PiCPoT project

AMSAT Italia e C.I.S.A.R.- Convegno “Radioamatori e Spazio”
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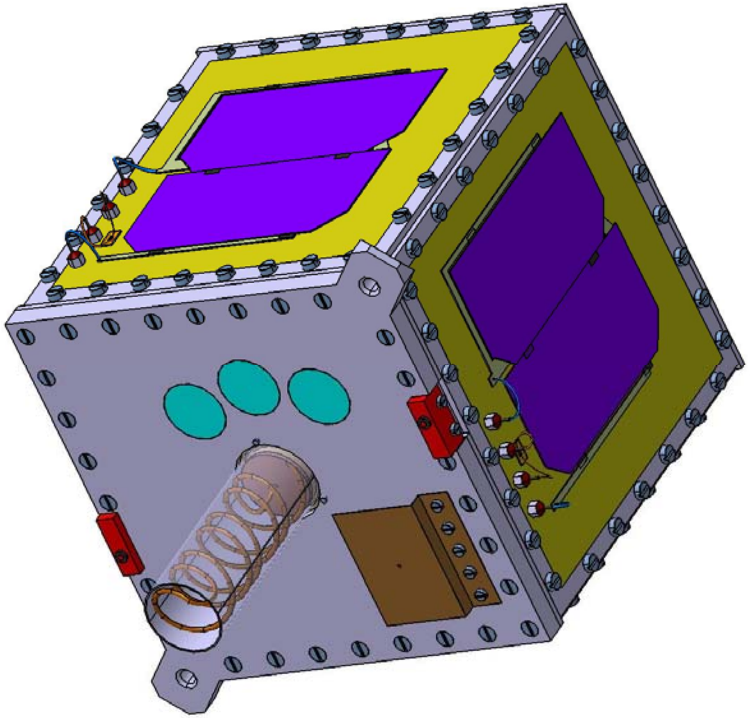

- PiCPoT: Piccolo Cubo del Politecnico di Torino (small cube of Politecnico di Torino)

PiCPoT people

- Responsabile del progetto
  Prof. S. Chiesa
  - Ingegneria Sistemistica Aerospaziale
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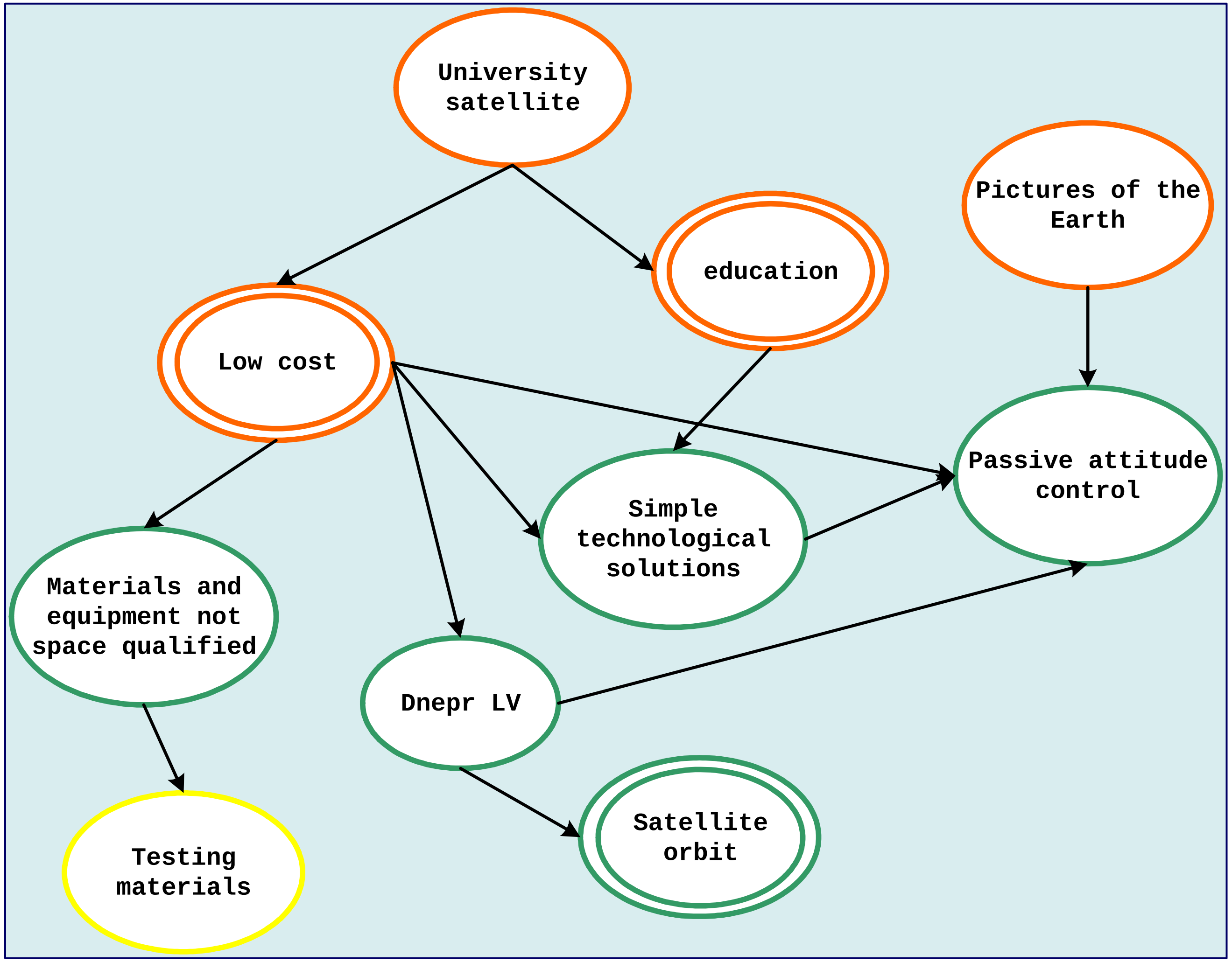
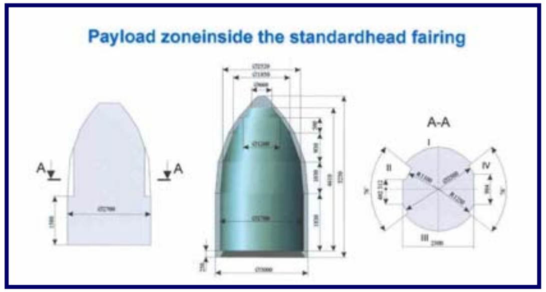
  - Elettronica e Telecomunicazioni
    Prof. L. Reyneri
    - Prof. Del Corso
    - Prof. Lo Presti
    - Prof. Mondin
    - Prof. Pozzolo
    - Prof. Sansoé
    - Prof. Vecchi / Orefice
  - Gruppi Vari
    - Ingegneria Energetica
      Prof. Masoero
    - Fisica
      Proff. Allia / Tartaglia

SiTI-Istituto Superiore sui Sistemi Territoriali per l'Innovazione

Mission and system overview: requirements and constraints

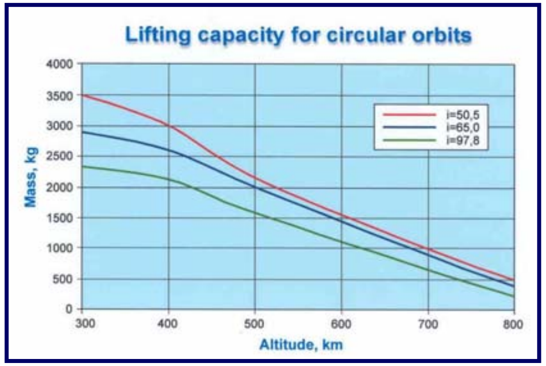


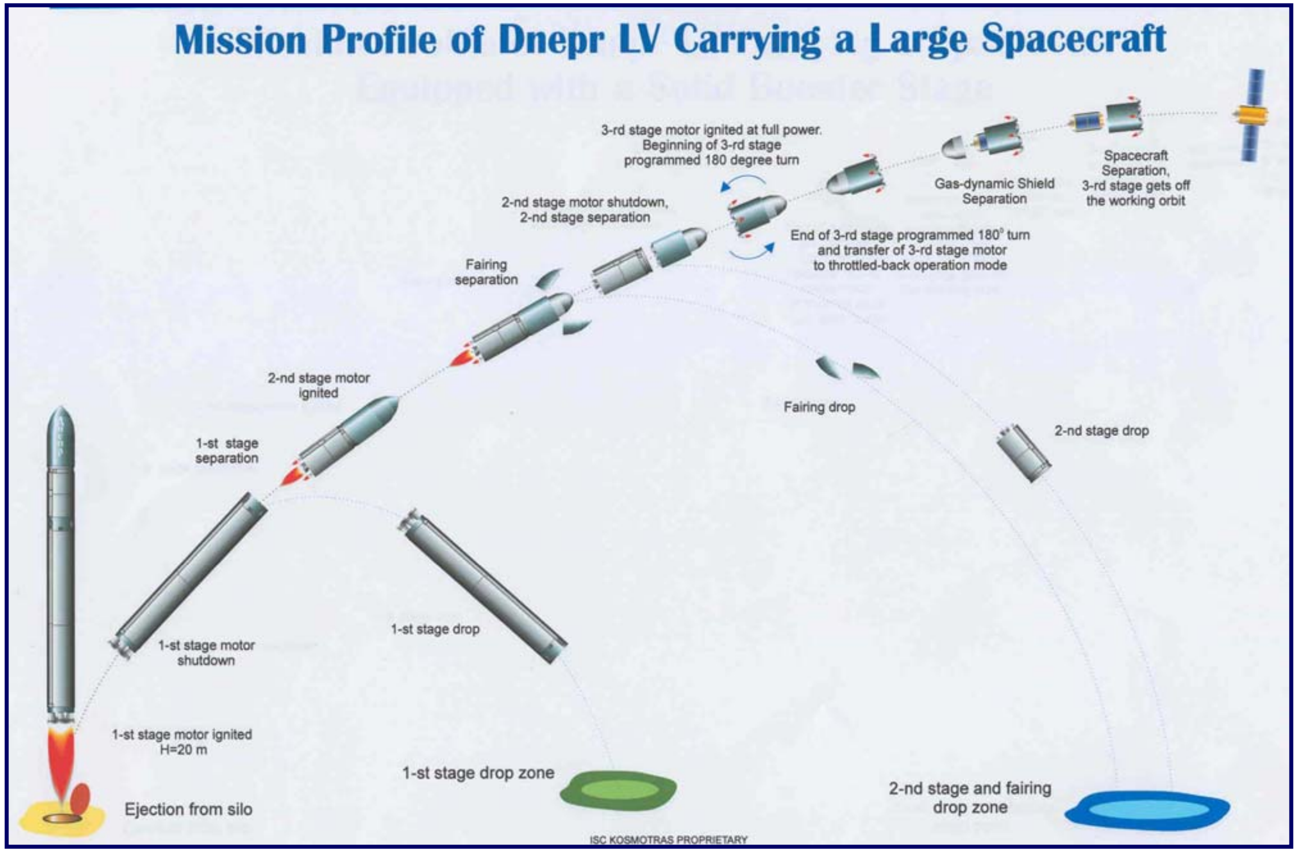
Mission and system overview: DNEPR LV, the launcher

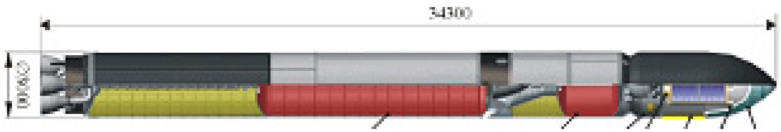


Dnepr LV Basic Characteristics

Total launch weight	210 т
Propellant components for all stages	amil+heptyl
Number of stages	3
Spacecraft injection accuracy (H=300 km):	
- for altitude	± 4.0 km
- for inclination	± 2.4 ang. min.
- for the right ascension of the ascending node	± 3.0 ang. min.
Orbit inclination	50.5°, 65°, 97.8°
Flight reliability	0.97
Loads affecting the spacecraft:	
- maximum axial quasi-static g-load	7.5
- maximum lateral quasi-static g-load	0.8
- integral level of sound pressure	140 dB







