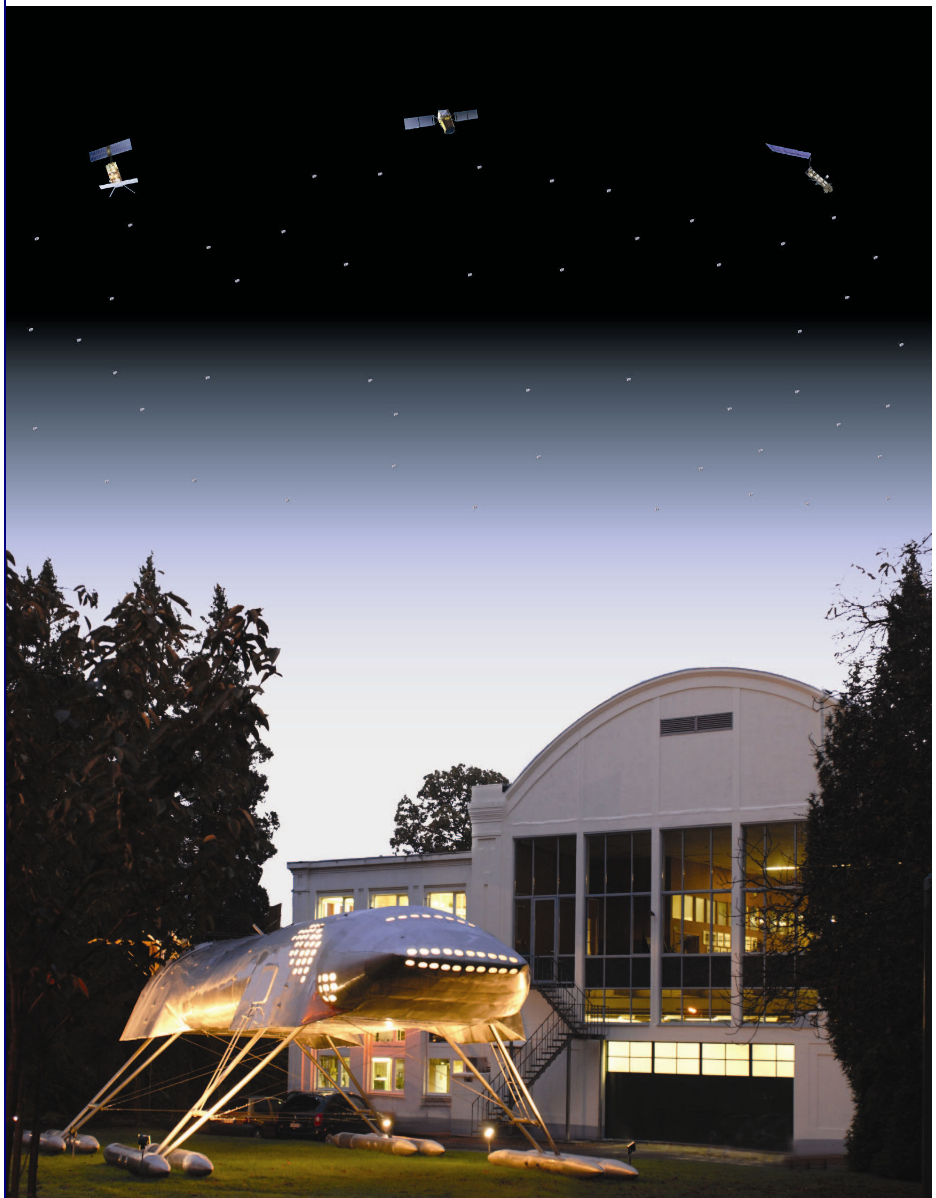


QB50

An international network of *50* double CubeSats for **multi-point, in-situ, long-duration** measurements in the lower thermosphere and for re-entry research

