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UniCubeSat

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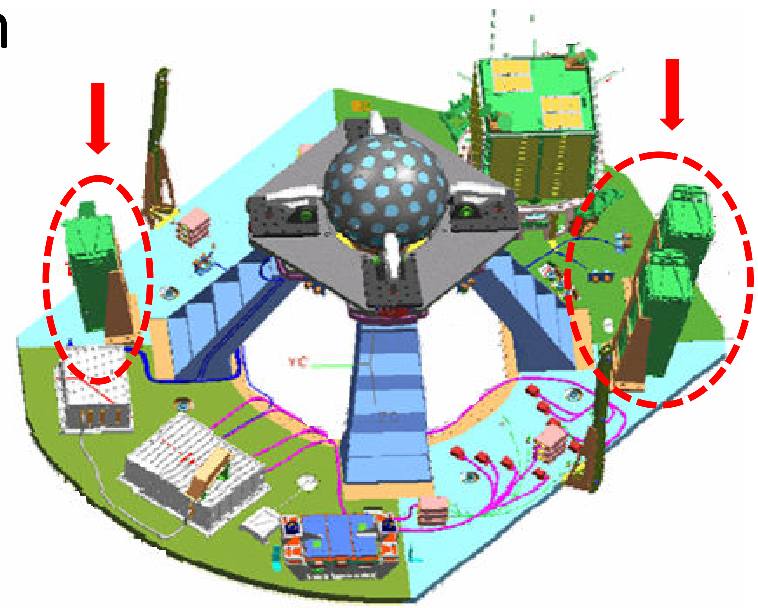
SCUOLA DI INGEGNERIA AEROSPAZIALE

A GAUSS Cubesat: UniCubesat

- Experience in designing and manufacturing small satellites since early nineties.
- In 2007 UniCubesat was selected by ESA for a free launch with the VEGA maiden flight.
- Launch was initially scheduled for 2008, but it is actually planned for 2011

VEGA maiden flight

- The Vega Maiden Flight will host nine cubesats from several European universities together with its primary payload, LARES experiment
- Cubesats are deployed in groups of 3, using 3 P-PODs installed on LARES platform
- Mission details:
  - 340x1447 km orbit, 71° inclination
  - no attitude control during Cubesats deployment



UniCubesat main subsystems

- Power:
  - Triple junction solar cells (efficiency 27% - maximum power provided by each panel 2.3 W)
  - Lithium Polymer batteries
- Communication
  - UHF radio (436.8MHz)
  - Deployable antenna
- Attitude control:
  - Spin + magnetic control (two magnetorquers)

Attitude control system

- Satellite spin rate determines the natural frequency of the measurement
  - We have to control spin rate
- Attitude has to be controlled in the direction of motion
  - We have to control the attitude in the direction of motion
- A magnetic control is used

Attitude control system

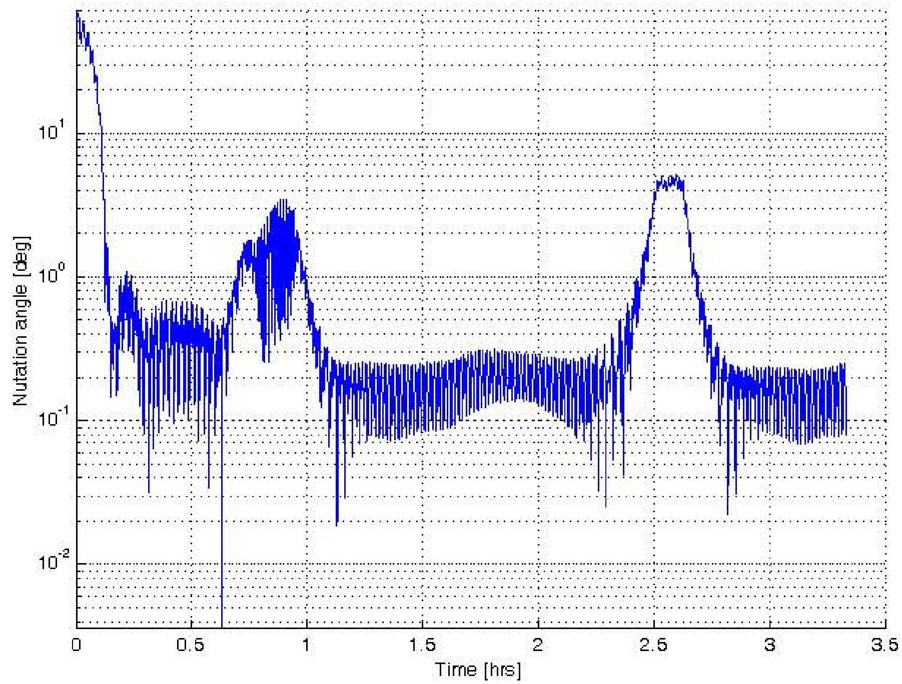
- The control system is composed by
  - Two magnetorquers: one along the spin axis, the other perpendicular

