INNOVATIVE SOLUTIONS FOR A LOW COST CUBESAT DEVELOPMENT

N.Bellini, N.Benini, A.Curti, A.Locarini, S.Naldi, D.Rastelli, M.Valdatta

NPC New Production Concept - Spacemind

10th Annual CubeSat Developers' Workshop 2013

Cal Poly, San Luis Obispo CA, April 24-26, 2013

WHAT IS SPACEMIND?

Spacemind is a business idea born inside the University of Bologna with core business focused on nanosatellite technologies.

The team is composed by Master Aerospace Students with experience in the Space Robotic Laboratory of the University of Bologna.

Spacemind won a EU SPINNER2013 call for creation of enterprise

ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA

spacemind

SPINNER 2013
PERSONE AL FUTURO

RegioneEmilia-Romagna
Assessorato Scuola, Formazione professionale, Università e ricerca, Lavoro

Unione europea
Fondo sociale europeo
Investiamo nel vostro futuro

WHO IS NPC?

NPC New Production Concept, founded in 2002, is a system supplier for multinational companies, with 24.5 Mln € turnover and 50 employees.

CURTI company NPC's shareholders has 47 years of experience in aerospace manufacturing.

The company works according to World Class Manufacturing and Lean Production guidelines.

The business idea is based on cost transparency, innovation in products and processes.

N.P.C.
New Production Concept S.r.l.

SpaceMind

- Space technologies
- Nanosatellite design
- Mission analysis
- Subsystem innovation
- Experimental activities
- Ground tests
- Software simulation & analysis
- Feasibility studies
- Co-development
- Co-design

NPC

- Supply machines and modules
- Critical parts and test rig
- Financial support
- Streamline organization low overheads with high flexibility
- Cost optimization in the development phase
- Supply chain with network of 430 suppliers
- Metodology WCM & LEAN production
- Prototyping/tests

THE BUSINESS IDEA

SpaceMind
R&D Competence

NPC
Supply Competence

Solution provider for nanosatellite application as a complete package

PAST AND PRESENT ACTIVITIES…

- **Space debris mitigation studies:**
  - Active debris removal concepts (ESA Rexus12)
  - Deorbiting technologies
  - Observation and detection campaign (ASI - UAI cooperation)
- **Cubesat subsystem development:**
  - Structures
  - Deorbiting system
  - Solar panels
  - Propulsion system
- **Cubesat missions:**
  - QB 50 (University of Rome cooperation)
  - CSDC (Polytecnique of Montreal - Polyorbite cooperation)

DEORBITING SYSTEM FOR NANOSATELLITE

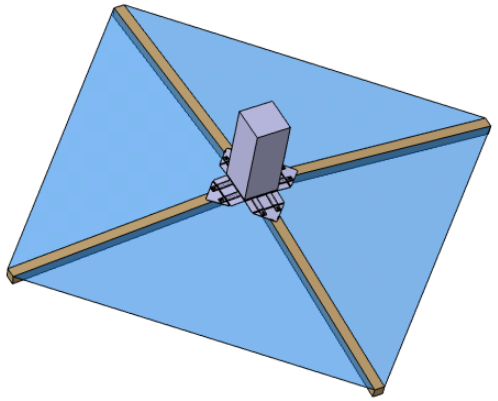
The deorbiting system is based on a drag sail. The system has been designed starting from the following guidelines:

- **Reduced storage volume: low impact on spacecraft design**
- **Simple and low cost technology**
- **Standalone solution**
- **IADC guidelines satisfaction**
- **Starting point for future improvement**

DEORBITING SYSTEM FOR NANOSATELLITE

Drag sail based on memory form sail spars.