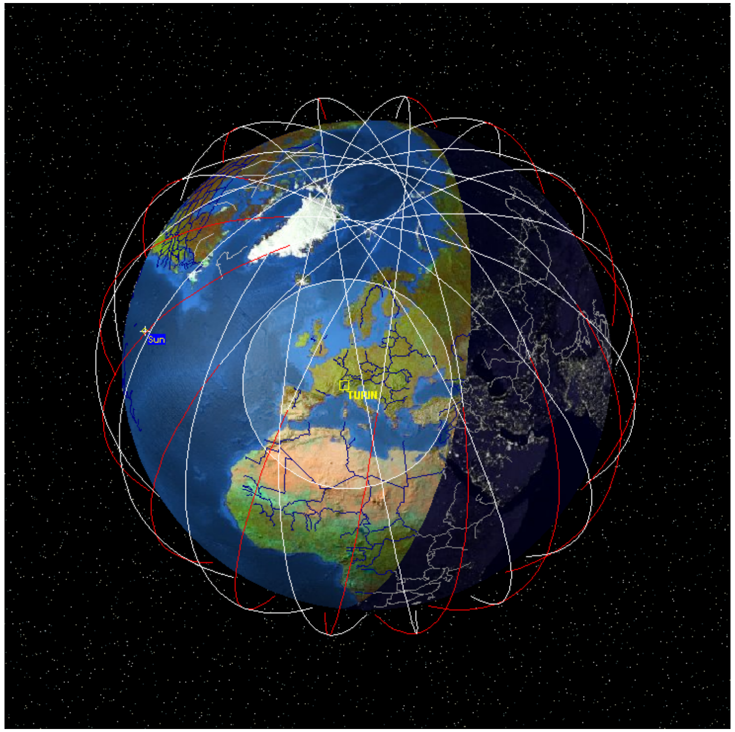
Mission and system overview: PiCPoT orbit

Dnepr LV Basic Characteristics

Total launch weight	210 т
Propellant components for all stages	amil+heptyl
Number of stages	3
Spacecraft injection accuracy (H=300 km):	
- for altitude	± 4.0 km
- for inclination	± 2.4 ang. min.
- for the right ascension of the ascending node	± 3.0 ang. min.
Orbit inclination	50.5°, 65°, 97.8°
Flight reliability	0.97
Loads affecting the spacecraft:	
- maximum axial quasi-static g-load	7.5
- maximum lateral quasi-static g-load	0.8
- integral level of sound pressure	140 dB

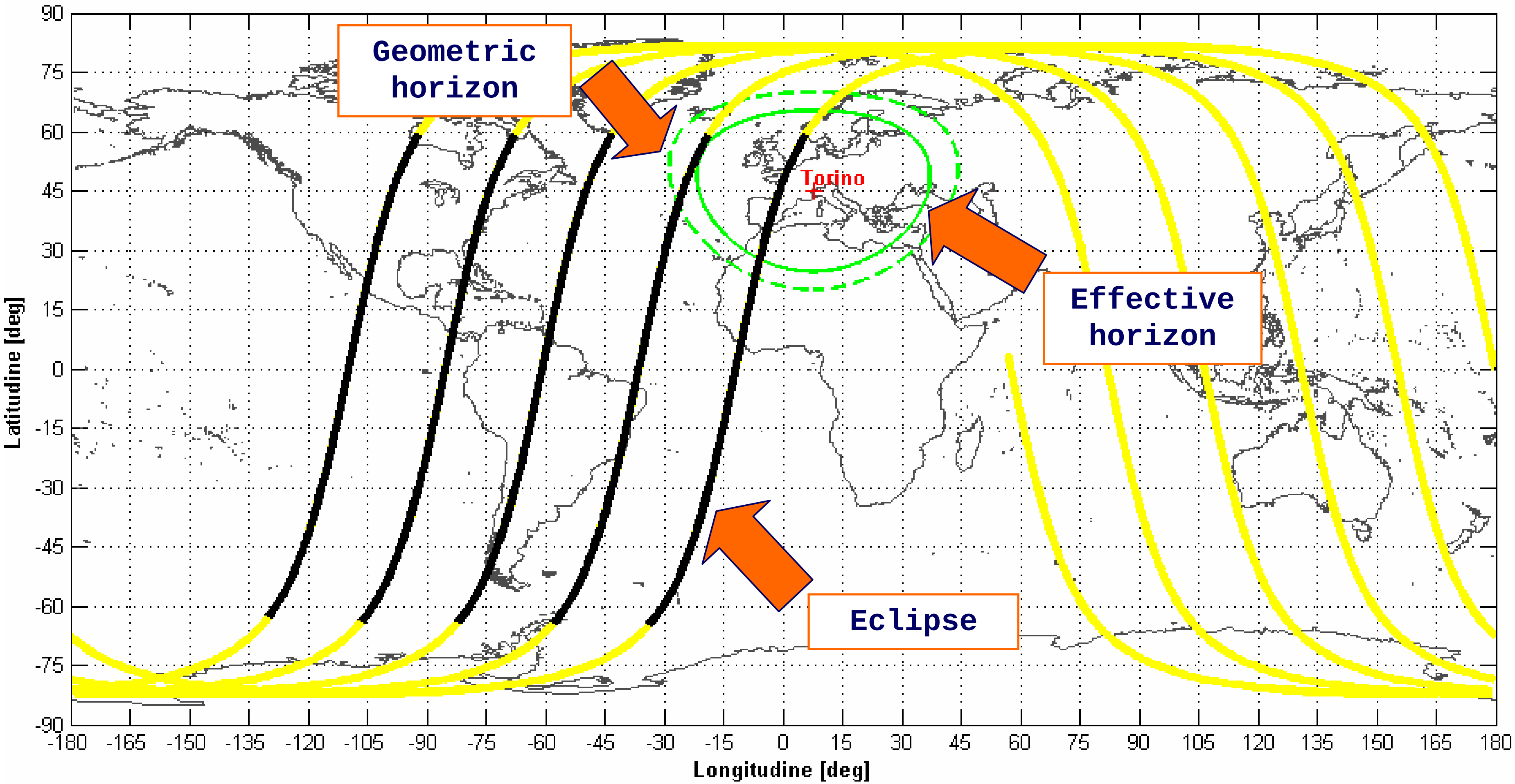
Orbit's characteristics:

- **inclination: 98°**
- **eccentricity: ~0°**
- **height of perigee: 600-800 km**

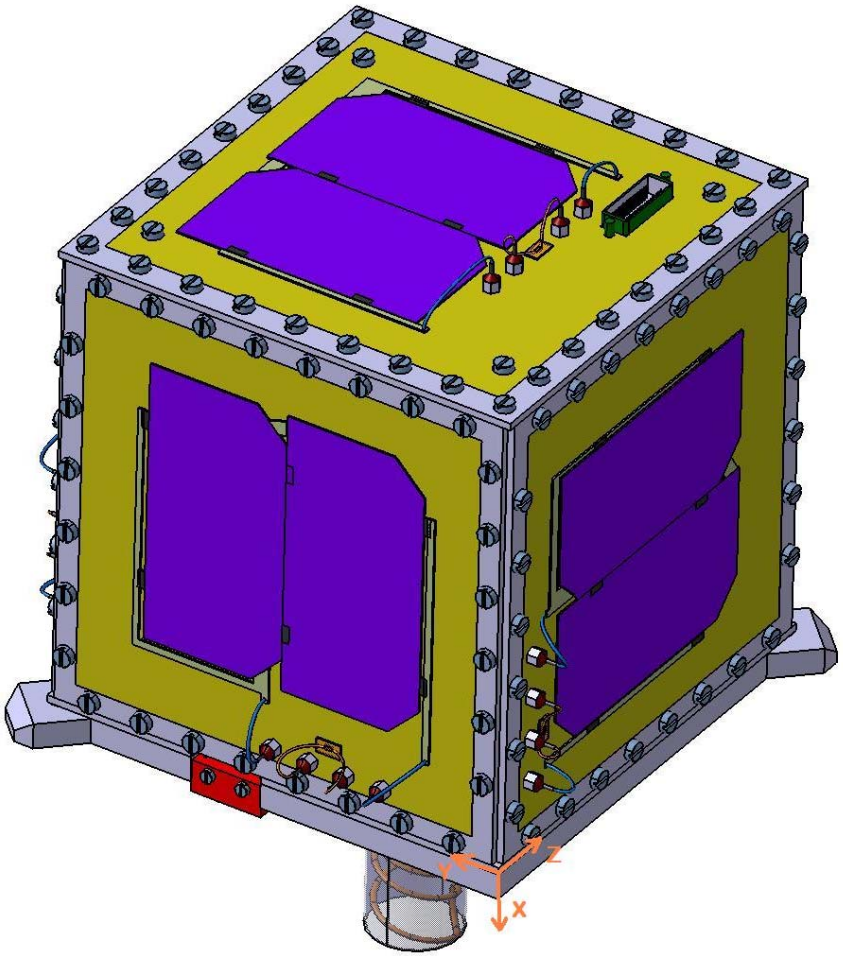


Mission and system overview: PiCPoT ground track

Satellite ground tracks for five orbits



Configuration



Main geometrical and mass characteristics:

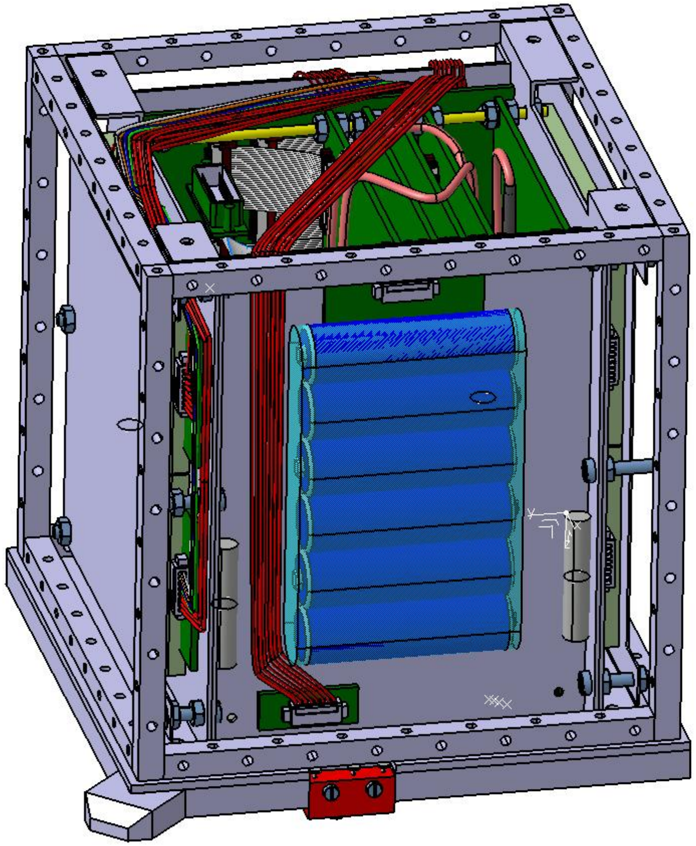
- shape: cube
- dimensions: 130 mm (side)
- mass: 2.5 kg
- C.o.G.:
  - x = -36.54 mm
  - y = 66.32 mm
  - z = 64.81 mm
- principal moments of inertia:

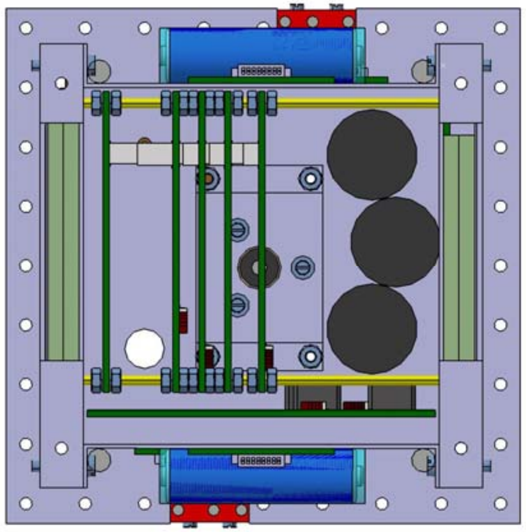
  Ixx < 0.015 kg*m^2

  Iyy < 0.022 kg*m^2

  Izz < 0.022 kg*m^2

Layout

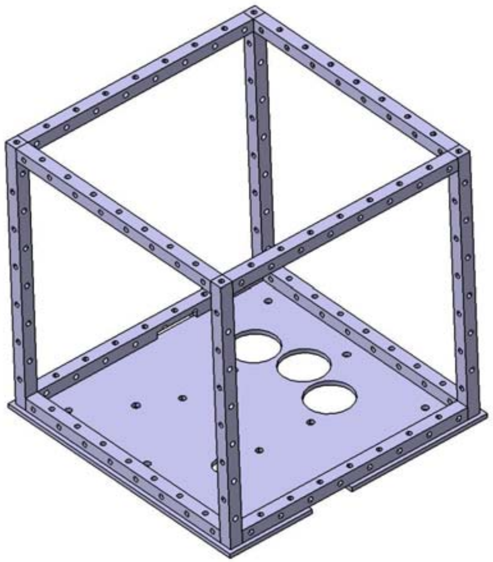


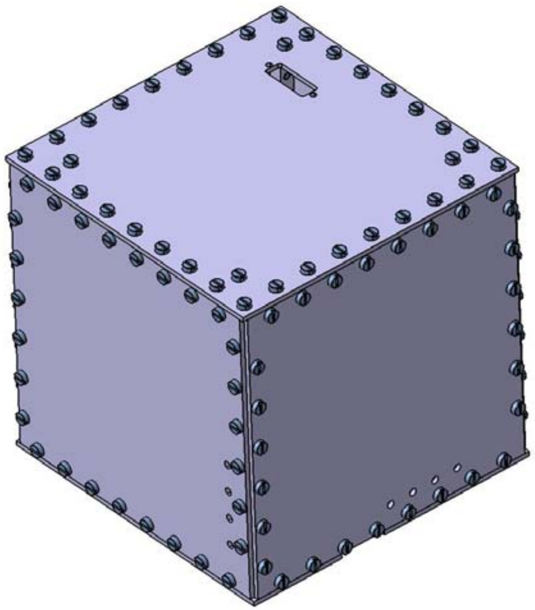


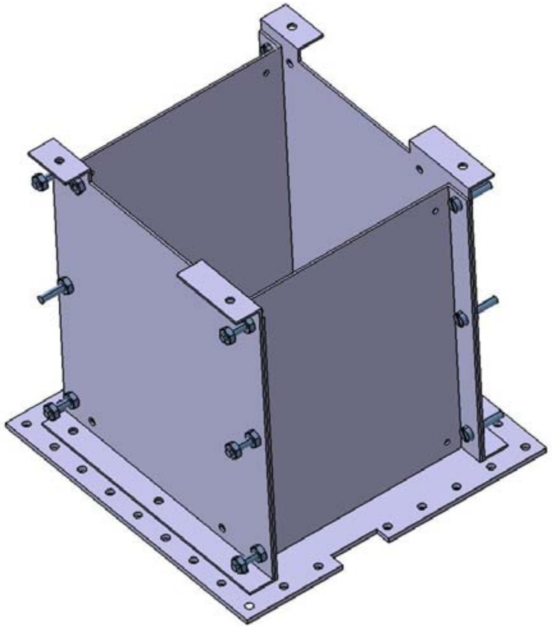
SUBSYSTEMS:

- **Structure**
- **Power supply**
- **Attitude control**
- **Communications**
- **Payload**
- **Command and data handling**
- **Connections and wirings**

Layout: structure





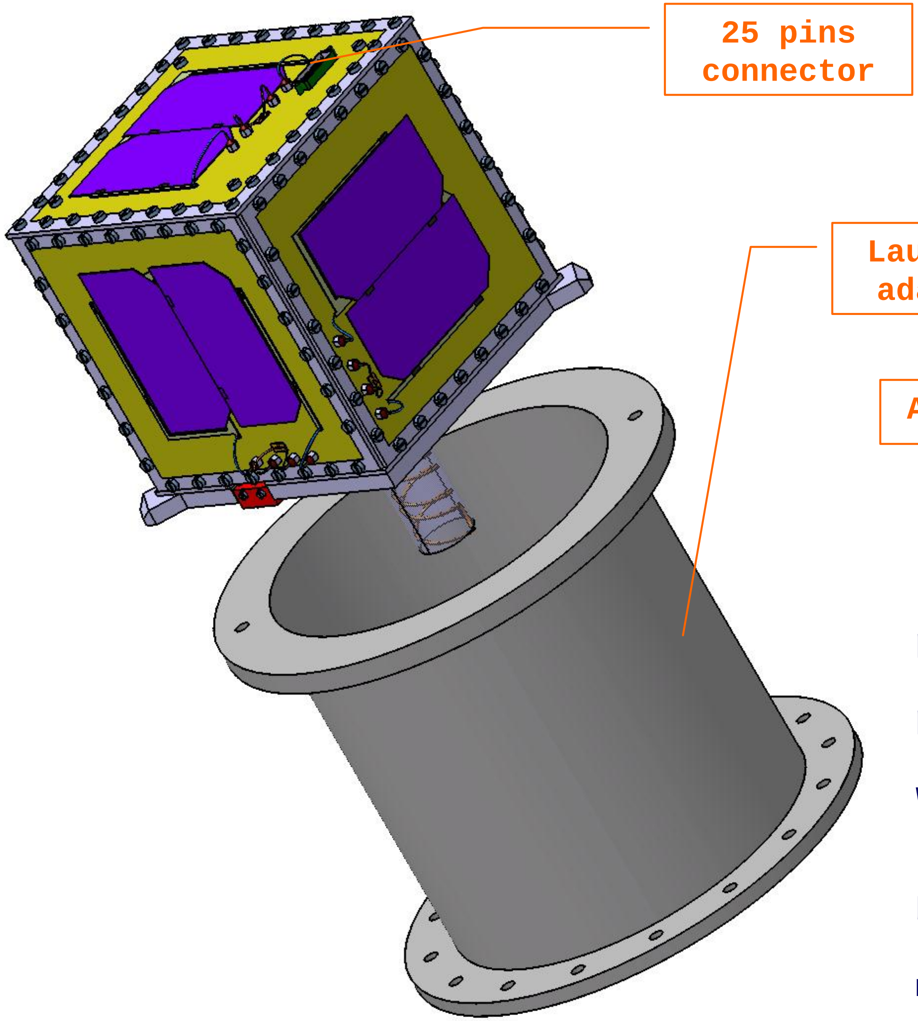


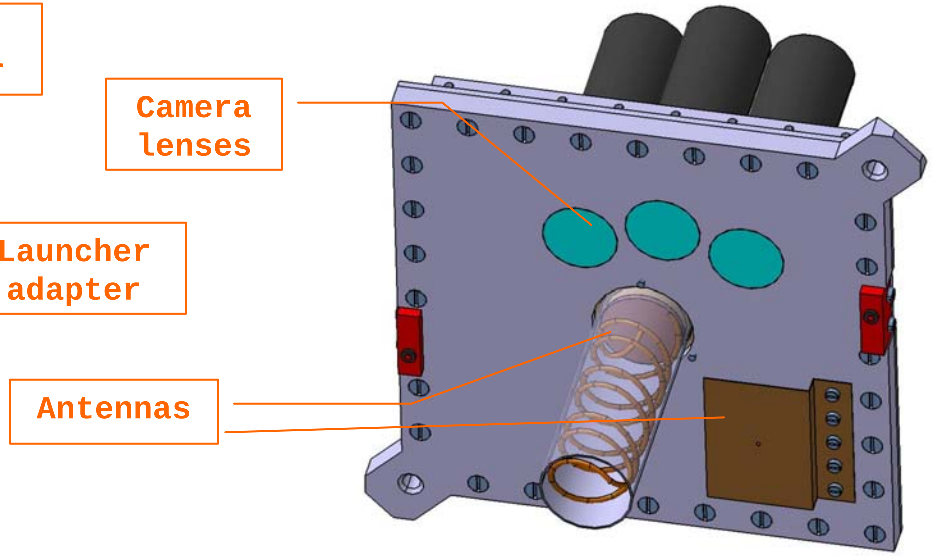
PiCPoT is constituted by bars and panels which are screwed together to form the external structure of the satellite.

C section panels are used to build the internal support structure.

All components of the structure are manufactured in Aluminium alloy, series 5000 Al-Mg.

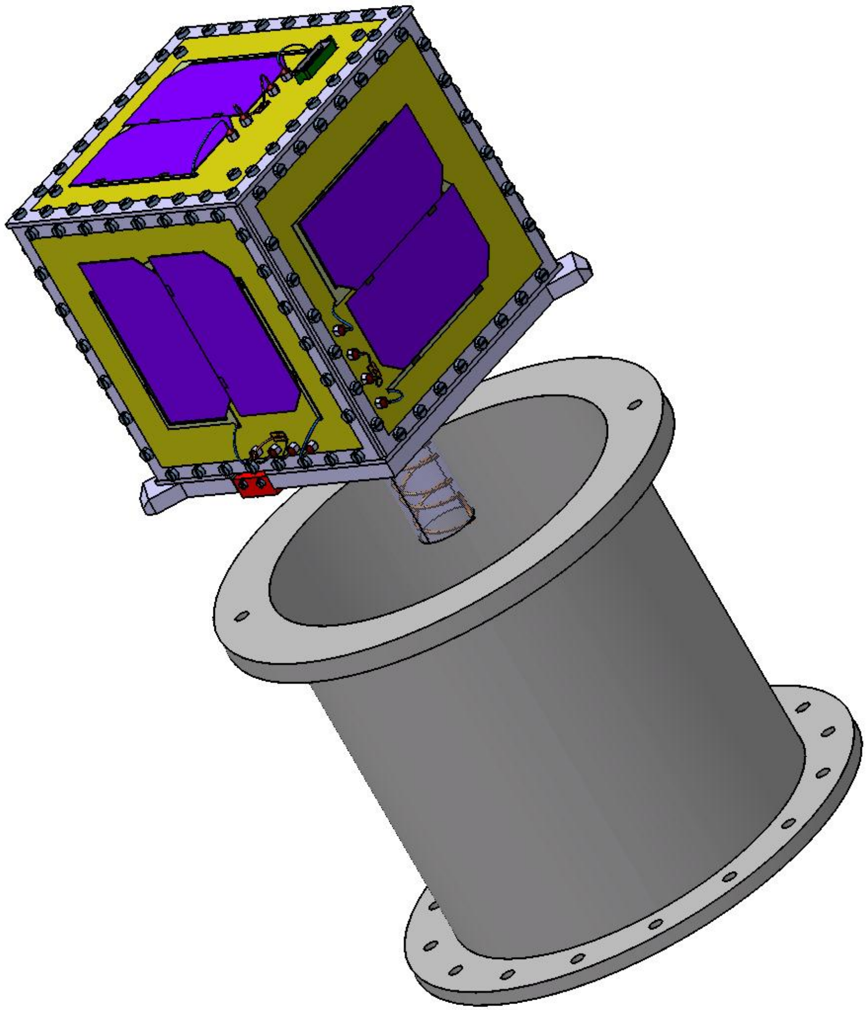
Layout: structure

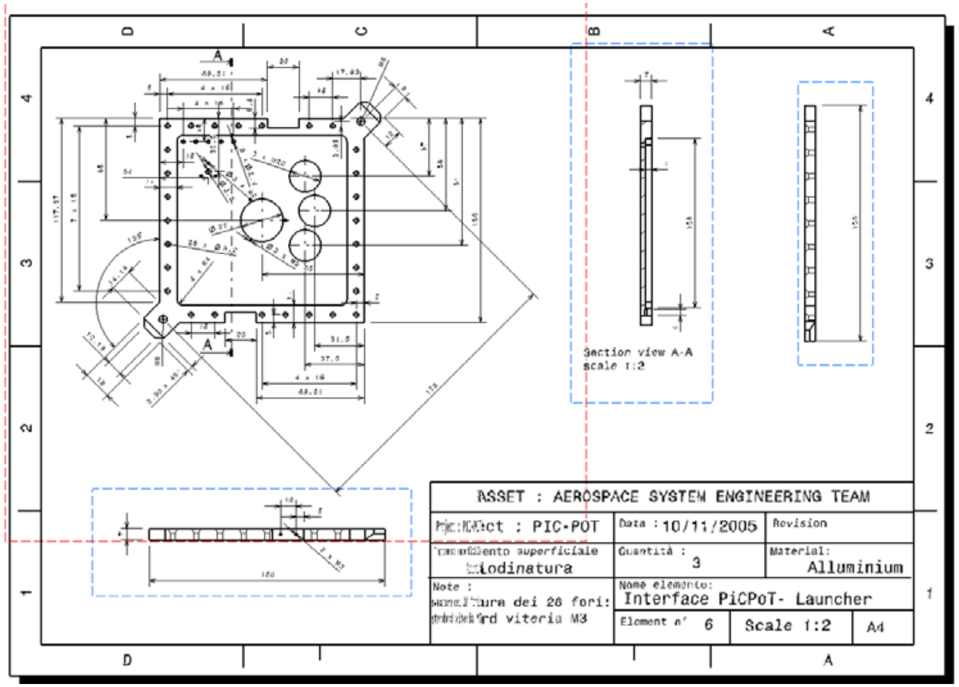


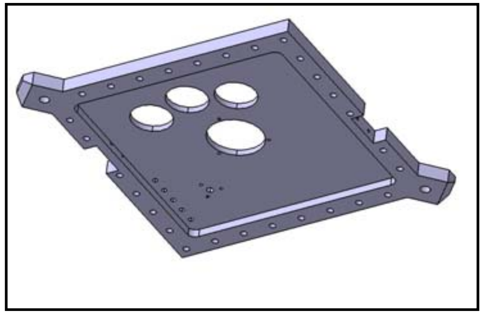


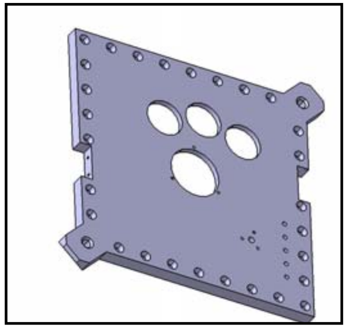
• A 25 pins connector for test operations is placed on the top panel (F5).
• The bottom panel and the launcher interface plate are screwed together.
• Two antennas are attached to the plate where no solar cells are glued. There are three holes to house the camera lenses and two kill switches to guarantee no power on board until the satellite’s release.
• The plate has a square shape with two machined tips which are used to fix the satellite to the launcher adapater.