LVLH Frame	WIRE MATERIAL	RESISTIVITY (Ohm/m)	WIRE DIAMETER (mm)	Wire Area (mm2)	PERIMETER (m)	COIL AREA (m2)	SPIRE NUMBER (n)	Length (m)	RESISTANCE (Ohm)	SUPPLY VOLTAGE (V)	CURRENT (A)	POWER (W)	DIPOLE MOMENT (A*m2)	Weight (g)
coil	Copper AWG 32	0,538	0,202	0,032	0,36	0,0081	400	144	77,472	4	0,0516	0,207	0,1673	41,1
coil	Aluminum AWG 30	0,554462	0,254	0,0509	0,36	0,0081	400	144	79,84251	4	0,0501	0,2	0,1623	19,79

  - One magnetometer

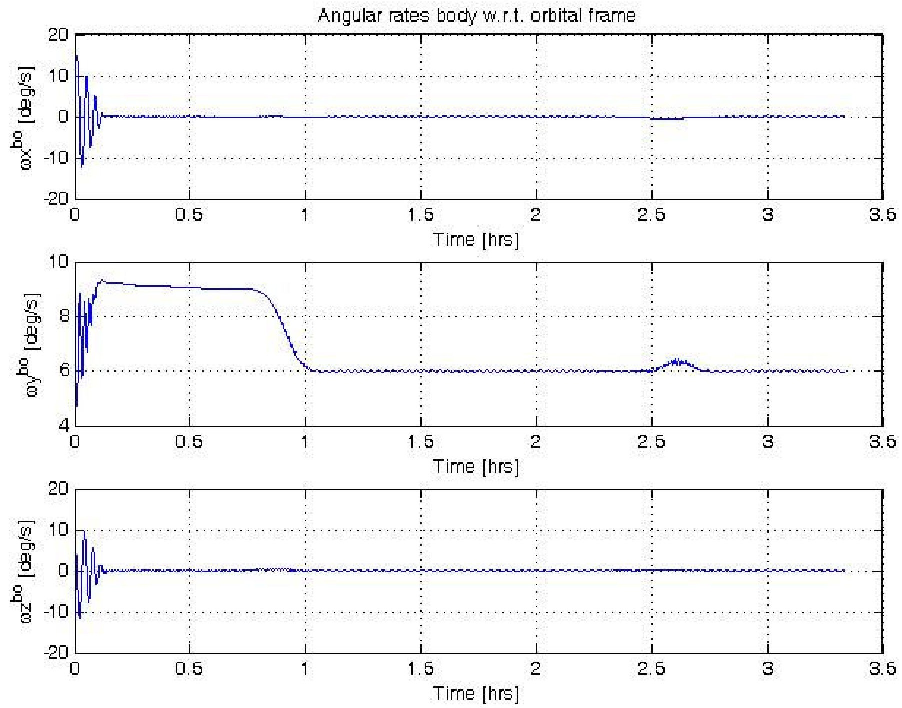
Simulation results

- Nutation angle is at maximum 5°



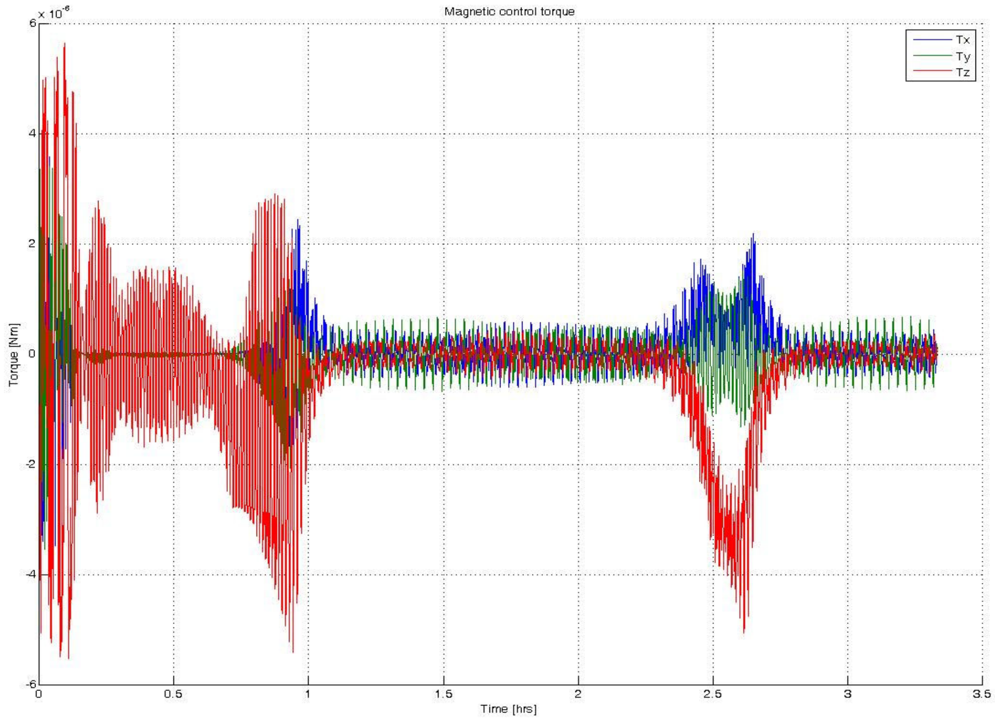
Simulation results

- Angular rates are null, apart from that on the spin axis



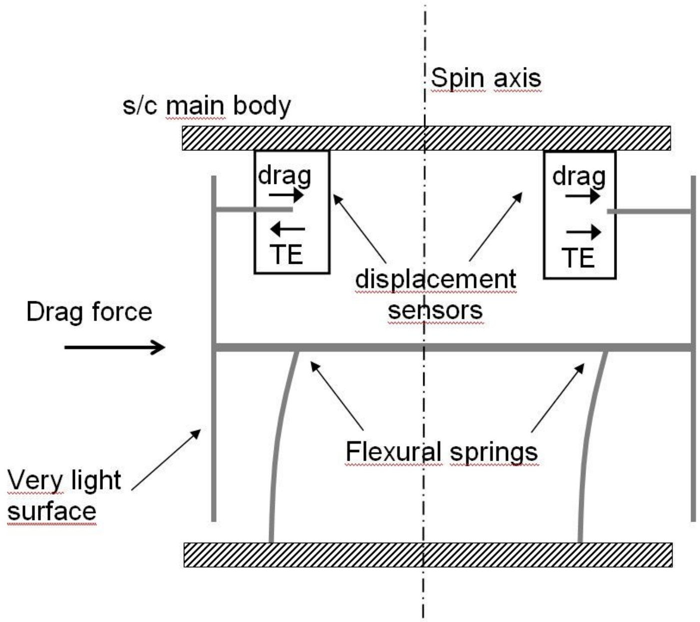
Simulation results

- Generated torque on the three axis



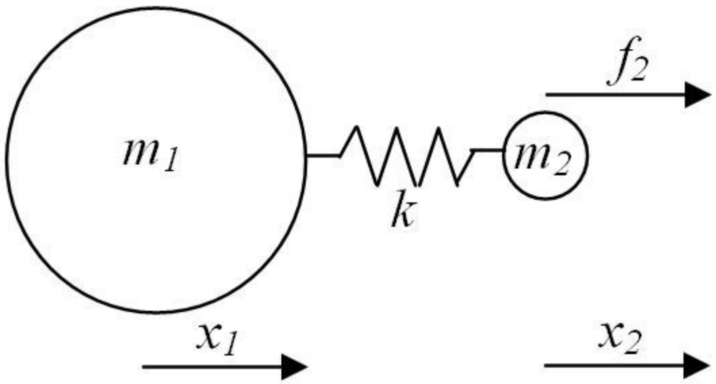
UniCubesat main payload

- UniCubesat main payload is the miniaturized version of the Broglio's balance
- Broglio's balance was implemented on San Marco satellites (1964-88)
- Low orbit allows to conduct even other atmospheric measurements



UniCubesat main payload

- The Broglio theory



$$m_1\ddot{x}_1 = -k(x_1 - x_2) + m_1 g$$
$$m_2\ddot{x}_2 = k(x_1 - x_2) + m_2 g + f_2$$

$$x = (x_1 - x_2)$$

$$k\left(\frac{1}{m_1} + \frac{1}{m_2}\right)x = \frac{f_2}{m_2} \quad \Rightarrow \quad x = \frac{m_1}{m_1 + m_2}\frac{f_2}{k}$$

$$m_1 >> m_2 \Rightarrow x \simeq \frac{f_2}{k}$$

Broglio Drag balance (dynamometer concept)

$$m_1 << m_2 \Rightarrow x \simeq \frac{m_1}{m_2}\frac{f_2}{k}$$

Traditional accelerometer concept

Other atmospheric measurements

- Ionosphere is the main source of error for GPS range measurements
- Signal delay is caused by free electrons in the ionosphere layers