Storage Volume	25% 1U CubeSat – 2.5 cm
Area	0.49 m2
Mass	0.200 kg
Operating Range	Up to 850 km



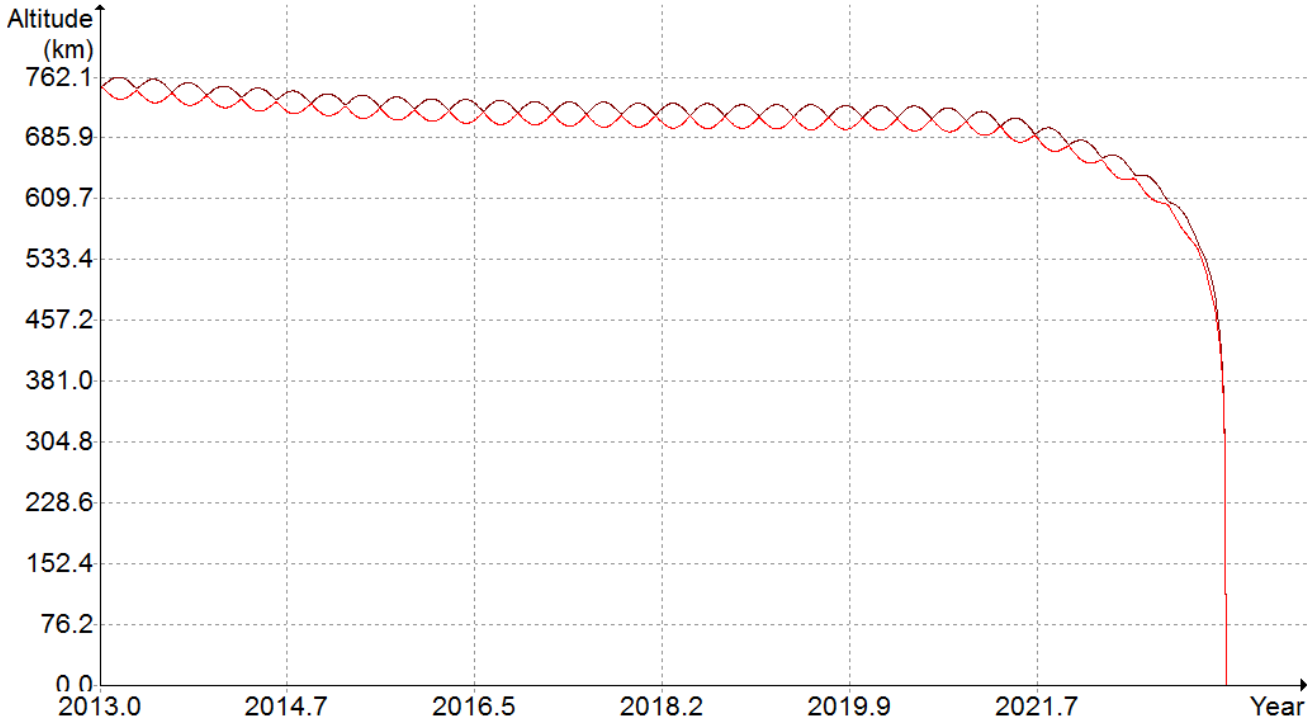
The system is suitable for missions in sunsynchronous orbit, the most critical region in terms of debris population.

The system will be the payload of CSDC mission – Launch in may 2014

DEORBITING SYSTEM FOR NANOSATELLITE

IADC Requirements satisfaction

✓ Max 25 years orbit lifetime



DAS preliminary simulation.
Suitable for SunSync orbits.