J. Muylaert, R. Reinhard, C. Asma

7th CubeSat Developers' Workshop
Cal Poly San Luis Obispo
21-23 Apr 2010

von Karman Institute for Fluid Dynamics

QB50 - THE IDEA

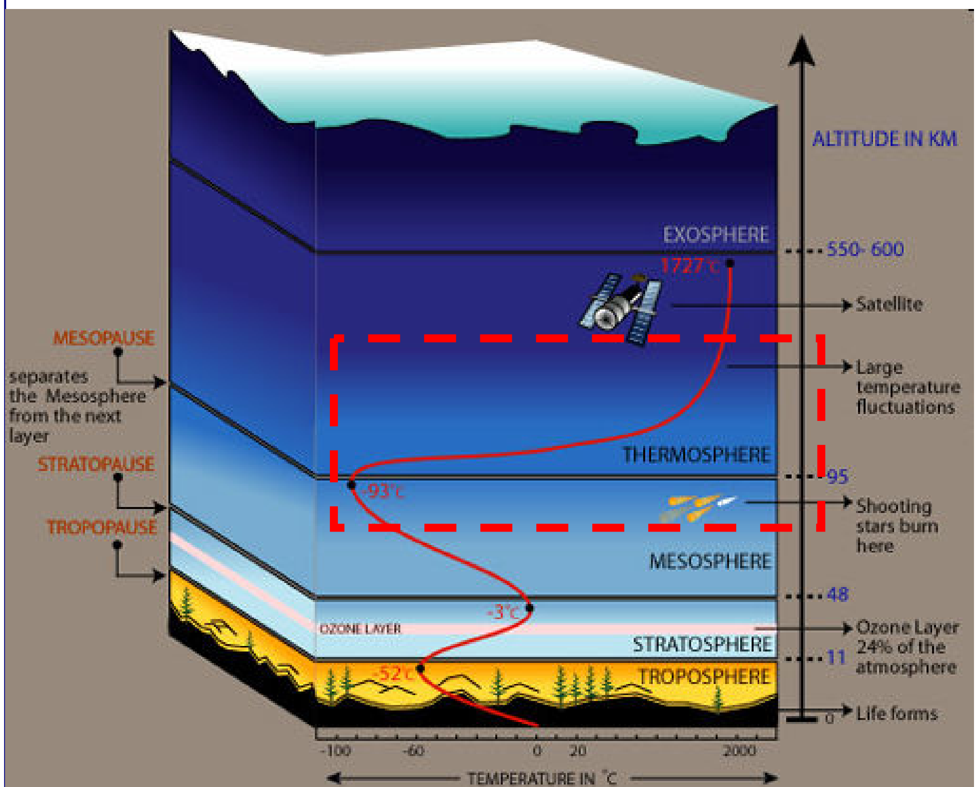
- A network of *50 double CubeSats* sequentially deployed

(1 CubeSat every orbit or every 2 or 3 orbits)

- Initial altitude: 330 km (circular orbit, i=79°)
- Each performing in-situ measurements of atmospheric parameters
- Downlink using the Global Educational Network for Satellite Operations (*GENSO*)

QB50 – Studying Lower Thermosphere

90 – 330 km: Why Lower Thermosphere?



- The ***least explored*** layer of the atmosphere
- Stratospheric balloons go up to 42 km max.
- Remote-sensing by ground based lidars and radars up to 105 km.
- Remote-sensing by Earth observation satellites in higher orbits (600 – 800 km) only observe constituents in the troposphere, stratosphere and mesosphere (lower thermosphere is too rarefied).
- In-situ measurements by sounding rockets in the mesosphere and lower thermosphere (MLT Region) provide only occasional (a few times per year) single-line measurements

QB50 – Studying Lower Thermosphere

A network of 50 CubeSats in the lower thermosphere compared to networks in higher orbits **has the following advantages**:

•The ***lifetime*** of a CubeSat in the envisaged low-Earth orbit will only be three months, i.e. much less than the 25 years stipulated by international requirements related to space debris

•A low-Earth orbit allows ***high data rates*** because of the short communication distances involved

•In their low-Earth orbits, the CubeSats will be below the Earth's ***radiation belts***, which is very important because CubeSats use low-cost Commercial-Off-The-Shelf (COTS) components

On all other missions CubeSats are a secondary payload, on QB50 the CubeSats are the **primary** payload.

The residual atmosphere at orbital altitude helps in three ways

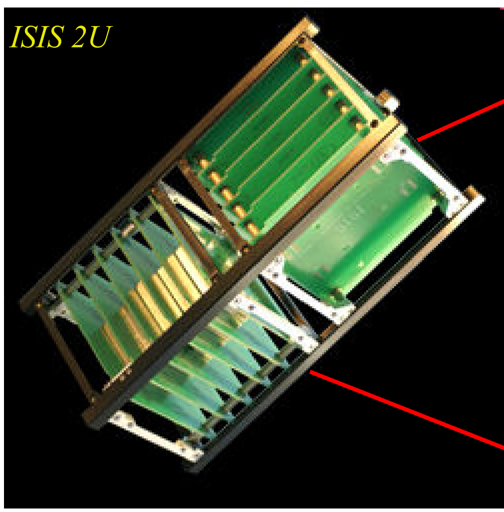
- Due to atmospheric drag, the orbits of the CubeSats will decay and progressively **lower and lower layers of the thermosphere will be explored** without the need for on-board propulsion, from 330 perhaps down to 90 km.

- Depending on the deployment velocity (which can be selected in the range 1 to 5 m/s) and the deployment sequence (one CubeSat every orbit or every two or three orbits), the initial separation between individual CubeSats in the network will be between a few tens and a few hundred km. Due to density variations along the orbit the separation distance will change, eventually leading to a non-uniform distribution of CubeSats all the way around the Earth. In this way, the CubeSats will be able to explore **temporal and spatial variations over a wide range of scale sizes**, from a few tens of km in the beginning to about 1000 km after a month.

- A deliberate small centre-of-mass/centre-of-pressure offset in the CubeSats will dampen the inevitable minor tumbling of the CubeSats after deployment and will eventually (after many orbits) lead to a **stable attitude as required by some atmospheric sensors**. Other attitude stabilization techniques making use of the residual atmosphere could also be considered. Such techniques would be applied in addition to magnetorquers and reaction wheels.