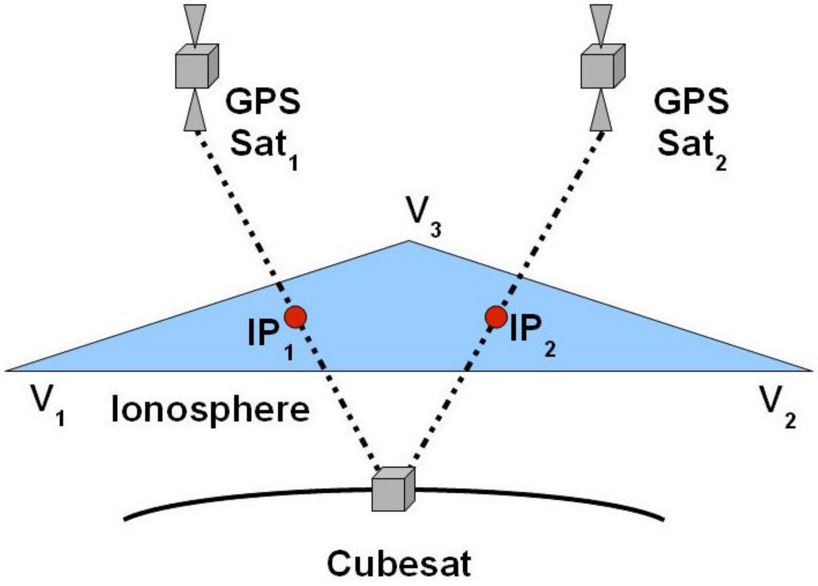
$$vTEC = \frac{1}{F(E)} \int N_e ds$$

- An evaluation of ionospheric delay on GPS signal is given by

$$\text{Iono delay} \equiv I \approx F(E) \cdot \left(\frac{1}{f^2} \cdot 40{,}31 \cdot vTEC \right)$$

Mapping the ionosphere

- GPS signals to cubesat receiver intersect ionosphere in IP points (cubesat altitude between 300 and 500 km)
- The idea is to build a grid over the ionosphere and to map the delays in the nodes of the grid
- With a sufficient number of range measurements iono delays can be evaluated



Processing raw code-range measurements

- GPS code-range measurements are affected by several errors:

$$\tilde{\rho} = \rho + c(dT_r - dT^e) + I + T + B_r + B^e$$

$\tilde{\rho} = \text{actual measure} \quad \rho = \text{'true' range} \quad c\left(dT_r - dT^e\right) = \text{time bias}$

$I, T = \text{iono and tropo delays} \quad B_r, B^e = \text{receiver and emitter biases}$

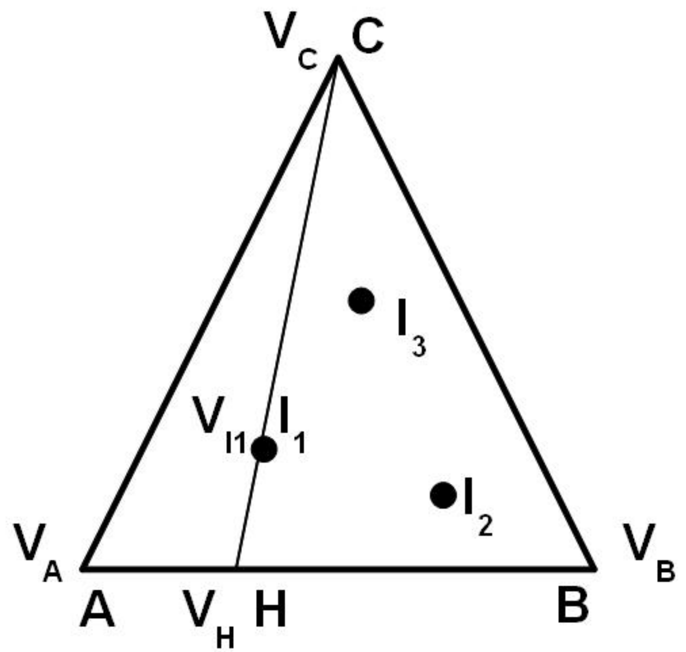
- One can isolate the term referring to iono delay

Interpolating iono terms

- Express iono delay values in terms of delay in vertices

$$I_1 = \frac{\overline{CI_1}}{\overline{CH}} V_H - \frac{\overline{HI_1}}{\overline{CH}} V_C$$

where $$V_H = \frac{\overline{AH}}{\overline{AB}} V_B + \frac{\overline{HB}}{\overline{AB}} V_A$$



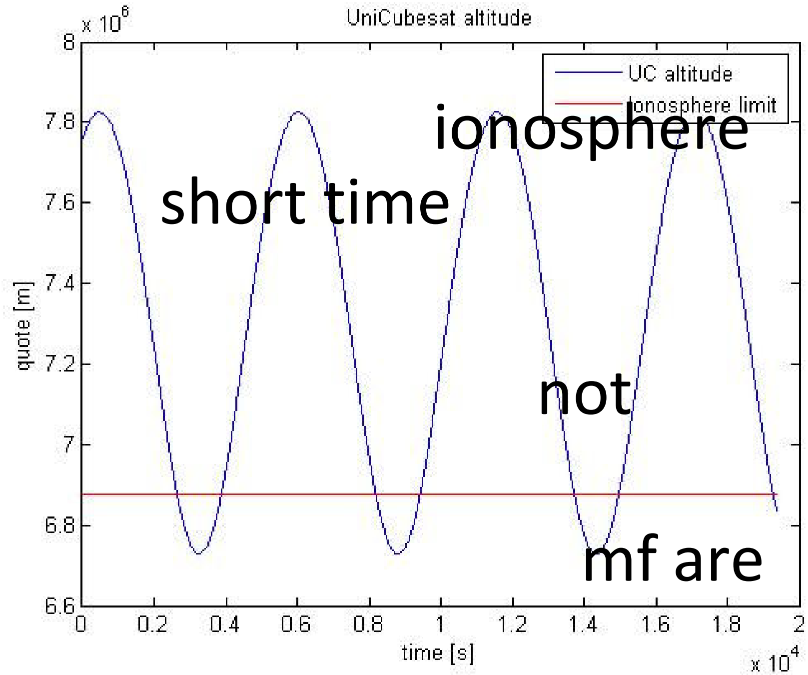
- Every measure adds a line to the matrix **M**

$$I = M(\varphi,\lambda)\cdot V \Rightarrow$$
$$V = M(\varphi,\lambda)^{-1}\cdot I$$