DEORBITING SYSTEM FOR NANOSATELLITE

IADC Requirements satisfaction

✓ **Limiting debris generating by collisions with large objects when operating in Earth orbit:**

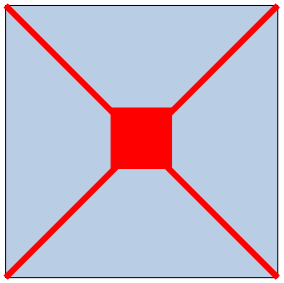
Due to the elastic property of the material the spars are a low energy impact region:

-Low density of the material
-High absorption of impact energy

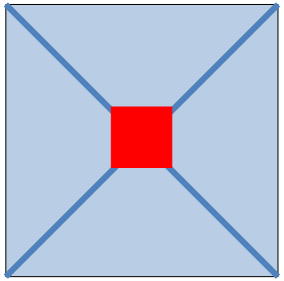
High energy impact region (DEBRIS GENERATING)

Low energy impact region

Aluminum spars



Polimeric spars



Reduction of debris generating collision ATP (Area time product)

DEORBITING SYSTEM FOR NANOSATELLITE

Performances have been evaluated considering the stability of the system in relation to the disturbance torques acting on it

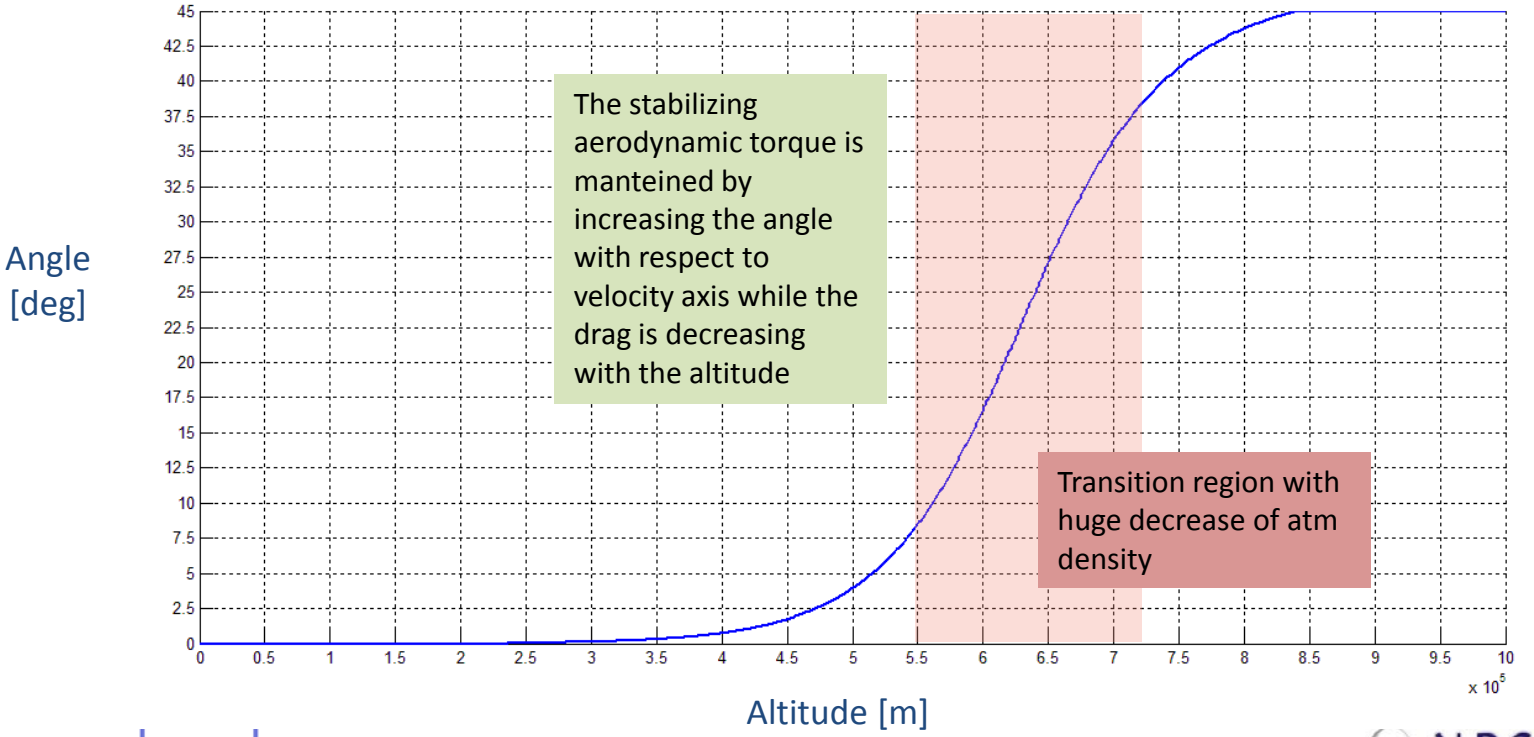
Disturbance Torque	Type	Formula
Gravity gradient	Constant / cyclic	$T_g = \frac{3\mu}{2R^3} \lvert I_y - I_x \rvert \sin 2\theta$
Solar radiation	Constant / cyclic	$T_s = F(C_p - C_g)$ $F = \frac{F_s}{c} A_S (1+q) \cos I$
Magnetic field	Cyclic	$T_m = DB$