Launcher adapter and interface



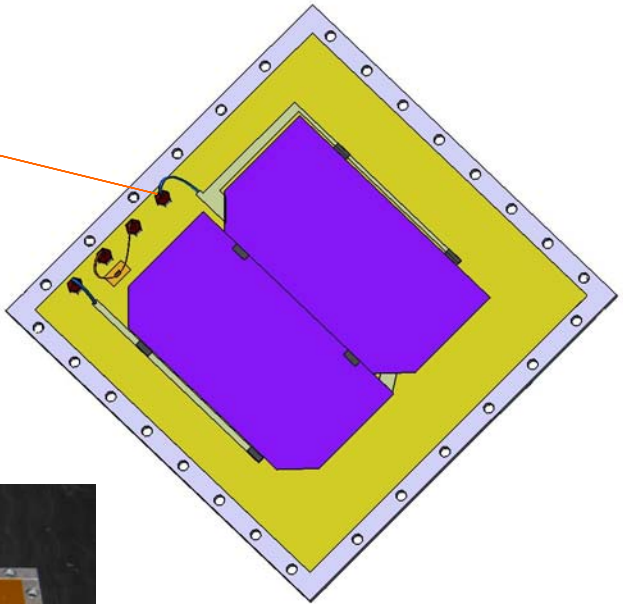


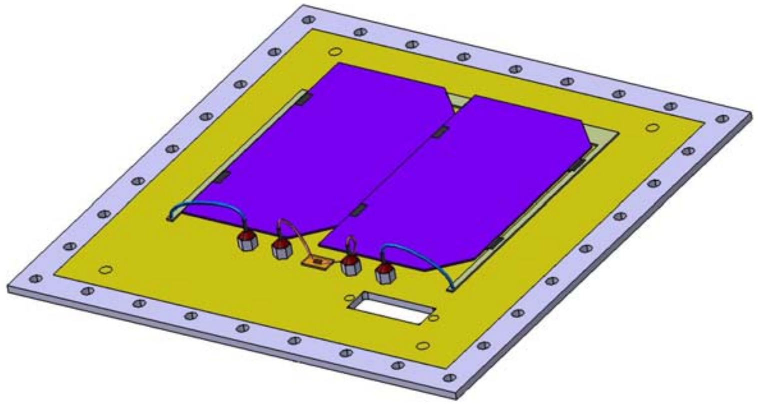


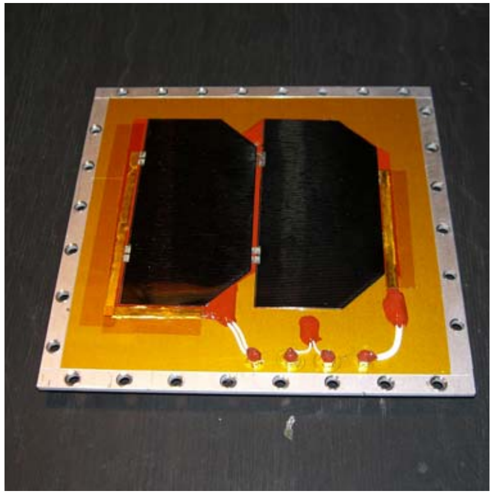


Layout: power supply

LC filter

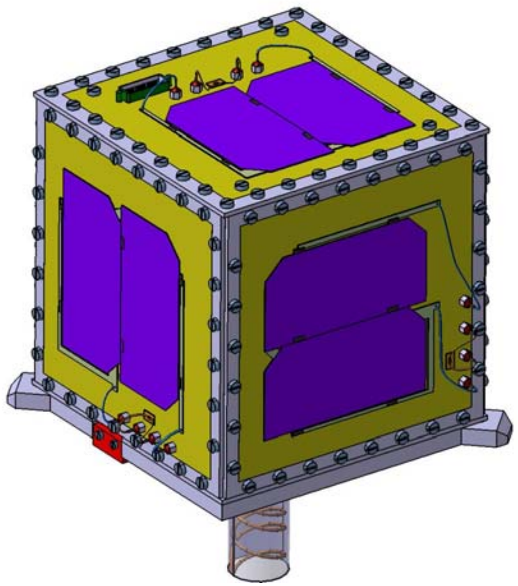




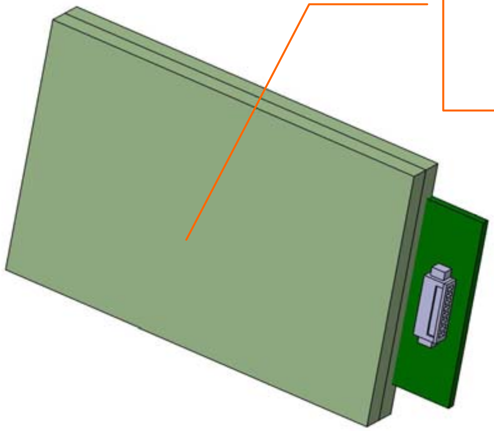


AsGa Solar cells

AsGa triple junction cell (CESI)
Electrical Output: 2.1 VDC-1.85 W
Dimensions: 40 mm x 80 mm
Availability: In Stock
Price: …

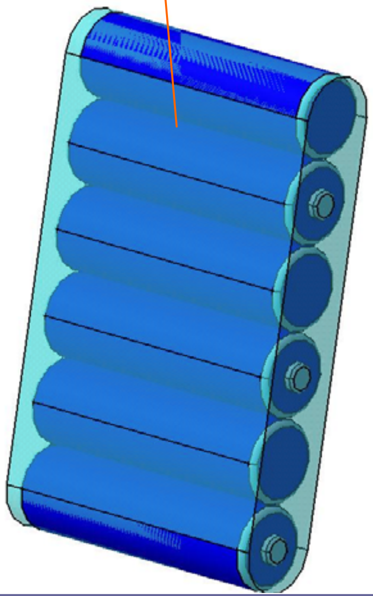


Layout: power supply

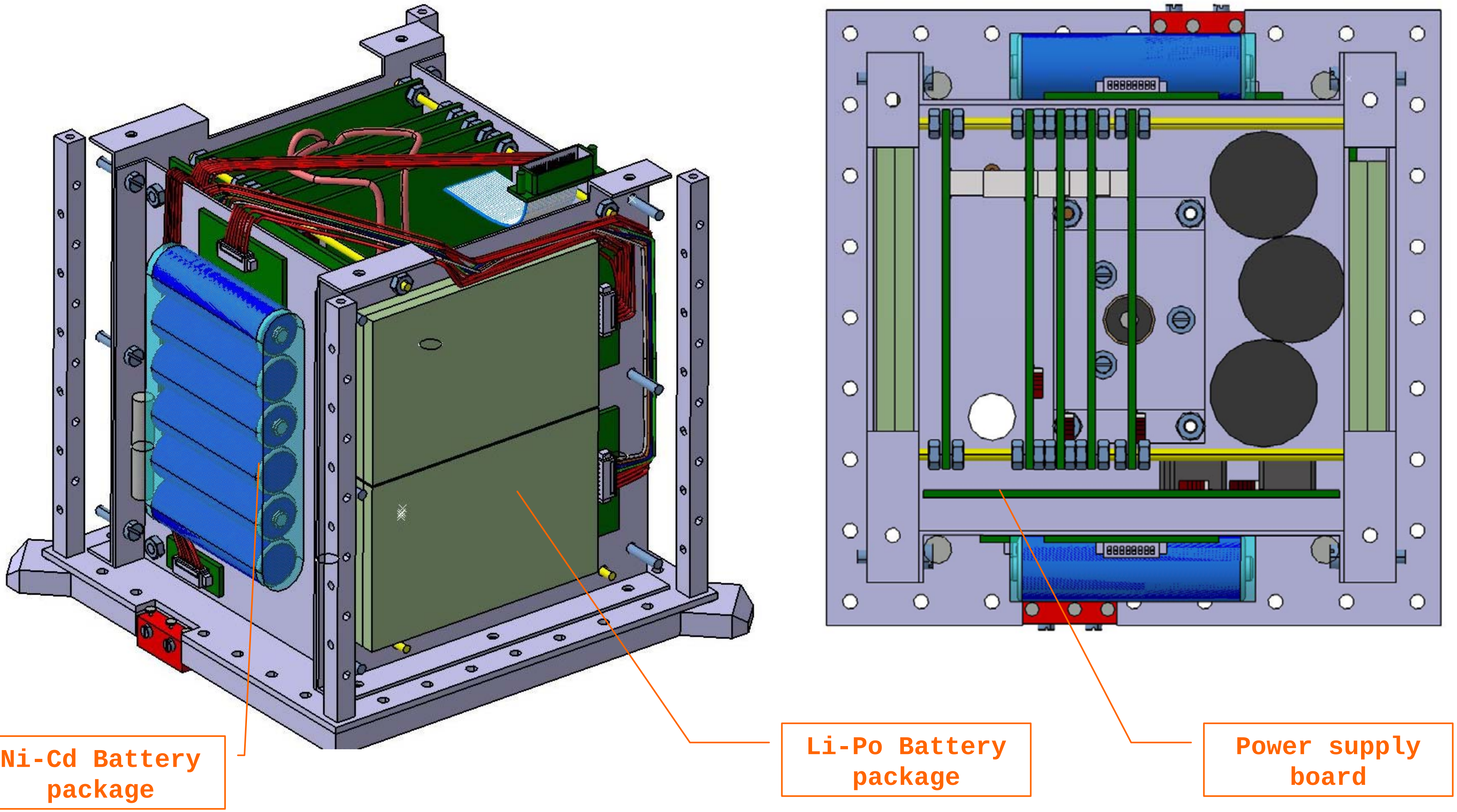


- *Ultralife* Li-Po cells, 3,7 V / 1600 mAh, 86 x 51 x 4.7 mm.
- 4 Li-Po battery packages each constituted by 2 cells connected in series.
- Each package supplies 7.2 V / 1600 mAh

- *Sanyo* Ni-Cd AA cells, 1.2 V / 1000 mAh.
- 2 Ni-Cd battery packages each constituted by 6 cells connected in series.
- Each package supplies 7.2 V / 1000 mAh