φ, λ = longitude and latitude of IP points

Critical aspects of the experiment

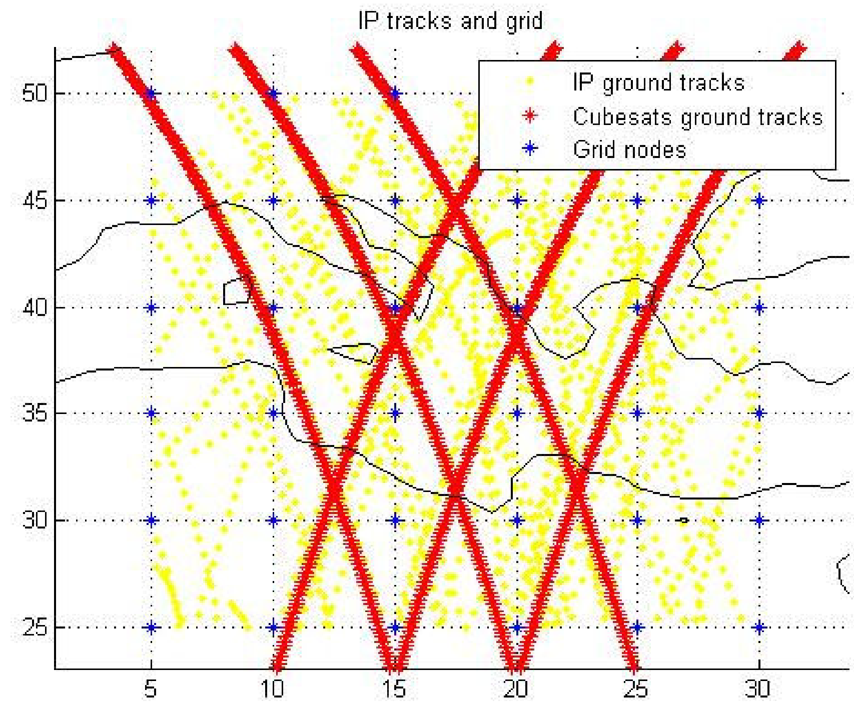
- Orbit is eccentric:
  - UniCubesat is below the ionosphere only for a short time
- More measurements needed:
  - Using only UniCubesat is not enough
  - Nine cubesats from VEGA mf are too close to one another