To be CONSERVATIVE, all the torques have been considered acting simultaneously on the satellite and in the same direction

DEORBITING SYSTEM FOR NANOSATELLITE

For different altitudes it has been possible to evaluate the evolution of the stability and the equilibrium angle

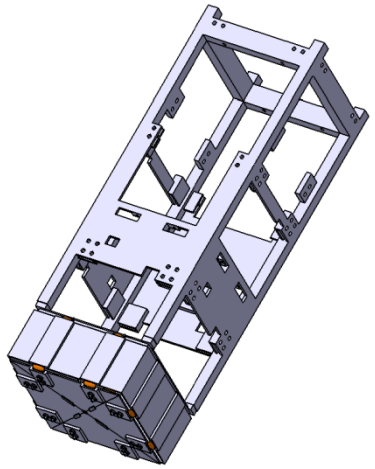
The inclination angle reduces the performance of the sail



DEORBITING SYSTEM FOR NANOSATELLITE

Expected Performance with stability consideration for 3U cubesat with 0.49 m2 (70x70cm) sail deployed

	Normal Orbit lifetime [yr]	A/m Nominal	Years Nominal	A/m Average	Years Expected	Increasing factor
SunSync	>100	0.1225	18	0.099	20	+11%
CSDC	>100	0.1225	8	0.108	8.5	+6%
Generic orbit	62	0.1225	1.17	0.118	1.2	+5%

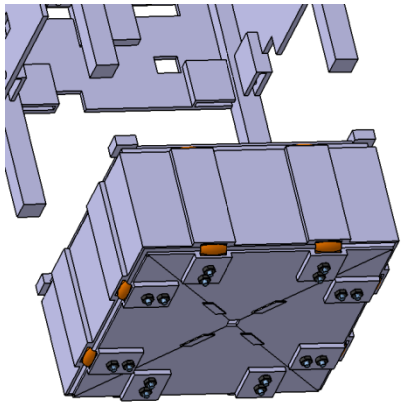


CSDC: 700x700 km 96°
SunSync: 800x800 km 98°
Generic Orbit: 600x600 km 45°

DEORBITING SYSTEM FOR NANOSATELLITE

Main advantages:

- Low storage volume
- Passive deployment
- No complicated mechanical parts (ex telescopic booms)
- Low debris generating ATP
- Easy replicable ground tests



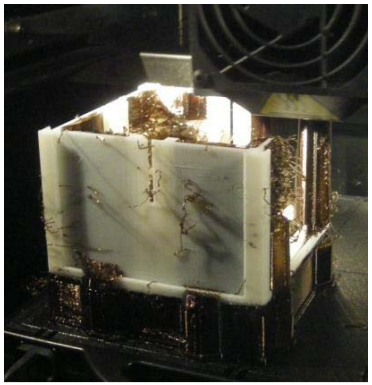
Future developments:

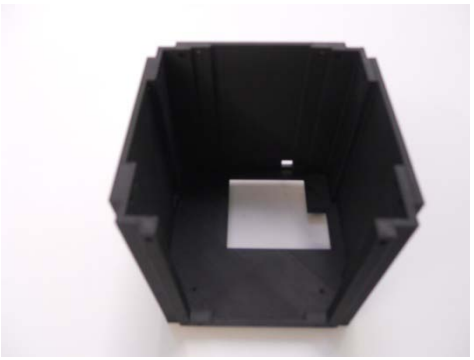
- Possibility to increase the area for defined storage volume
- Increase of stability and performances using backward angle

ABS CUBESAT STRUCTURE

Cubesat structure realized using prototipation technique FDM (Fused Deposition Modeling)

- **Possibility to create very complex shapes**
- **Easy customization of inner and external details**
- **Lighter structure**
- **Short time of manufacturing and low costs**

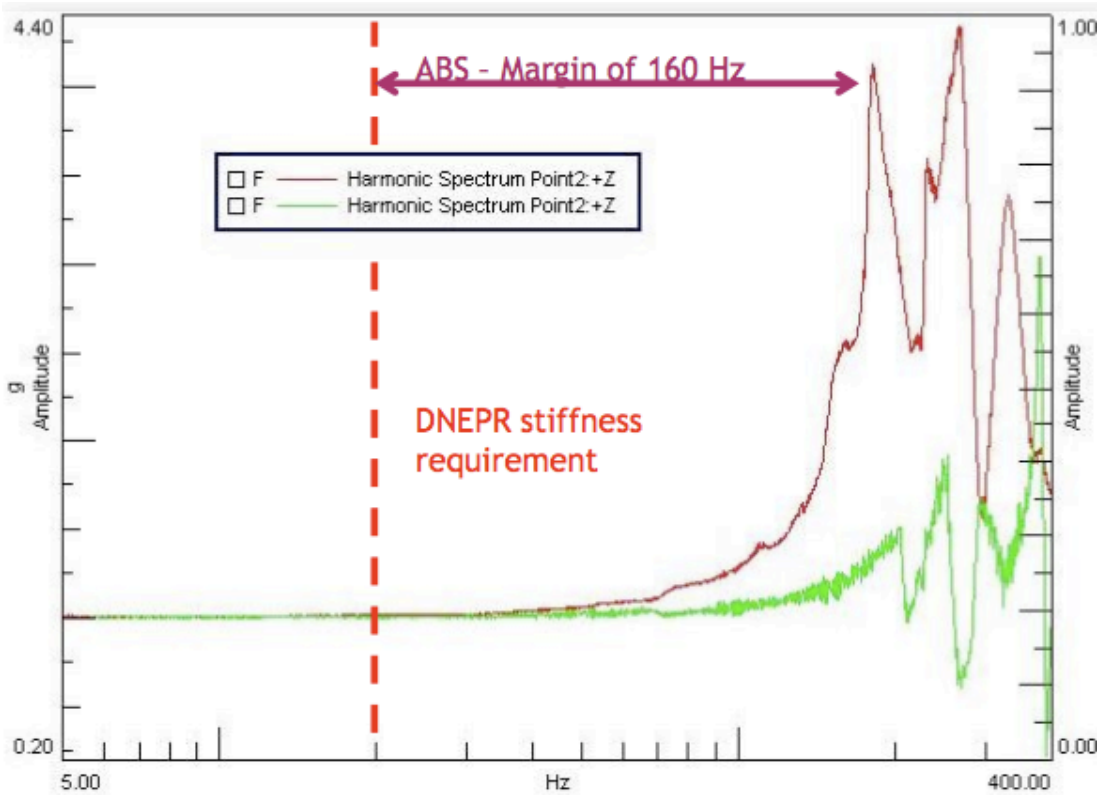




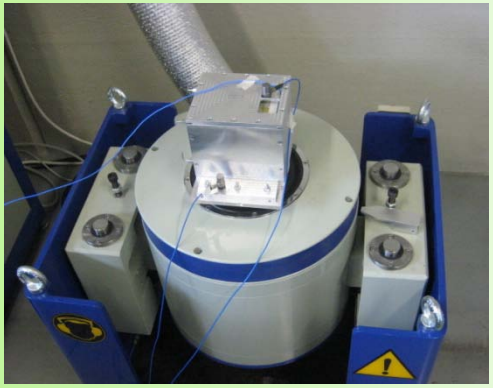
Tests and analysis on the material have been performed in order to satisfy requirements for space applications