QB50 - THE IDEA

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



Science Unit:

Lower Thermosphere Measurements

Sensors to be selected by a Working Group

Standard sensors for all CubeSats

Functional Unit:

Power, CPU, Telecommunication, IMU, GPS

Optional Technology or Science Package

Universities are free to design the functional unit

QB50 – Sensor Selection

Mission objective: to make multi-point, in-situ measurements of the neutral component in the lower thermosphere

Examples for sensors/instruments:

- *FIPEX sensor for measurement of atomic oxygen*
- *Atmospheric density measurements*
- *Miniaturized neutral mass spectrometer*
- *Accelerometers*
- *Gyroscopes*
- *Thermocouples / Thermistors / Resistance temperature detectors*
- *GPS*

Selection of the standardized sensors for in-situ measurements will be made by the ***Sensor Selection Working Group*** *(SSWG) in 2010*

QB50 – Orbital Dynamics

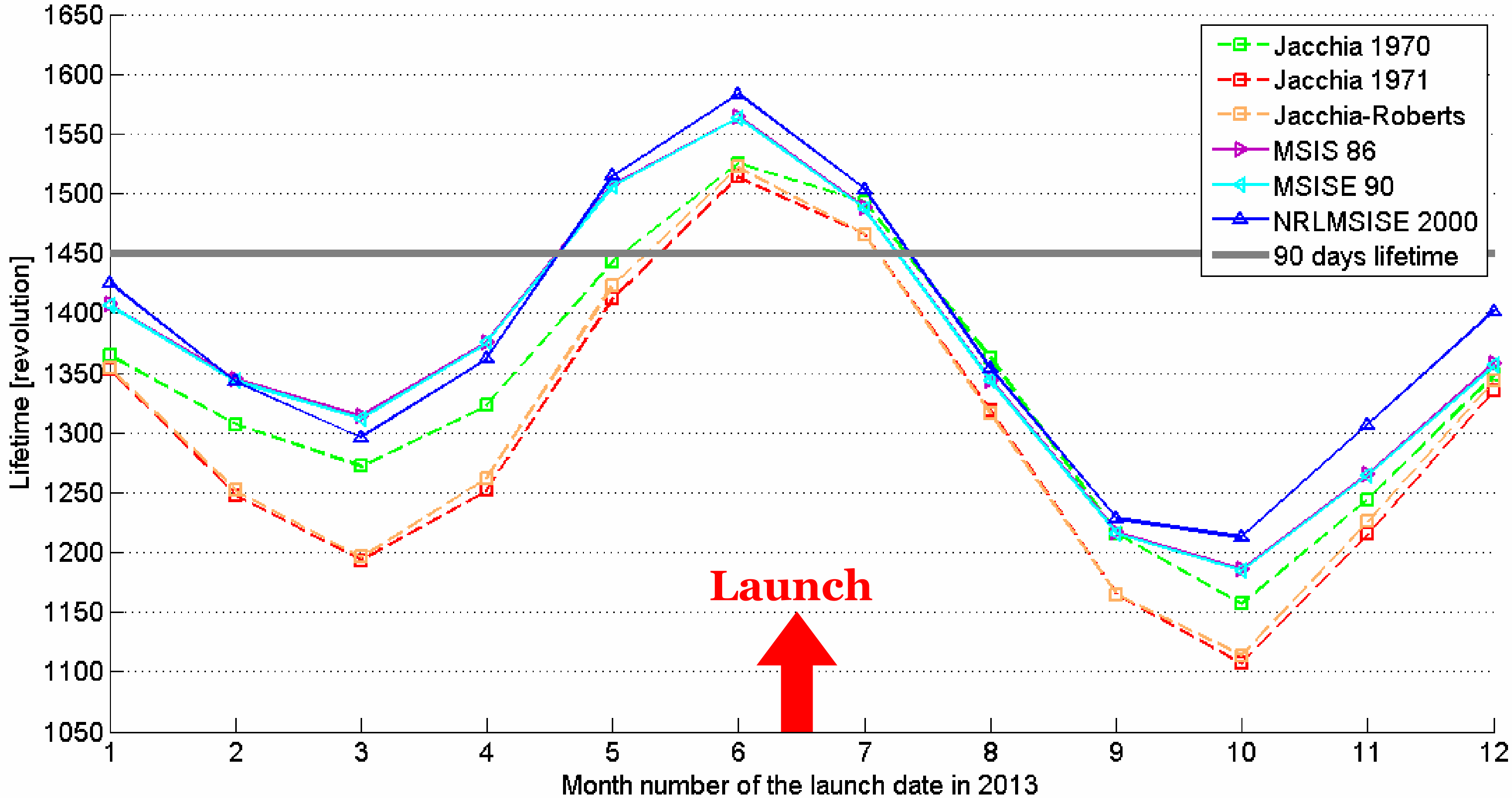
To be determined:

- *Initial orbital altitude (present assumption 330 km) to ensure minimum lifetime of 3 months*
- *Separation speed (present assumption in the range 1 to 5 m/s)*
- *Should the CubeSats be deployed in flight direction, anti-flight direction, upward, downward, east or west direction?*
- *Deployment sequence (1 CubeSat per orbit or 1 CubeSat every 2 or 3 orbits?)*
- *Which atmospheric models should be used (present assumption several different models)*
- *Which trajectory simulation software should be used?*
- *Which drag coefficient should be used (probably a range of coefficients)*