- Need for more heterogeneous measurements

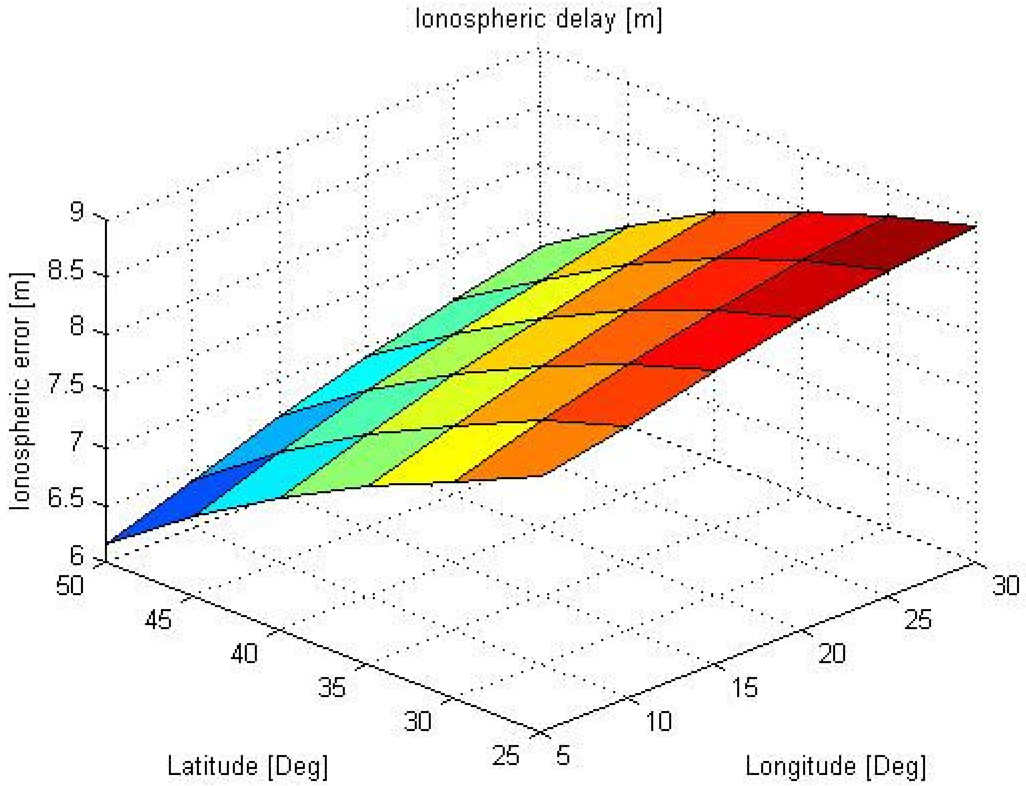
A possible configuration

- 6 Cubesats divided in 2 clusters of 3 satellites with different argument of perigee
- Circular orbits with a quote of 350 km (VEGA mf perigee quote)
- The number of measures (yellow points on the map) is sufficient