ABS CUBESAT STRUCTURE

FEM analysis and Vibration test

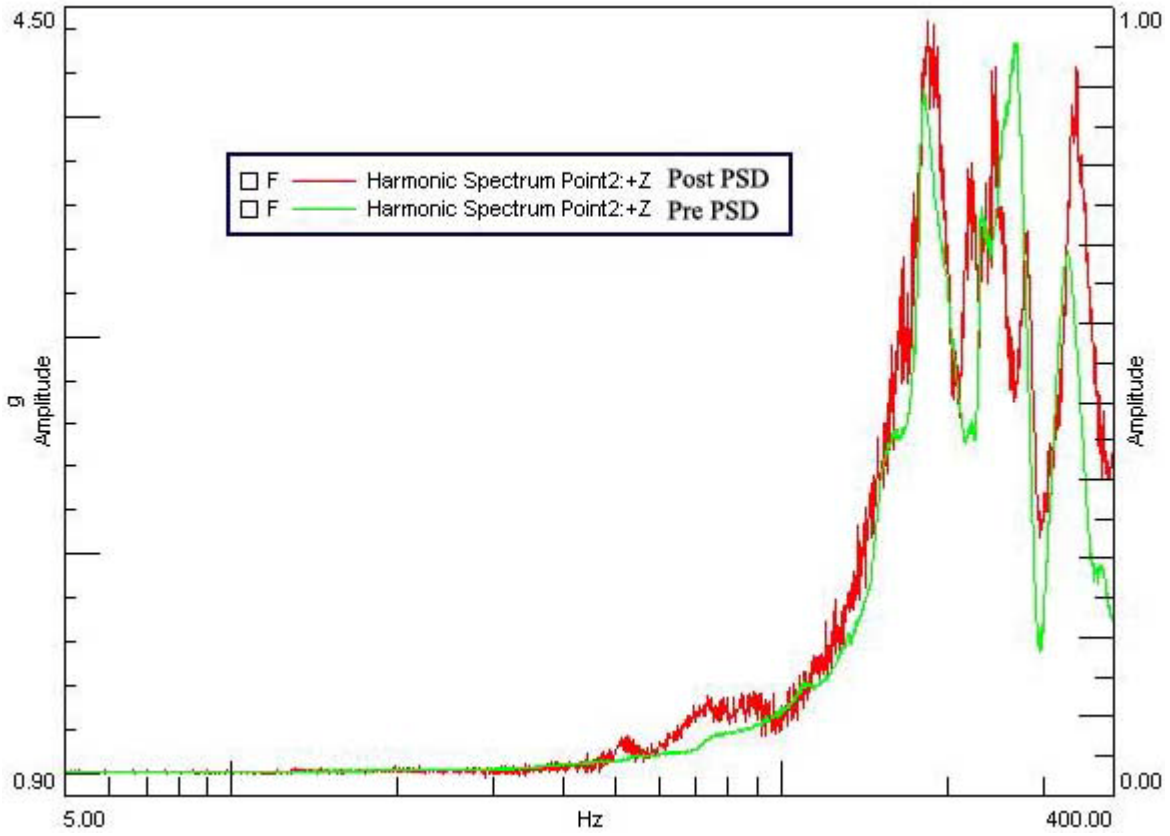


Vibration test on ABS structure compared with aluminum structure shows that ABS satisfies stiffness criteria.