These questions will be addressed by the ***Orbital Dynamics Working Group*** *(ODWG)*

QB50 – Orbital Dynamics

Lifetime prediction at h_0 = 335 km



The intention is to provide **free-of-charge**

for the participating CubeSat teams the

- launch vehicle
- custom-designed deployment system
- standardized sensors for the science unit
- launch services and interfaces to the launch vehicle authorities
- environmental testing at ESTEC (if requested)
- transport of the 50 CubeSats from ESTEC to the launch site
- CubeSat checkout testing during the launch campaign

SHTIL 2.1

This is very attractive to the CubeSat community and there is a lot of interest to participate in QB50. Letters of Intent (LoI) from interested universities are now coming in (**32** already received).

QB50 – CubeSat Community

2 Austria	2 Netherlands
2 Belgium	1 Norway
1 Czech Republic	1 Poland
2 Denmark	1 Portugal
1 Estonia	1 Romania
1 Finland	3 Spain
3 France	1 Sweden
3 Germany	2 Switzerland
1 Greece	3 United Kingdom
1 Hungary	**10 USA**
1 Ireland	2 Canada
3 Italy	2 Japan

50 CubeSats

This table is not an 'allocation', it is only an 'assumption' for planning purposes.

The final selection of the 50 CubeSats (plus 5 backup) will be made in November 2010, based on proposals by the CubeSat teams submitted in response to a Call for Proposals.

Letters of Intent have also been received from universities in the following countries :

Australia

Chile

China

Peru (a collaboration of 5 universities)

Puerto Rico

Taiwan

Vietnam

Likely participation also by universities in the following countries:

Egypt

India

Israel

Russia

South Africa

Turkey

Selected CubeSat teams are required to

- *Supply the required documentation in a timely manner*
- *Participate in major project reviews*
- *Support the test campaign (but not the launch campaign)*
- *Operate their CubeSats in orbit (expected lifetime is ~3 months)*
- *Provide calibrated science and selected housekeeping data within 6 – 9 months to the QB50 Data Processing Center at VKI*
- *Secure the funding for the development of their CubeSat*

The von Karman Institute (VKI) will provide:

- *Identification of the* ***funding sources*** *for the launch vehicle,*
- *Management of the interface to the* ***launch vehicle authorities****, including management of the launch campaign,*
- *Support for the selection of the* ***standardized sensors*** *for lower thermosphere and re-entry research to be used on board the CubeSats,*
- *Detailed* ***orbital dynamics*** *calculations, using a variety of trajectory simulation software tools and atmospheric models, and comparison of model predictions with actual CubeSat re-entry data,*
- *Provision of a* ***CubeSat*** *to the QB50 Network (Re-EntSat),*
- *Management and funding of the QB50* ***Data Processing Centre****,*
- *Organization of the annual* ***QB50 Workshops****,*
- *Installation and management of the VKI Ground Station*
- *Maintenance of the QB50 website:* ***http://www.vki.ac.be/QB50***

QB50 – Management

***QB50 Steering Group** (20 members)*

- *Top - level management body*
- *Composition*
  - *A few CubeSat PIs*
  - *A few atmospheric physicists/chemists*
  - *Space agency representatives*
  - *QB50 Project Manager*

***Orbital Dynamics Working Group (ODWG)** (15 members)*

- *Defines deployment sequence and speed*
- *Defines initial orbital altitude (which determines the lifetime)*
- *Compares simulated trajectories with actual trajectories*
- *During the mission, initial acquisition of the CubeSats and determination of their orbital parameters as f(t)*
- *Composition*
  - *Atmospheric modeling experts*
  - *Trajectory simulation software experts*
  - *Orbital dynamics experts from D/OPS and D/TEC*