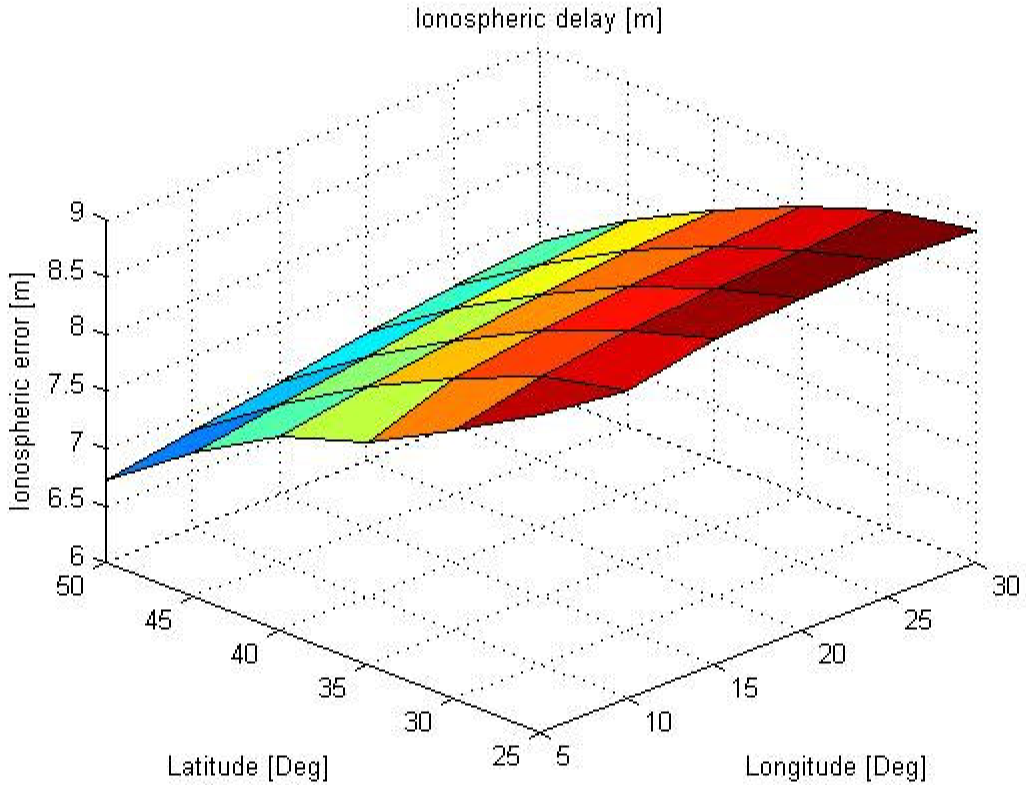
Estimated Ionospheric delay

- 11:00 am – 12:00 am



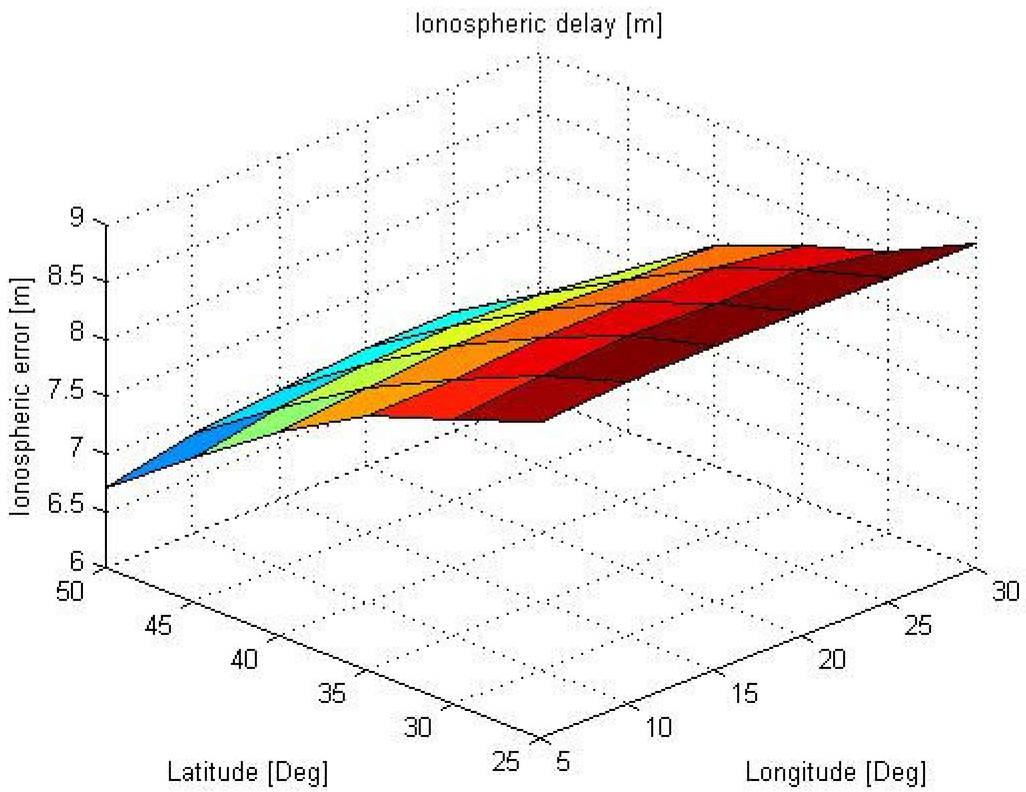
Estimated Ionospheric delay

- 12:00 am – 1:00 pm



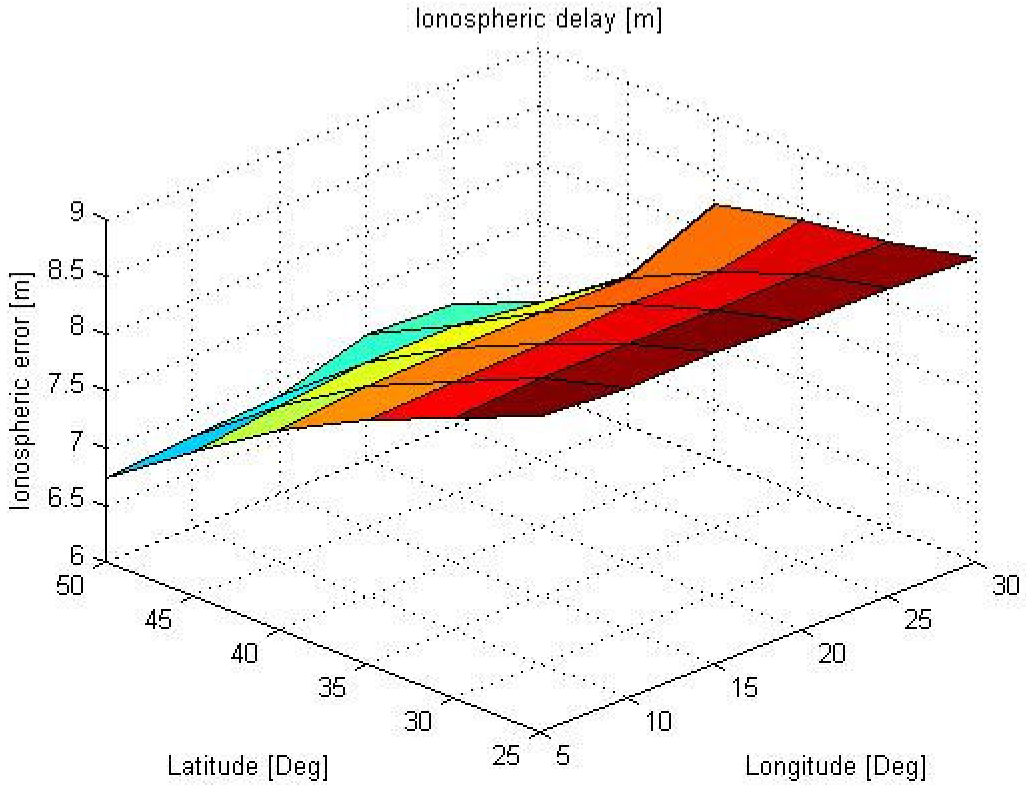