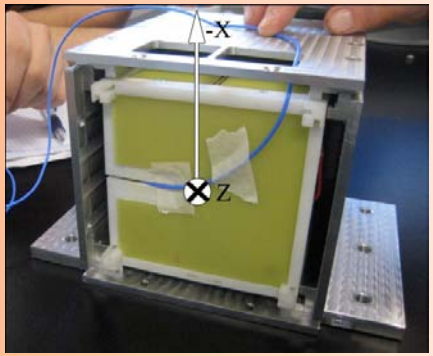


ABS CUBESAT STRUCTURE

FEM analysis and Vibration test

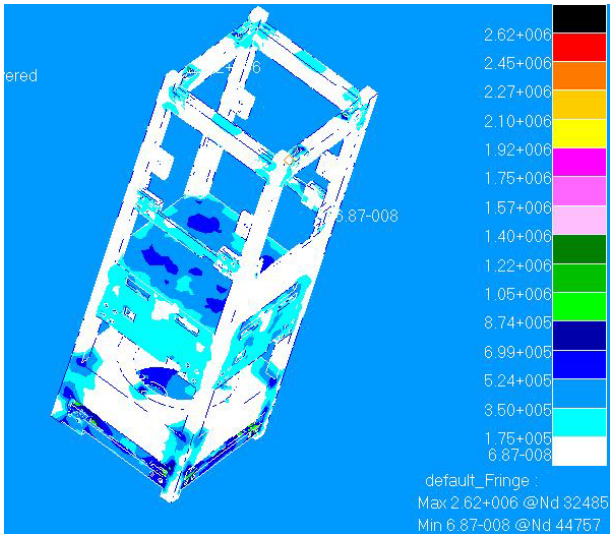


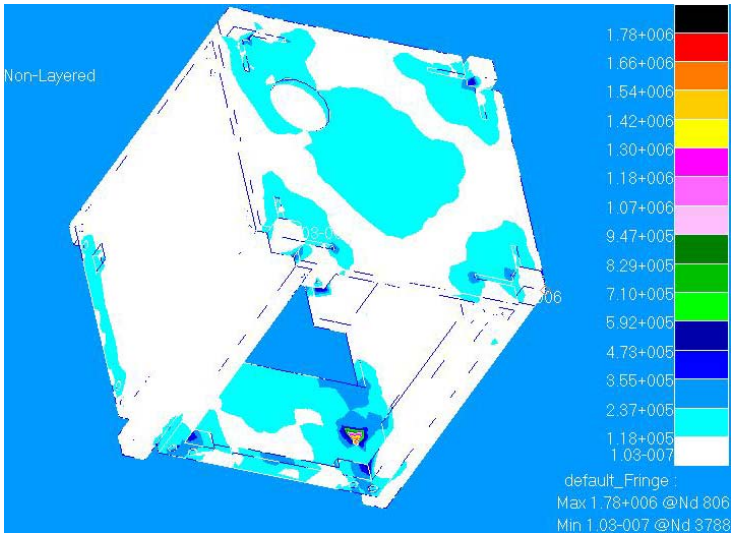
Pre and post random vibration excitation on ABS structure: no evident alteration in the behaviour.



ABS CUBESAT STRUCTURE

FEM analysis and Vibration test





FEM analysis have been performed considering an integrated standard cubesat.