QB50 – Management

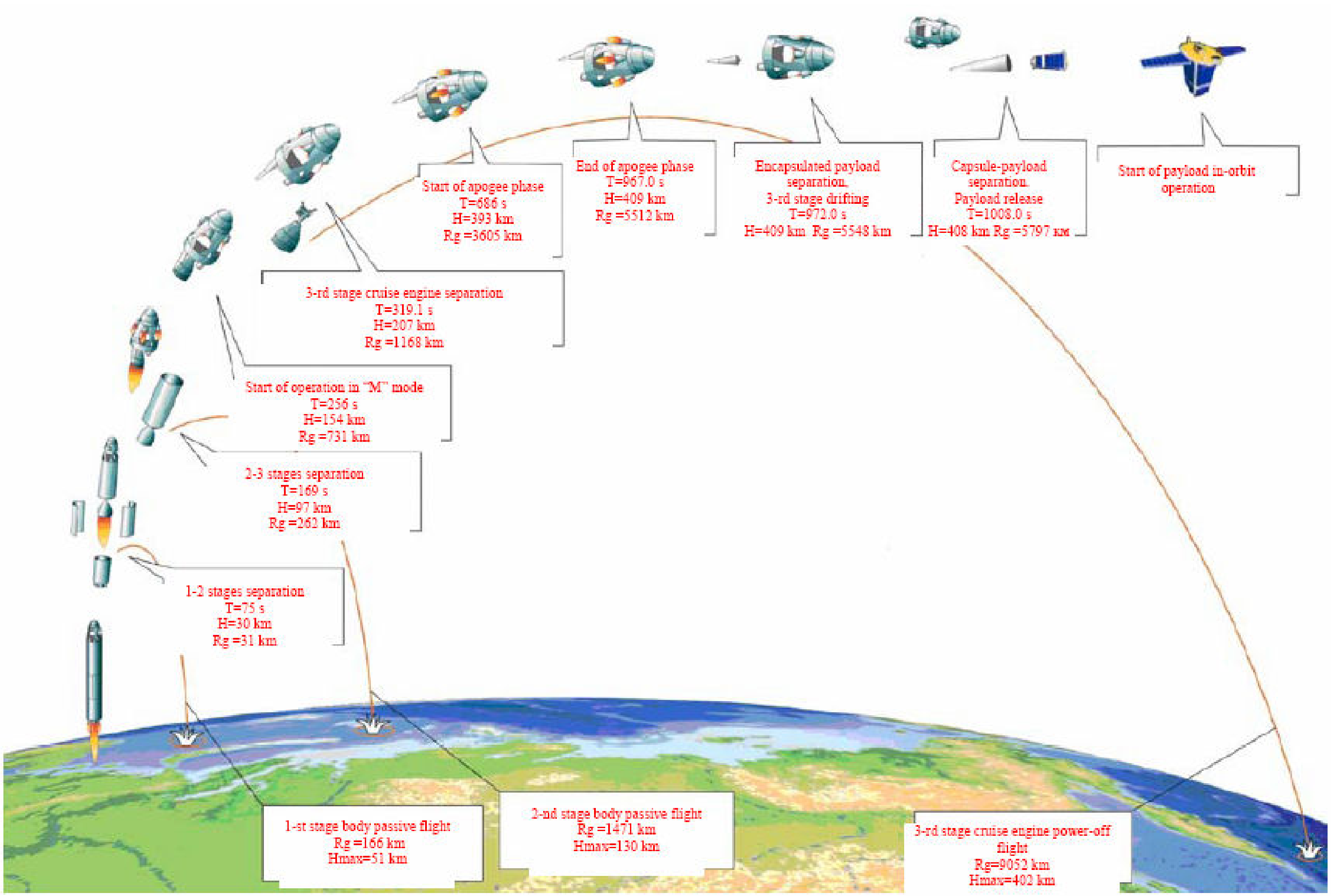
***Sensor Selection Working Group (SSWG)** (15 members)*

- *Defines exactly what should be measured*
- *Sensor selection (starting with a list of ~20 sensors and then gradually narrowing that down to 3 -5 sensors, including scientific priority and volume, mass, power, field of view and data rate requirements)*
- *Composition*
  - *A few CubeSat PIs*
  - *A few atmospheric physicists/chemists*
  - *Experts for in-situ instruments for atmospheric research*
  - *D/EOP representatives*

***Ground station network and Frequency allocation Working Group (GFWG)** (15 members)*

- *Interface to the Global Educational Network for Satellite Operations (GENSO)*
- *Selection of frequency band (UHF / VHF or S–band)*
- *Ground station coverage / GENSO interface*
- *Preparation of request for frequency allocation*