Layout: power supply



Layout: attitude control

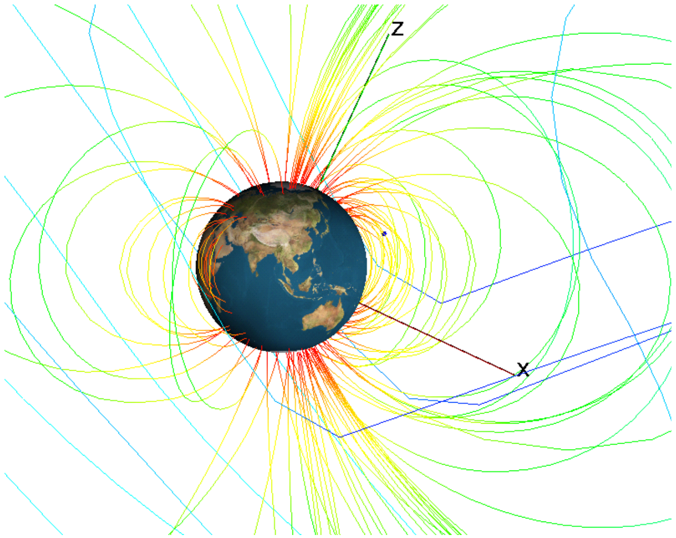
- Low cost and easy technological solutions
- Low Earth pointing accuracy required for taking pictures of Europe

Passive attitude control

SOLUTION

Permanent magnets to align the satellite with the Earth magnetic field

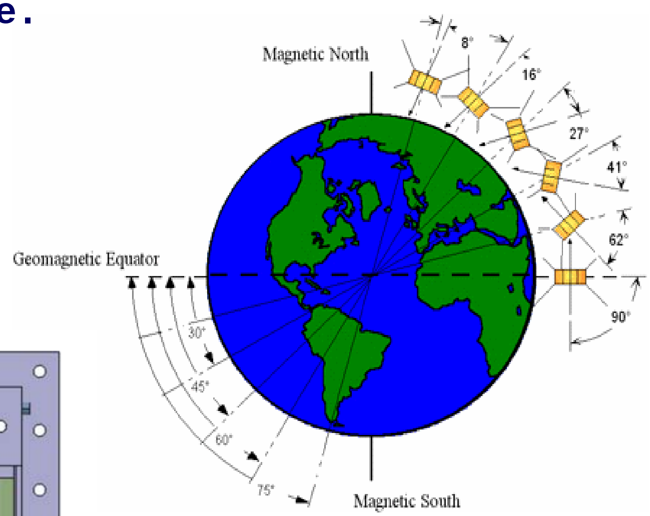
Hysteresis plates as passive dampers to lessen the oscillation



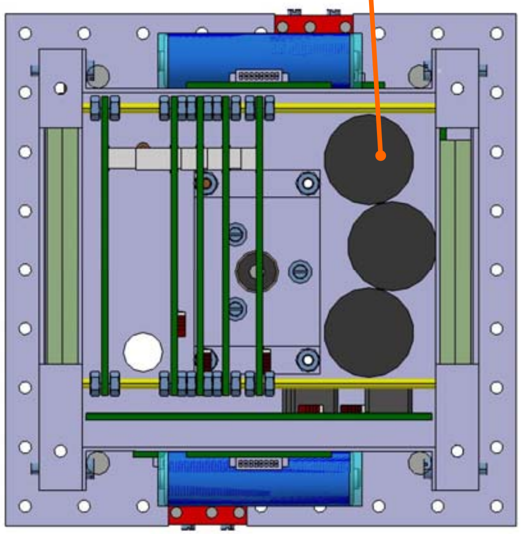
Favourable orientation of the Earth magnetic field vector in the geographical area of Europe

Layout: attitude control

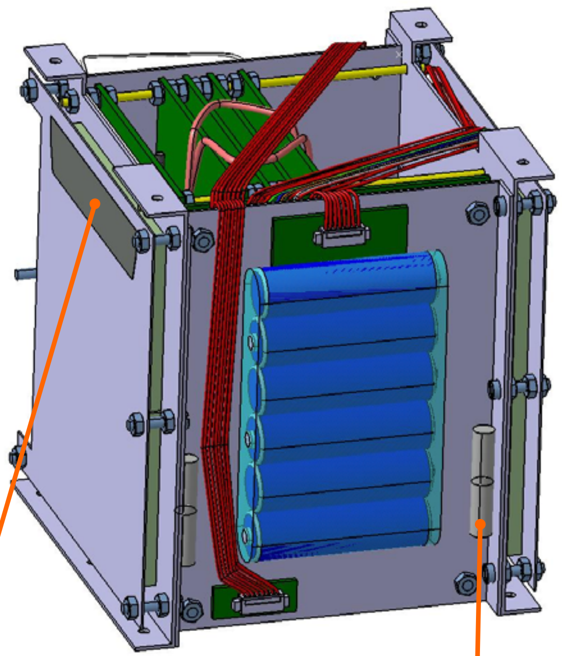
The magnets are mounted in the inner shell of the satellite and are oriented such that PiCPoT's top bottom panel (F0), where the camera lenses are installed, will face Earthward when over the northern hemisphere and out to space when over the southern hemisphere.



Top view:
camera lenses



Hysteresis plate
39 (radius) x 0.5 mm



Permanent magnet
30mm x diam 5 mm (2X)

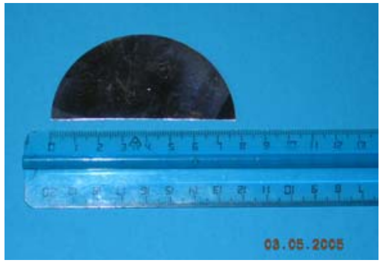
Layout: attitude control

Neodymium 27 SH

Characteristic	Value
Curie Temperature, T_C	310°-340° C
Working Temperature, T_w	150° C
Density, ρ	7.4 g/cm^3
Coercitive Field, H_c	9600-10500 Oe
Residual Induction, B_r	1.2-1.6 T

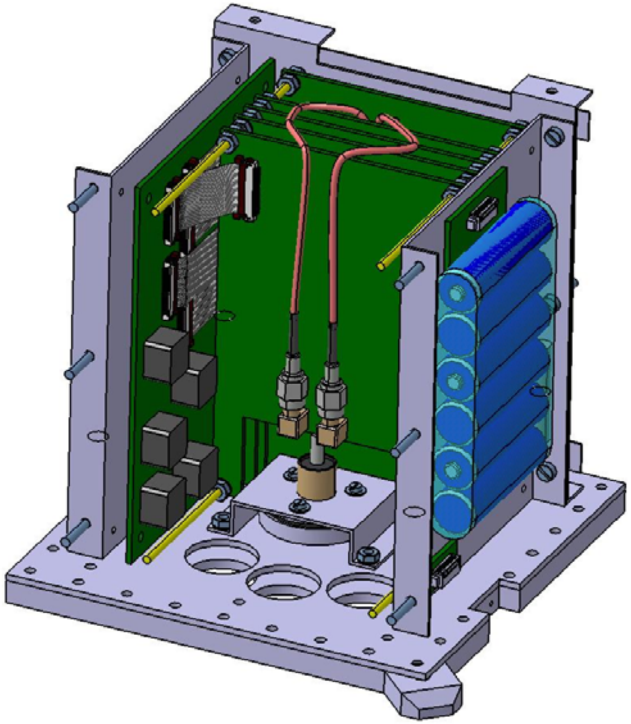
Hydrogenized Iron (Cioffi)

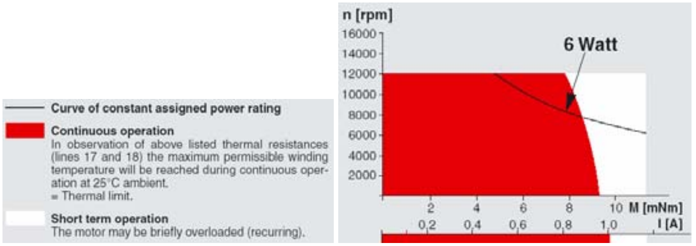
Characteristic	Value
Density, ρ	7.4 g/cm^3
Coercitive Field, H_c	4 A/m
Residual Induction, B_r	2.1 T
Saturation Induction, B_S	2.15 T
Dumped Energy (cycle)	$8.6*10^{-6}$ J/cm^3



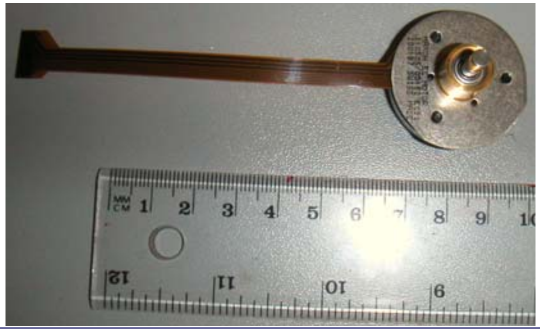
Layout: attitude control

- The passive control stabilizes the satellite only about two axes. To achieve a complete three axes control, a reaction wheel is mounted on the x-body axis.
- As the attitude determination software is not present on board, the active control about the x axis is possible only when the satellite flies over the effective horizon.
- The active control is not necessary to satisfy the requirement of taking picture of Europe. The main interest lies in testing the reaction wheel itself, which is constituted by a brushless motor.

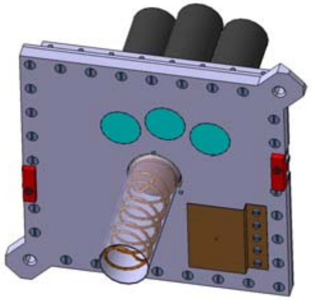


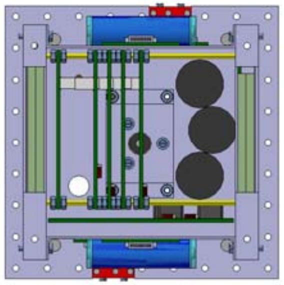


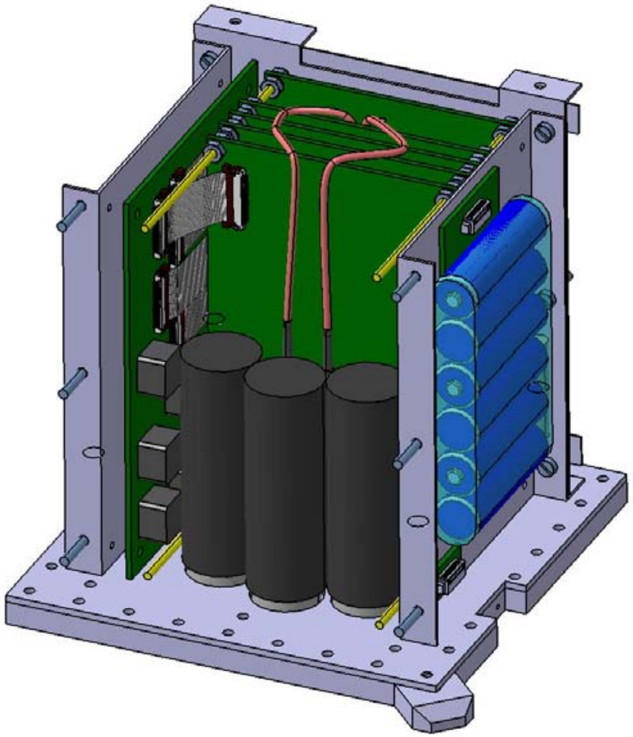
Maxon EC 32 flat motor data	Value
Power rating [W]	6
Nominal voltage [V]	9
No load speed [rpm]	8600
Stall torque [mNm]	20
No load current [mA]	110
Max. continuous current at 5000 rpm [A]	1.03
Rotor inertia [g*cm^2]	13.9
Weight [g]	32
Ambient temperature range [°C]	-40/+100



Layout: Payload

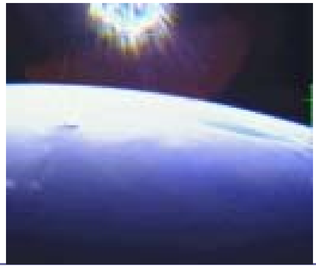


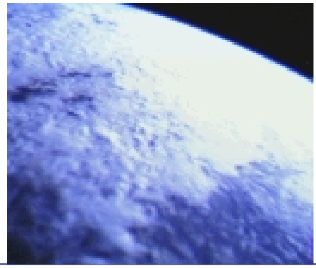




- Three cameras (redundancy) with the longitudinal axis aligned with the x body axis. Camera lenses are mounted on the interface plate (F0).
- Three cameras have different focal length and resolution of 512 rows x 582 columns.
- The cameras are manufactured by ITEM srl – Torino.