Estimated Ionospheric delay

- 1:00 pm – 2:00 pm



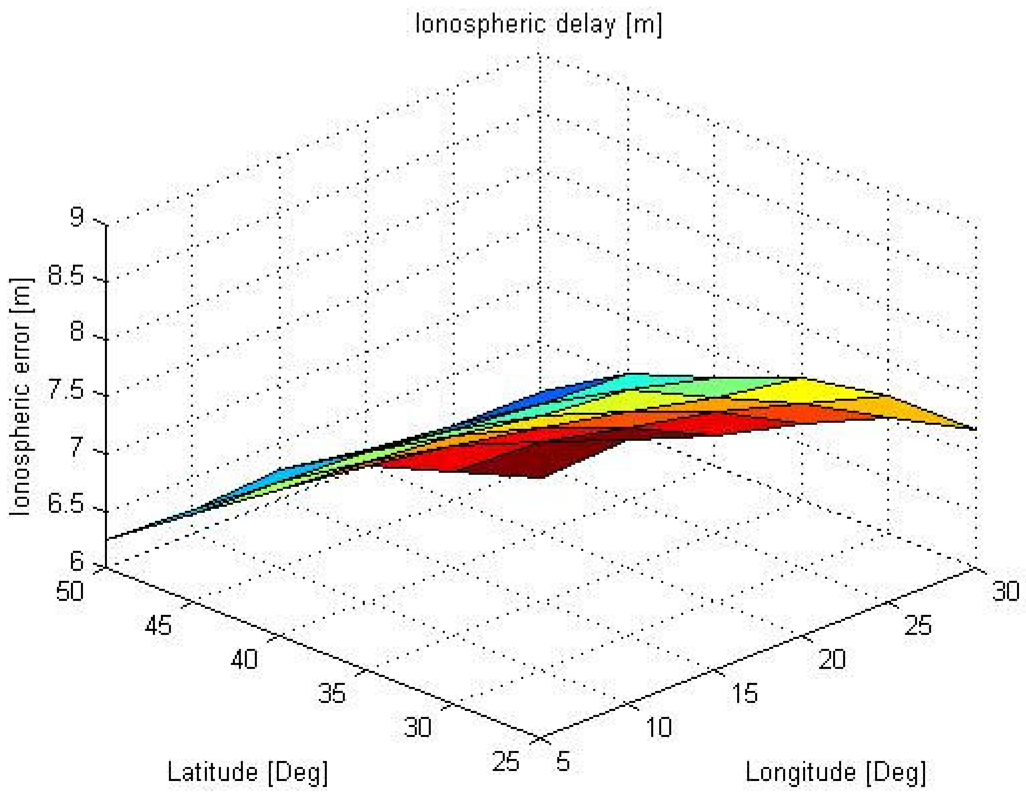
Estimated Ionospheric delay

- 2:00 pm – 3:00 pm



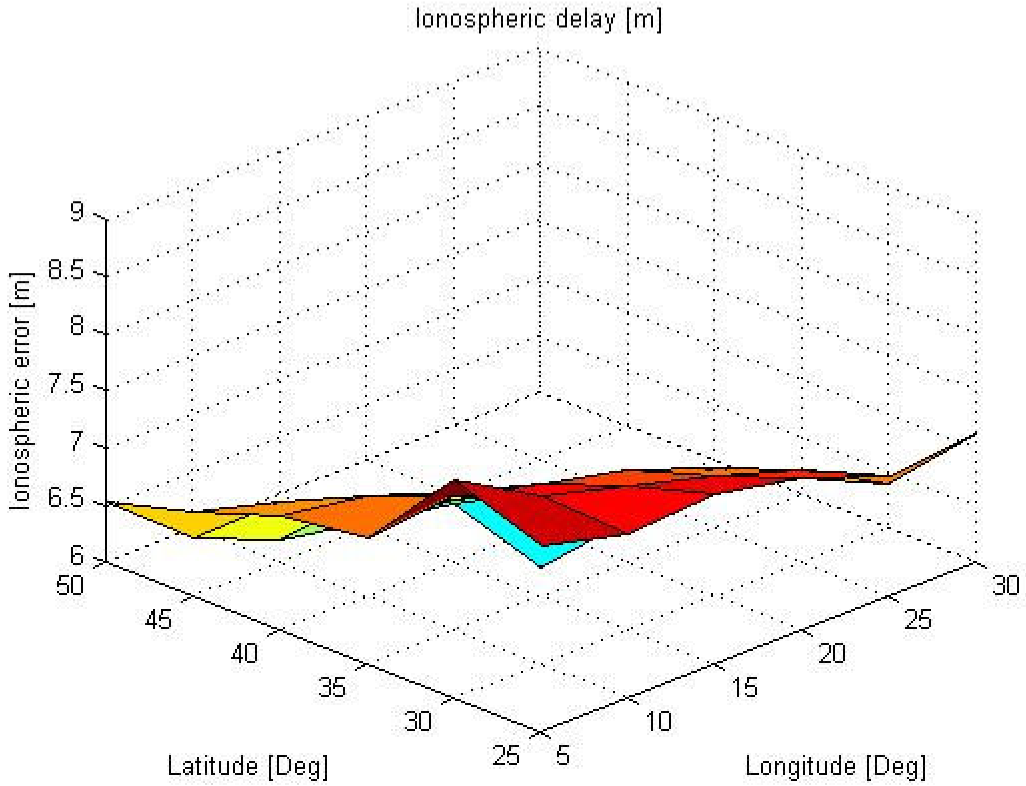
Estimated Ionospheric delay

- 3:00 pm – 4:00 pm



Estimated Ionospheric delay

- 4:00 pm – 5:00 pm



Conclusions

- The main subsystems of UniCubeSat have been showed
- The launch date depends on the schedule of the VEGA launcher (expected date in 2011…)