QB50 – Launching & Deployment



SHTIL 2.1

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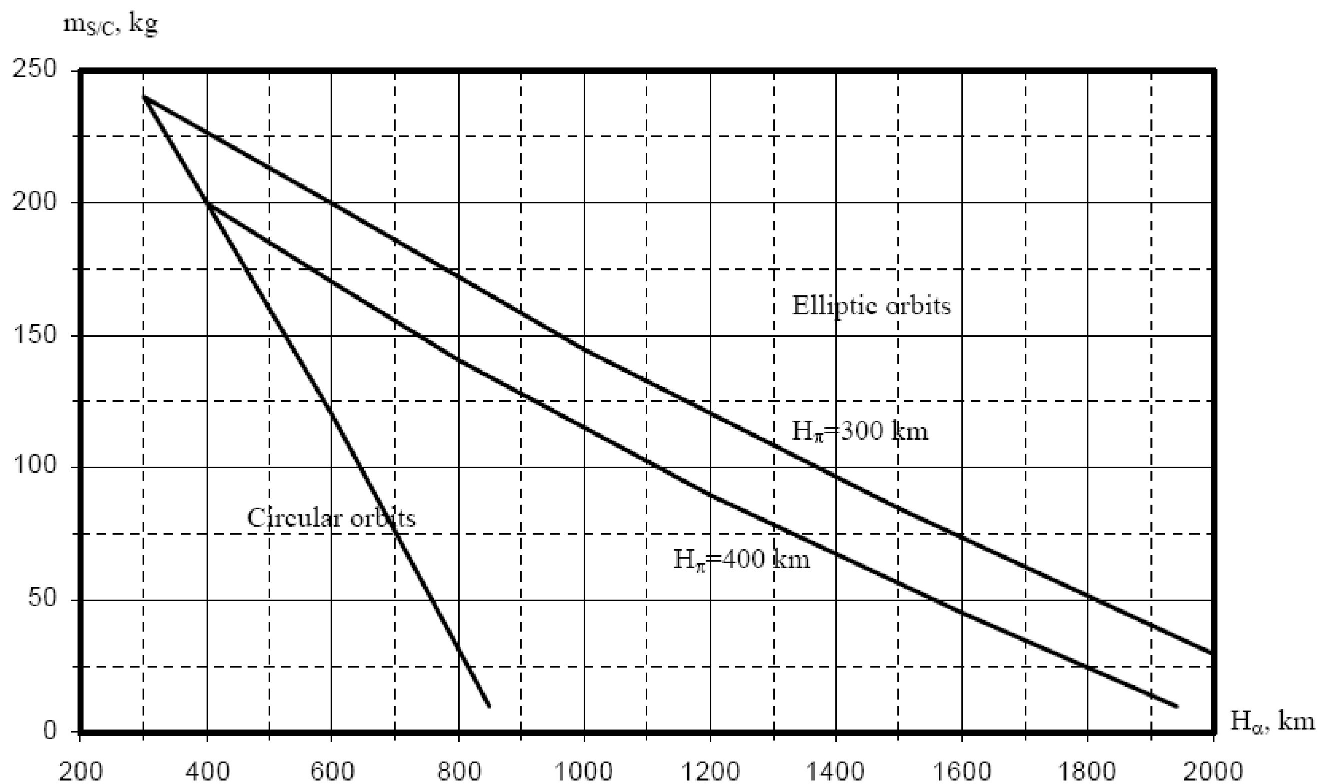
QB50 – Mass Allocation

50 Double CubeSats	100 kg
Deployment system (including margin)	100 kg
Solar sail package (including margin)	23 kg
	223 kg

QB50 – Launching & Deployment

The payload mass versus the altitude of an orbit inclined 78.9°

(above the mean Earth radius R_{mean}=6371 km)



SHTIL 2.1

QB50 – CubeSat Accommodation

Platform 1:

A platform of 840 mm diameter

6 Double-CubeSats

and a solar sail technology demonstration mission package (45 x 45 x 50 cm^3)
19 kg + 4 kg margin

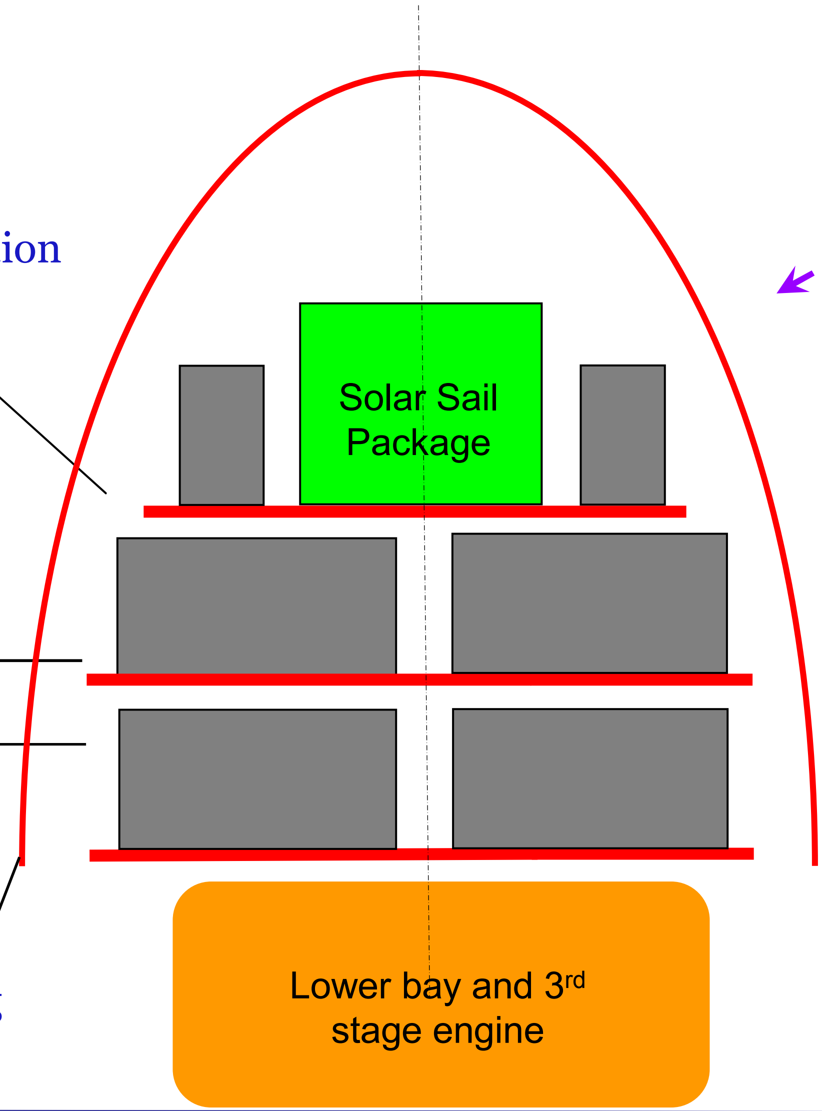
Platform 2 & 3:

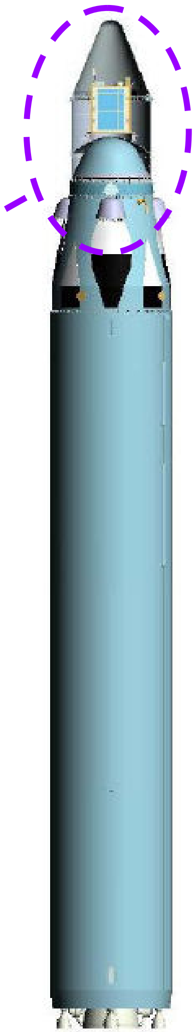
A platform of 1000 mm diameter

22 2U-CubeSats on upper platform

22 2U-CubeSats on lower platform

Fairing





SHTIL 2.1

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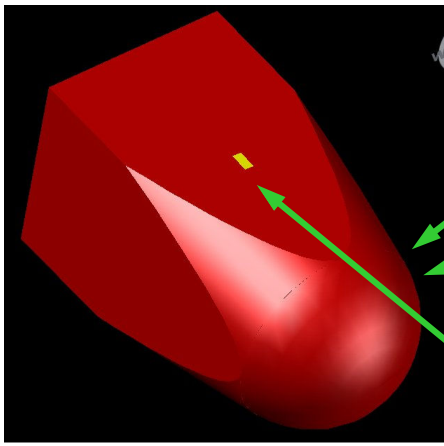
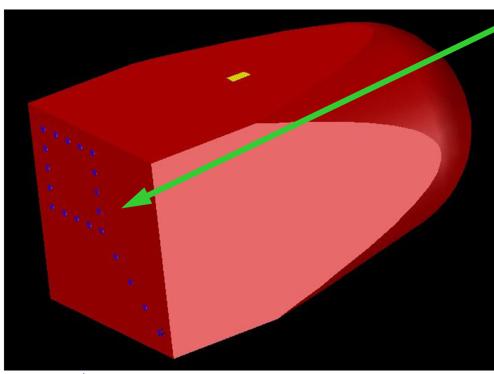
VKI Re-EntSat – Concept

Atmospheric Re-Entry Flight Data

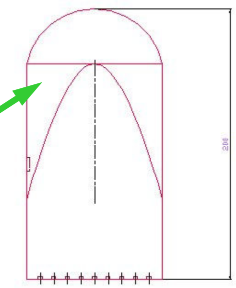
Flight data for Debris/Disintegration Tool (RAMSES) Validation

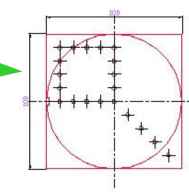
Re-EntSat to survive until ~70 km altitude





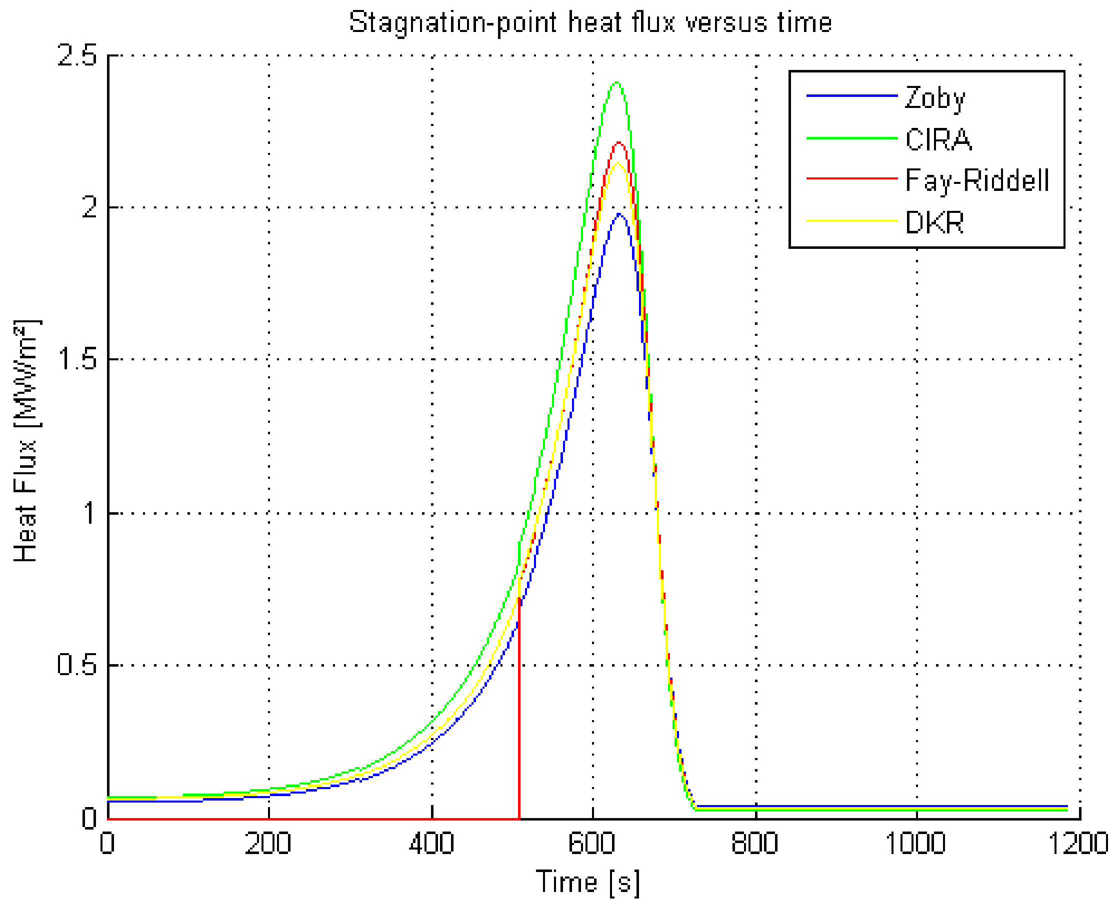
- Light ablative material as thermal shield
- Temperature & Pressure measurements on the thermal shield
- Skin friction measurements on the side
- Base flow measurements
- Materials experiment (tbc)
- Blackout experiment (tbc)