Camera	Focal length	FOV on the ground	Resolution on the ground
T1	3.6 mm	750 km	800 m/pixel
T2	6.0 mm	450 km	500 m/pixel
T3	16.0 mm	170 km	180 m/pixel



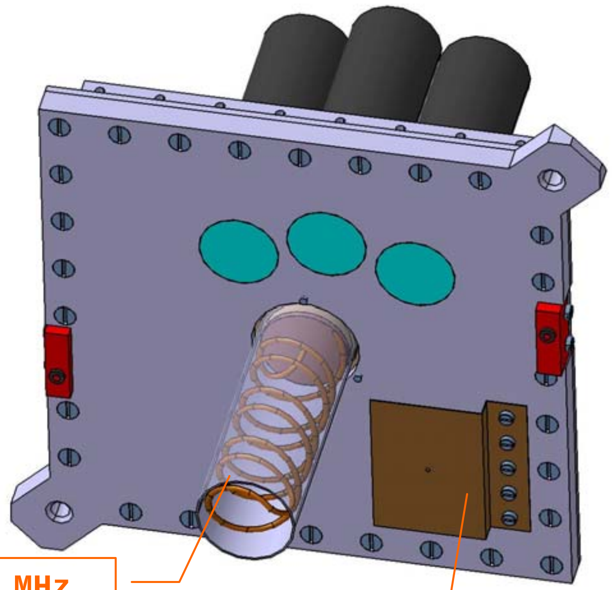


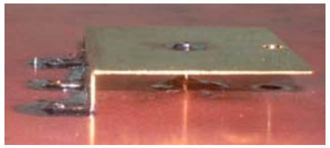
Layout: antennas

The interface between PiCPoT and the Earth is guaranteed by two antennas characterized by two different communication channels (redundancy) both working in amateur frequencies.

- One double-helical antenna (435 MHz)
- One PIFA (Planar Inverted F Antenna) antenna (2.4 GHz)

Both antennas transmit and receive RF signals.



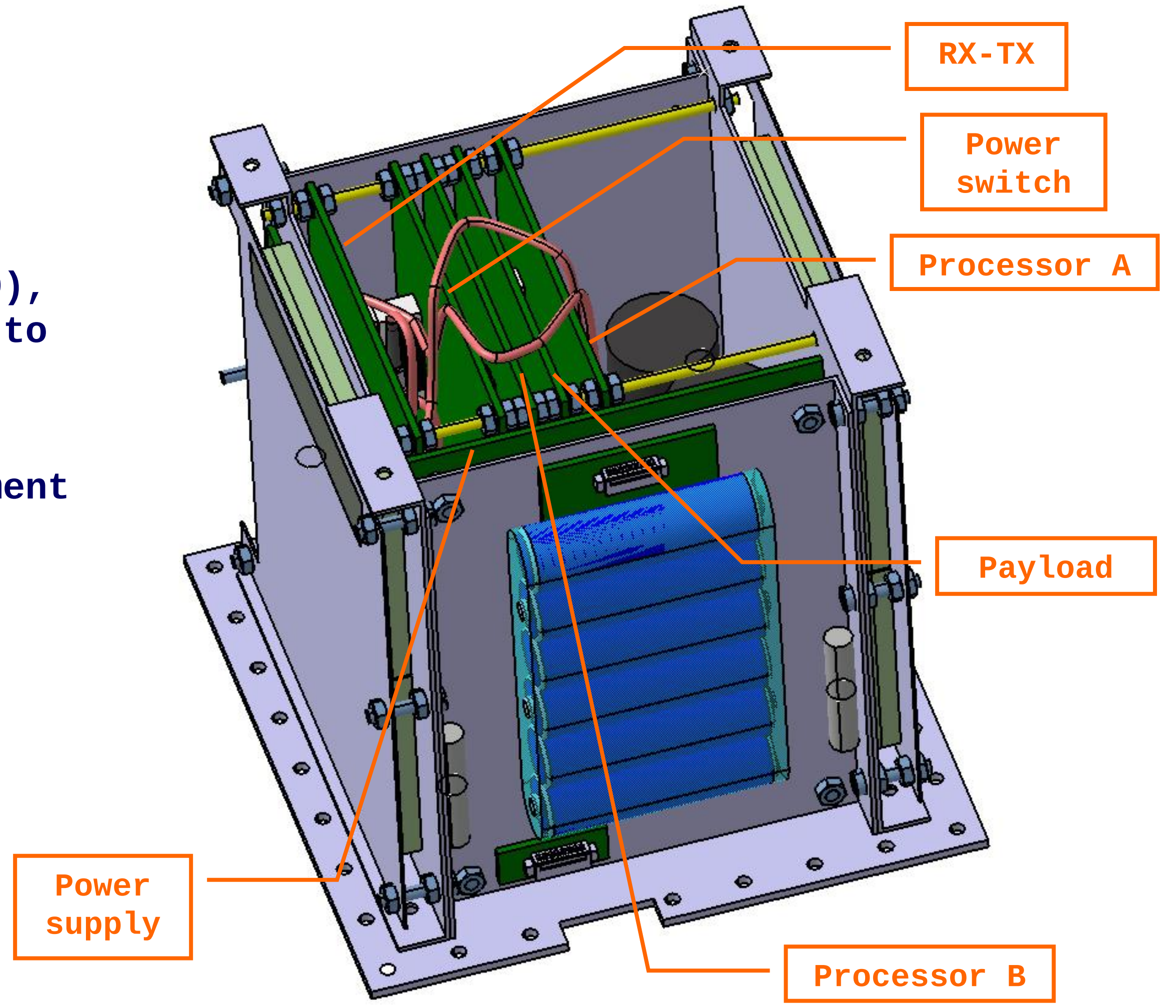


Layout: command & data handling

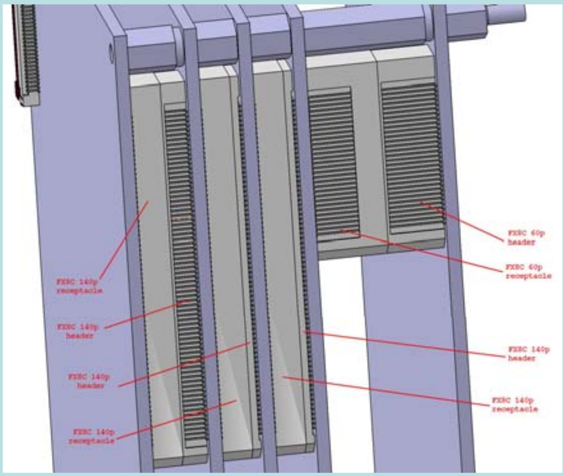
PiCPoT has three indipendent processors on board.

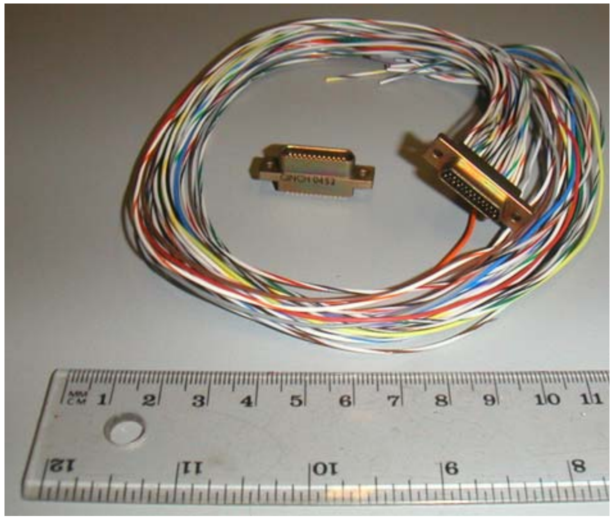
1. Processor A (Chipconn 1010), for housekeeping, devoted to 435 MHz communication channel.
2. Processor B (Texas Instrument MSP430), for housekeeping, devoted to 2.4 GHz communication channel.
3. Payload processor (Analog Devices BlackFINN), for payload management.

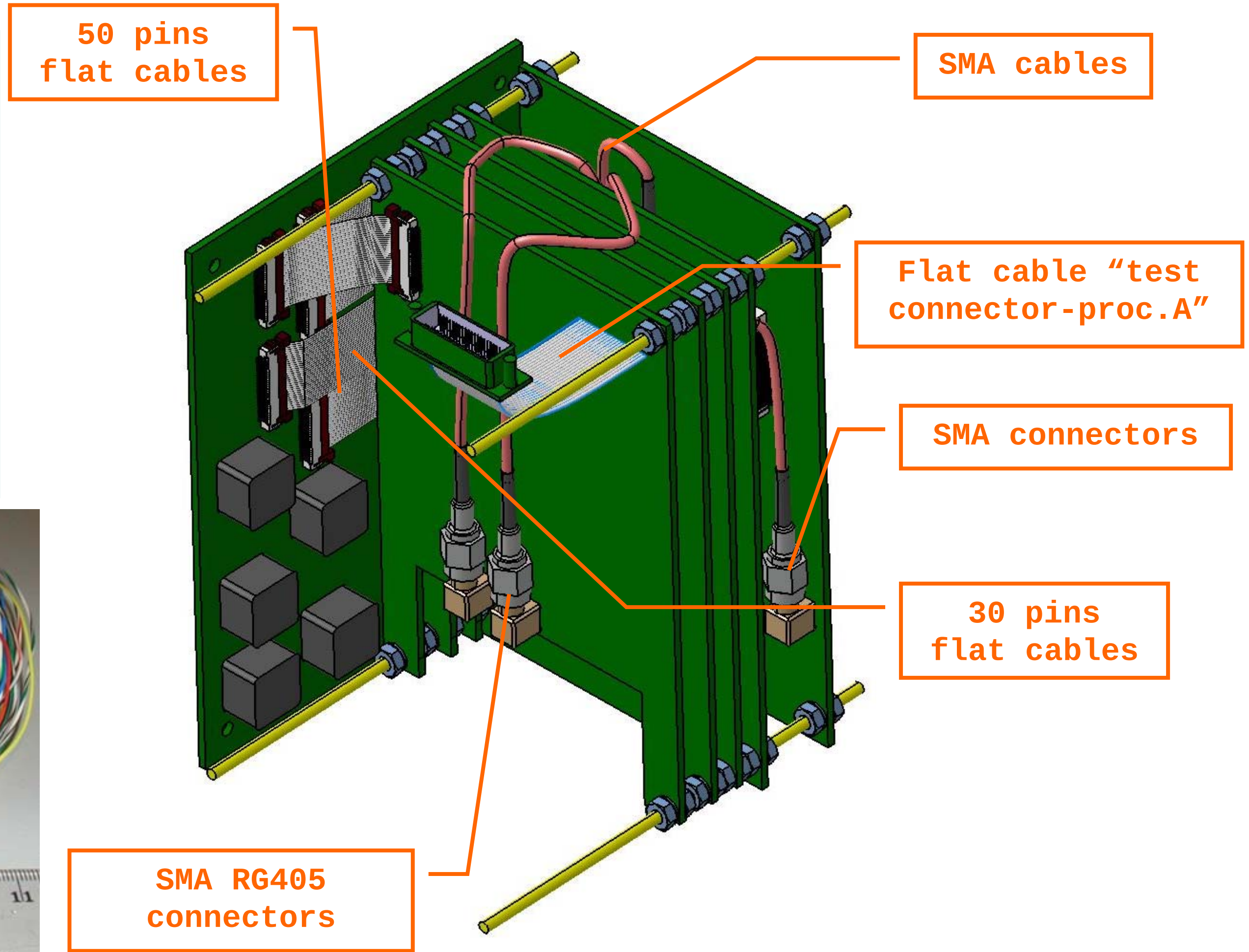
Processor A and B double the main satellite functions.