Experimented stesses are below ABS tensile strength with high safety factor

ABS CUBESAT STRUCTURE

Outgassing properties

The Outgassing is the generation of spurious molecules which may act as contaminants to other surfaces and degrade the performance of electro-optical instrumentation. TML and CVCM are indicator of the quantity of these molecules

The material provider has performed outgassing tests following the ASTM E-595 requirements

	LIMIT ADMITTED	FDM ABS
TML	1 %	0.41%
CVCM	0.1 %	<0.01%

TML = Total Mass Loss CVCM = Collected Volatile Condensable Materials

ABS CUBESAT STRUCTURE

Thermal dissipation:

- A thermal analysis campaign has been planned
- Possibility to use metal inserts or other thermal conductive material

Plasma charge mitigation:

- Plasma interaction simulation using software SPIS (ESA)

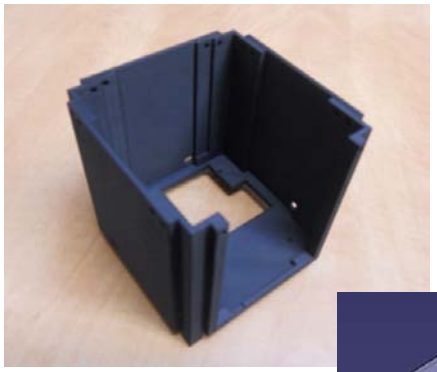
ABS CUBESAT STRUCTURE

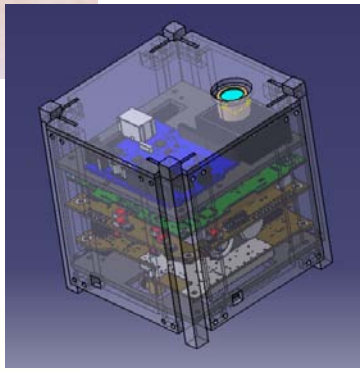
Different prototypes have been already realized

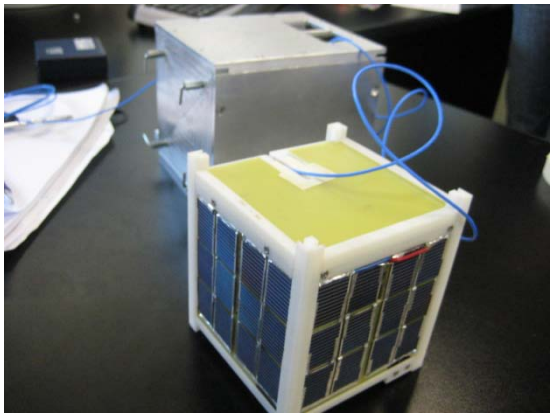
- **1U CubeSat for SRL with ad hoc internal design**
- **1U CubeSat for commercial components integration**
- **1U CubeSat for spherical shapes interface**
- **3U CubeSat for experimental PPT interface**

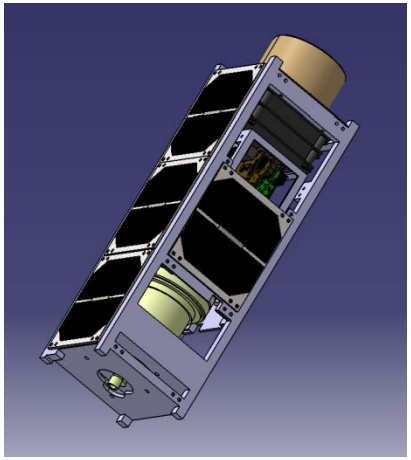
A 3U ABS structure will fly in QB50 mission of the University of Rome "La Sapienza" in cooperation with the University of Bologna.

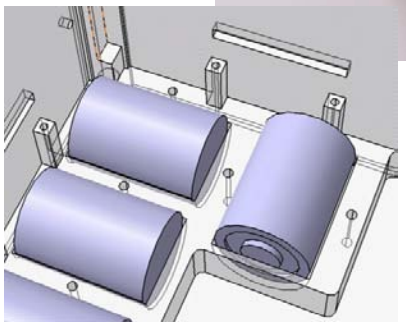
ABS CUBESAT STRUCTURE











ABS CUBESAT STRUCTURE

Future works…

- **Aluminum profiles for rails to avoid abrasion during deployment from the PPOD**
- **Investigation upon the use of different rapid prototyping technique**
- **Necessity of full characterization of the material**

THANKS FOR YOUR ATTENTION