VKI Re-EntSat – Analysis

Stagnation point heat flux estimation by CADAC software for a 2U CubeSat



Worst case scenario: Peak stagnation point heat flux is 2400 kW/m^2

QB50 – Schedule

17-18 Nov 2009	*First QB50 Workshop at VKI*
13 Sep 2010	*Issue by VKI of the Call for Proposals for QB50 CubeSats*
1 Nov 2010	*Deadline for submission of CubeSat proposals to VKI, including letters of funding*
1-15 Nov 2010	*Proposal clarification period*
15-22 Nov 2010	*Evaluation of proposals by a Selection Committee and recommendation of selection of 50 CubeSats + 5 backup CubeSats*
24 Nov 2010	*Selection of 50 + 5 CubeSats by the QB50 Steering Group*
29 Nov 2010	*Notification of selection to CubeSat PIs*
11 Oct 2010	*Meeting of the SSWG at VKI*
18 Oct 2010	*Meeting of the ODWG at VKI*
25 Oct 2010	*Meeting of the GFWG at VKI*
3 Feb 2011	*09:00 – 16:00, Second QB50 Workshop at VKI*
3 Feb 2011	*16:00 – 20:00, Parallel meetings of the SSWG, ODWG and GFWG*
4 Feb 2011	*09:00 – 12:00, Parallel meetings of the SSWG, ODWG and GFWG*
4 Feb 2011	*13:00 – 17:00, Steering Group meeting*

Schedule for selected CubeSats

Jan 2011-Dec 2012	*CubeSat development at universities*
Sep 2011	*Shipment of the standardised sensors for atmospheric research from ESTEC to universities*
Nov 2012	*CubeSat mass dummies delivery to ESTEC*
Jan-Feb 2013	*CubeSat flight models environmental testing at universities*
Mar 2013	*CubeSat flight models delivery to ESTEC*

Launch associated activities

Mar 2013	*Launch campaign preparation workshop at ESTEC*
Apr 2013	*Shipment of CubeSat flight models to the launch site*
May-Jun 2013	*Launch campaign*
End Jun 2013	***Launch***

CubeSat Symposium

31 January – 2 February 2011

Ecole Royale Militaire, Brussels

www.vki.ac.be/CubeSatSymposium

Important Dates:

11 Oct 2010	*Deadline for the submission of abstracts*
8 Nov 2010	*Notification of acceptance*
13 Dec 2010	*Publication of the programme and the abstracts*
17 Jan 2011	*Deadline for online registration*
31 Jan-2 Feb 2011	*CubeSat Symposium*

Registration fee: 100 € (this includes 3 lunches and all coffee breaks)

CubeSat Symposium Topics/Sessions

Scientific instruments/sensors on CubeSats

Biology experiments on CubeSats

Technology demonstration on CubeSats

CubeSat networks/constellations/swarms

Micro-propulsion subsystems, formation flying

Attitude determination and control

Telecommunications, ground stations and ground station networks

Orbital dynamics for CubeSats

CubeSat flight experience, lessons learned

Other topics (e.g. expandable solar arrays, atmospheric re-entry, CubeSats as free-flying payloads for the exploration of the Solar System)

Future technologies on CubeSats

Deployment systems

Small companies specialized in CubeSats

To avoid a large number of rather similar CubeSat presentations, authors should not attempt to describe all aspects of their particular CubeSat design in a 15-minute presentation. Instead, they should focus on the most interesting/novel aspect of their CubeSat design and describe that in some depth. If a CubeSat design has several novel aspects, several papers on that particular CubeSat, each focusing on a different novel aspect, may be submitted and would be given in different sessions. When submitting a paper, authors are requested to select the session that is the most appropriate for their presentation.