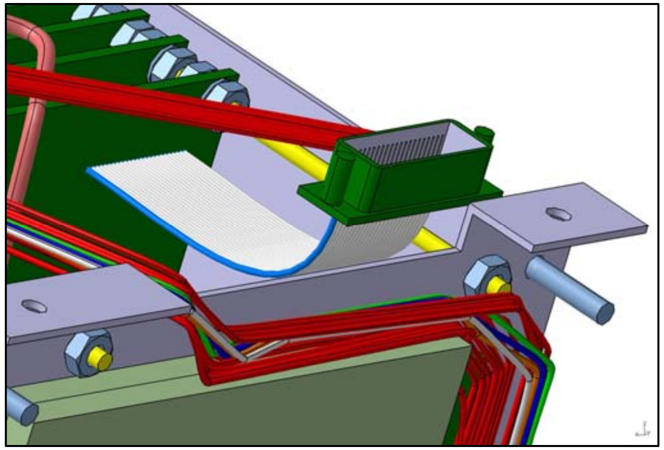
Layout: connections & wirings

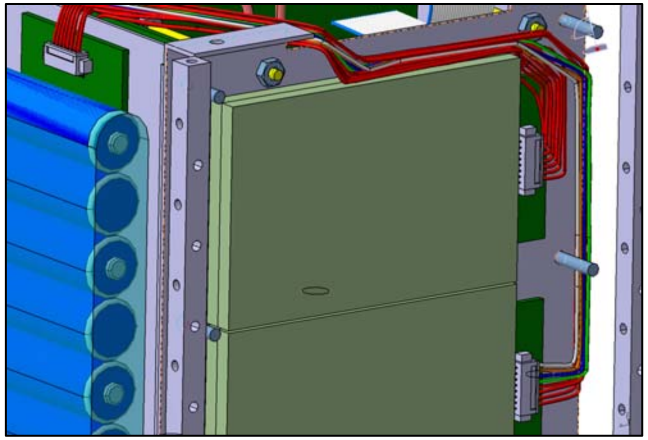


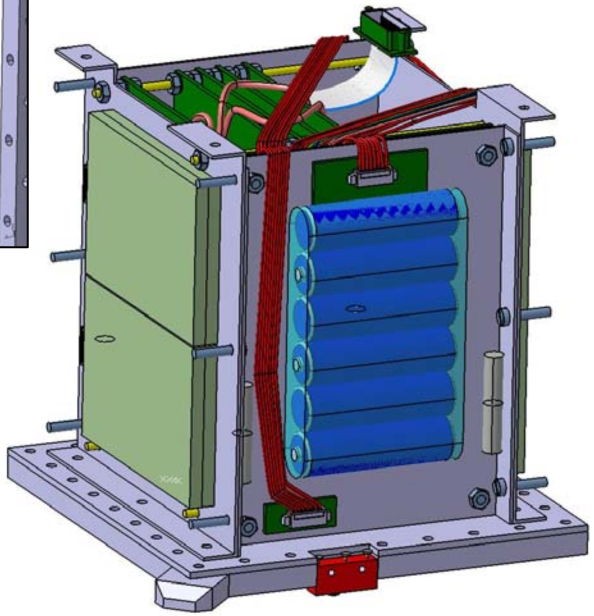


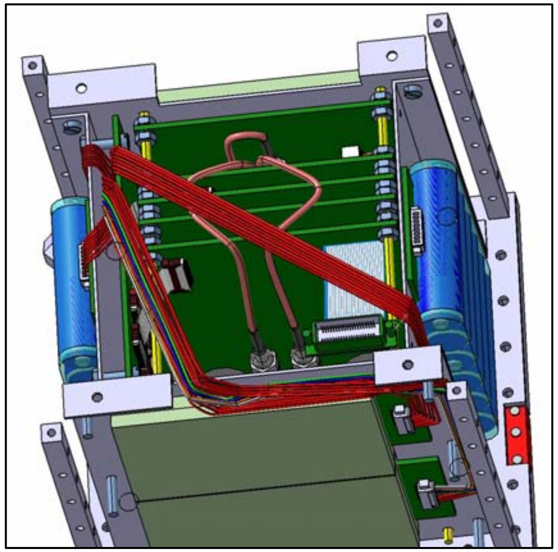


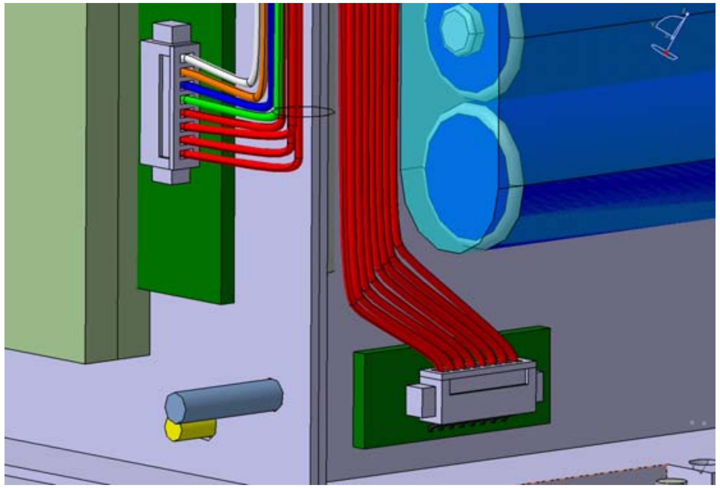
Layout: connections & wirings











Campagna Sperimentale

Requirements

	YUZHNOYE design office	DOC № DNR YZH ICD 001 00 ISSUE: 1	DATE: PAGE 1 of 190

DNEPR PROGRAM

SPACE LAUNCH SYSTEM

INTERFACE CONTROL DOCUMENT

For BelKA SC, Baumanets SC, UniSat-4 SC, PicPot SC, P-Pod Containers with CubeSat SC and Dnepr Launch Vehicle

Requirements have been established by the Kosmotras Company and the Yuzhnoye Design Office, and are listed in the ICD.

The requirements relate to:

- ❑ **Spacecraft dimensions and mass**
- ❑ **Electromagnetic compatibility**
- ❑ **Structural design**
- ❑ **Operational conditions**

SC characteristics in compliance with requirements must be demonstrated by dint of computations and ground testing procedures.

Requirements & verification: planning

- Some verifications were required by the Companies involved in the program. The ICD states exactly which ground tests have to be performed and the procedures which must be followed.
- Other verifications have been established by the design team to test the quality of the spacecraft. Most of these verifications have been performed via computation and analyses. On the basis of the operational conditions described in the ICD the following analyses and ground tests have been planned:
    - Stress analysis
    - Thermal analysis
    - Thermo-vacuum chamber test
    - Power supply system test
    - Electronic system test
    - Communication system test

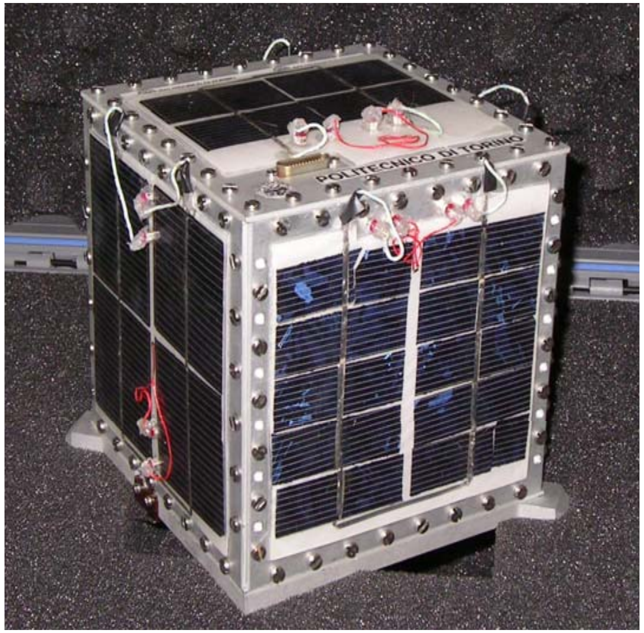
Campagna Sperimentale

2nd International Workshop on
Verification and Testing of Space Systems

Requirements & verification: FIT CHECK

In order to verify the geometrical compliance of the spacecraft with the launch vehicle, PiCPoT has been undergone to the FIT CHECK. The test has been done at the Yuzhnoye plant in Dnepropetrovsk (Ukraine) in November 2005. PiCPoT passed the test successfully!

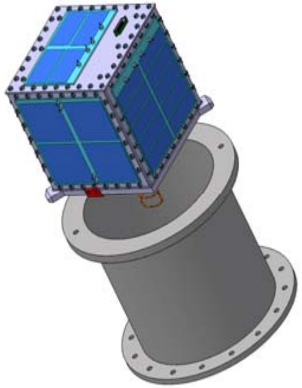
- **The fit check has been conducted by means of a mock up of the satellite and the launcher adapter designed by Yuzhnoye Design Office for the purpose.**
- **The PiCPoT mock up has been installed on the adapter by means of two special screws and the pyrotechnical mechanism has been fixed.**
- **The mock up and the adapter have been mounted together on the Space Head Module (SHM).**
- **The clearances between PiCPoT and the SHM have been measured and they ensure collision-free mating and separation.**

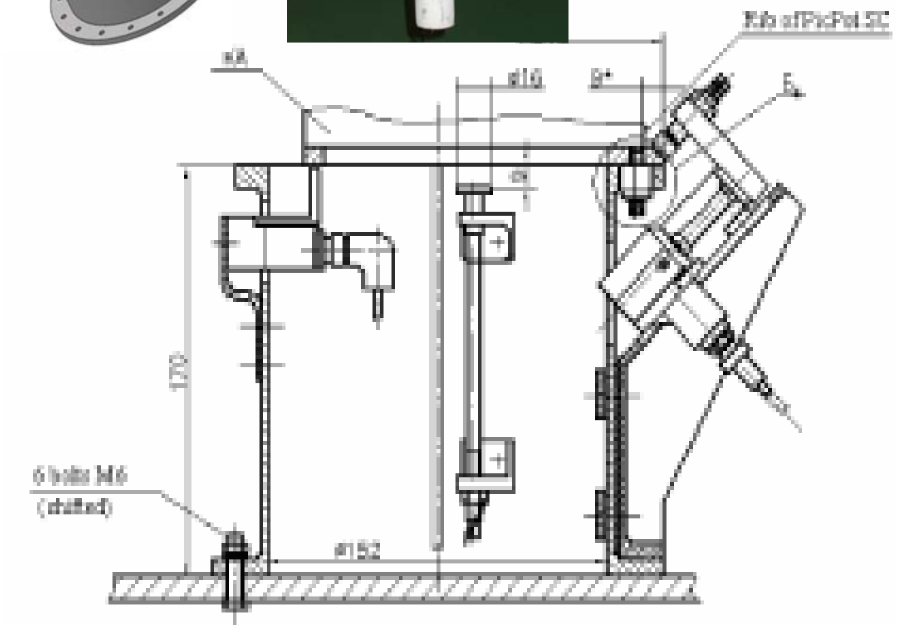


Campagna Sperimentale

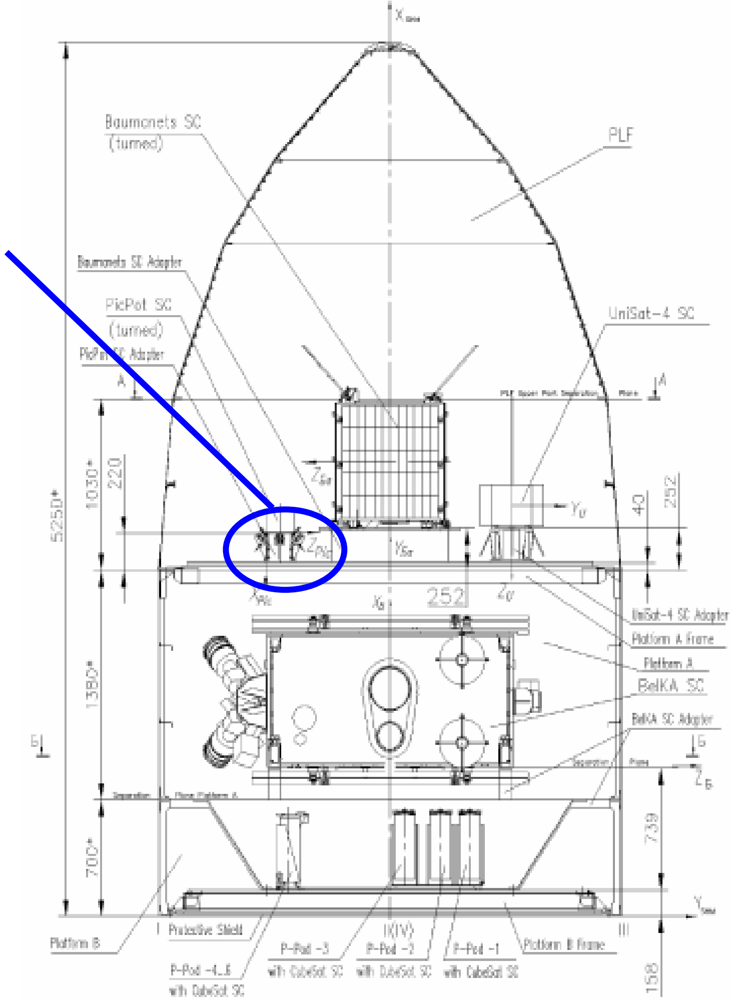
2[nd] International Workshop on Verification and Testing of Space Systems

