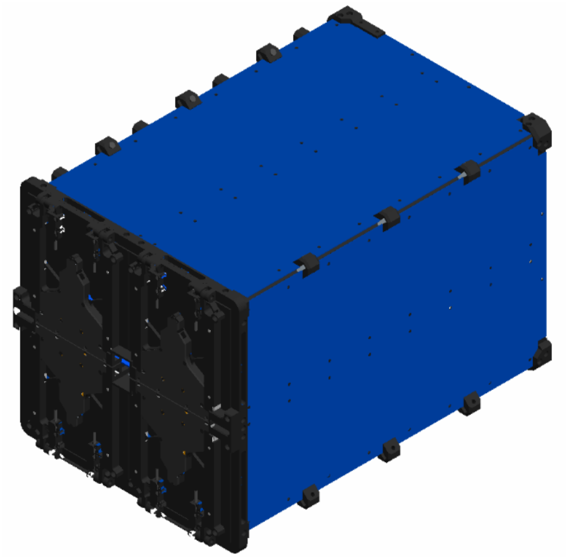



Side View

# Deployment System



**Concept De-risk**
**Prototype**
Prototype



**Precursor**
**Flight**
QuadPack

**QB50**
StackPack

# Hands on Experience for young Aerospace Engineers

– **Unique expertize for students, PhD's, young engineers to :**

- **Learn on Cu development, design , qualification, flight and post flight within short cycle ( 3 years )**
- **Understand missins analysis, system engineering, launcher interface loads and commucation issues**
- **Work in international frame learning and exchanging from each other through the bi annuakl workshops at the VKI**
- **Perform great atmospheric science with CU Networks**
- **Execute In Orbit Demonstrations advancing TRL ( Technological Research Level) for new Space Technologies**

# Hands on Experience for young Aerospace Engineers

– **Great future for Cu developments and applications :**

- **Earth atmosphric science measurements measurements , net work of 3 CU with S band , IMS's , LP, Fipex, ( Lessons learned from QB50)**
- **In Orbit Demonstrations for technologies such as nano propulsion, debris mitigation, sensors, sloshing, camera's,**
- **Im Orbit demo of systems such as R&V and docking, formation flying, inspections, network communications, cloud computaions**
- **Planetary entry , Exploration flights**
- **Space station retrieval system , Micro G and reentry**
- **Dual use , science piece and security ( NATO SPS)**
- **United Nations environmental monitoring**

# Next Steps


- www.CubeSatSymposium.eu
  - Abstract submission: 15 Mar 2013
  - 6 June 2013: 6th QB50 Workshop at VKI, Brussels

# ACKNOWLEDGEMENT

**The QB50 Project, and all related activities are supported by the European Community Framework Programme 7, Grant Agreement no. 284427**