Requirements & verification: FIT CHECK





PICPOT



Campagna Sperimentale-
-verifiche di calcolo

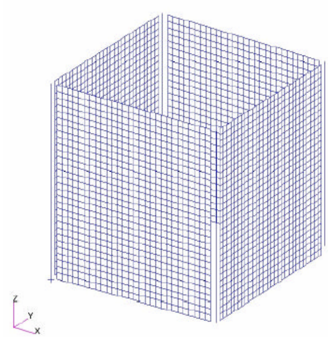
Requirements & verification: static loads

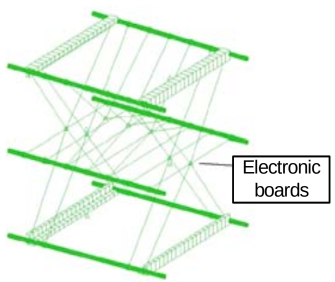
To obtain the qualification for the launch, the SC must carry the following values of g-loads (from ICD):

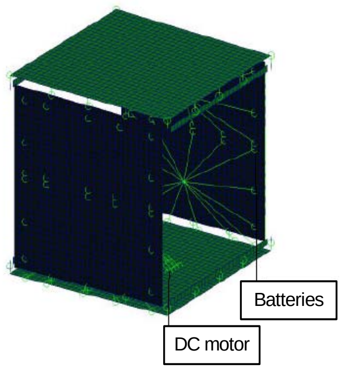
Table 6.1 – Maximum g-load values for qualification and acceptance tests

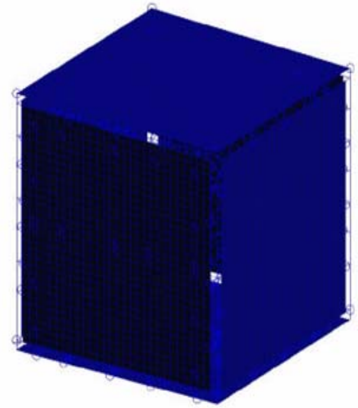
		Qualification tests	Acceptance tests
Flight	Longitudinal g-load, un.	10.0	7.7
	Transverse g-load, un.	1.3	1.0
Transportation	Longitudinal g-load, un.	0.8	0.4
	Transverse g-load, un.	3.4	1.7

To verify the compliance of the satellite with the loads acting during all launching phases, a FEM model of the SC has been carried out and loaded with the required accelerations.





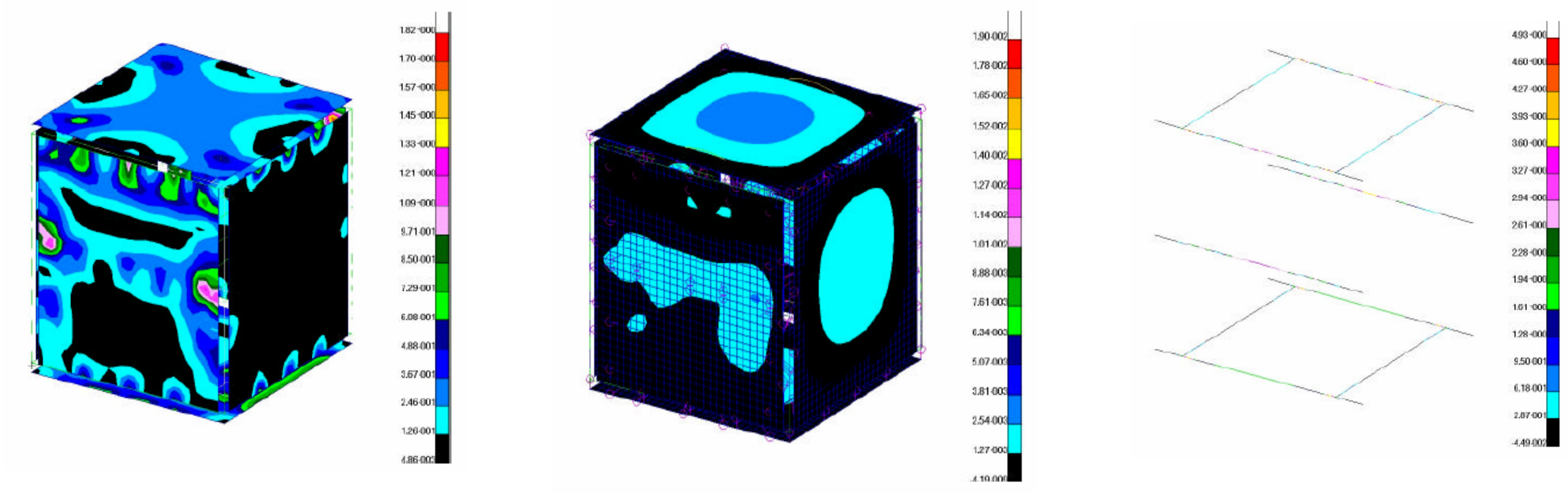




Campagna Sperimentale-
-verifiche di calcolo

2[nd] International Workshop on
Verification and Testing of Space Systems

Requirements & verification: static loads

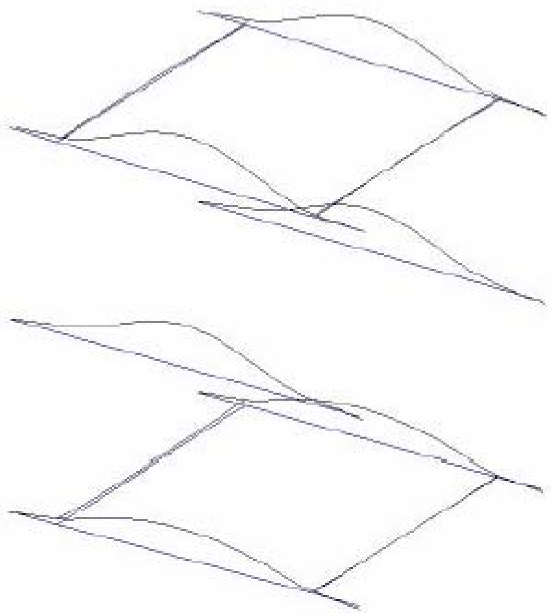


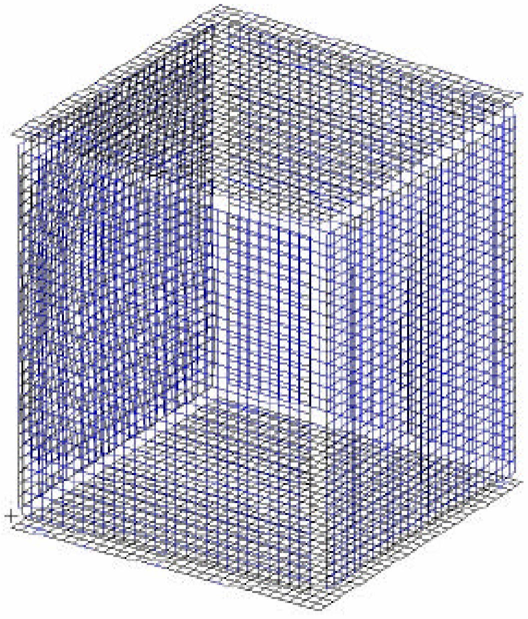
The analysis shows that no problems will arise with respect to this aspect. In fact the maximum stress achieved on the structure is much lower of the ultimate strength of the material

Campagna Sperimentale-
-verifiche di calcolo

Requirements & verification: resonance frequency

The spacecraft characteristics have also been computed and verified by means of a FEM model of PiCPoT SC. The stiffness characteristics – primary resonant frequency is 400 Hz for x, y and z orthogonal axes. The pictures below show the vibration mode of the internal and external structure respectively

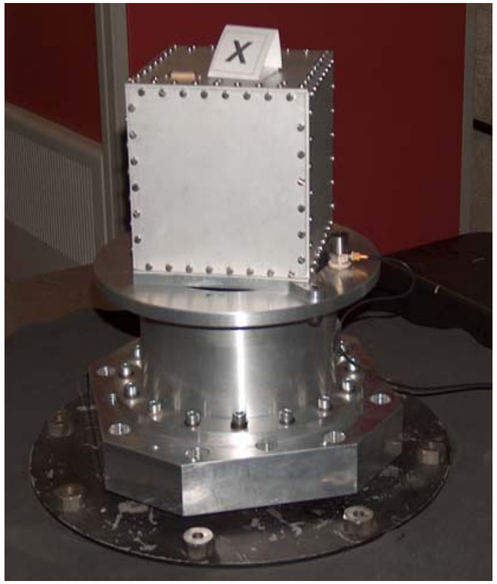




Campagna Sperimentale

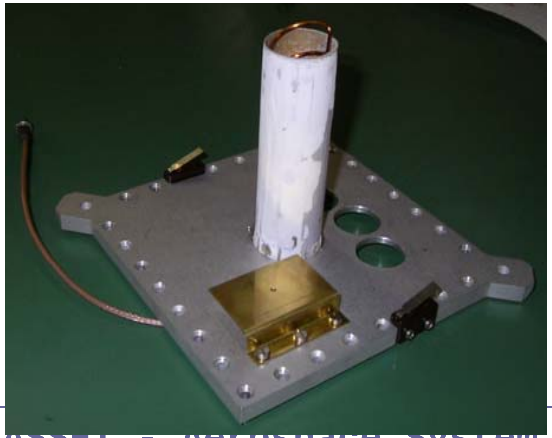
2nd International Workshop on
Verification and Testing of Space Systems

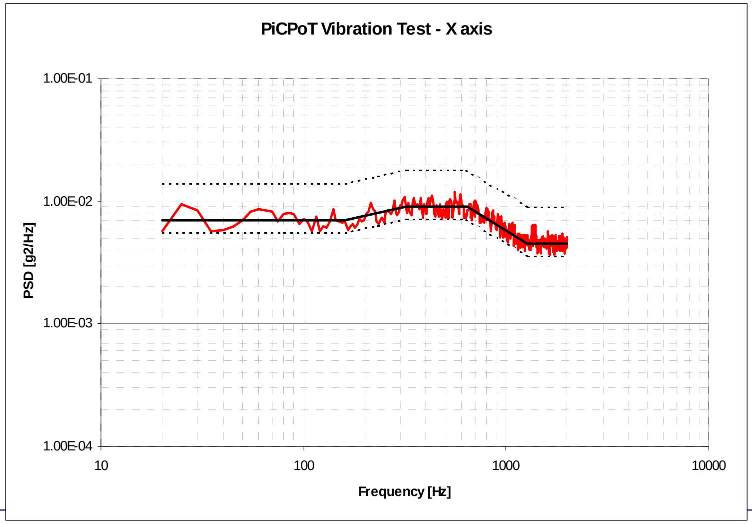
Test for Mechanical load: random vibrations



Ground tests have been conducted at the laboratories of Alcatel Alenia Space in December 2005.

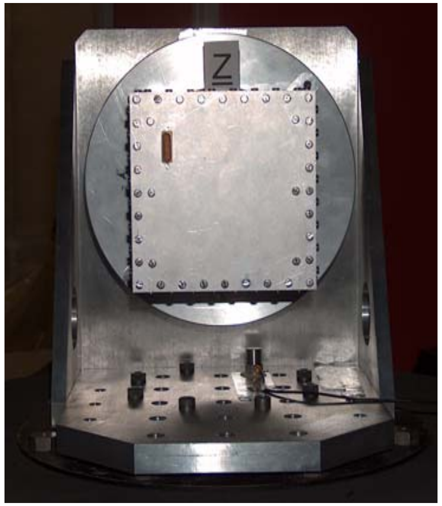
The SC has been put to test characterized by the recommended frequency spectra, for x, y and z orthogonal axes respectively.

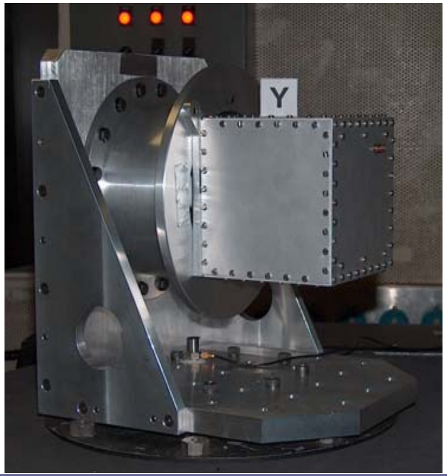




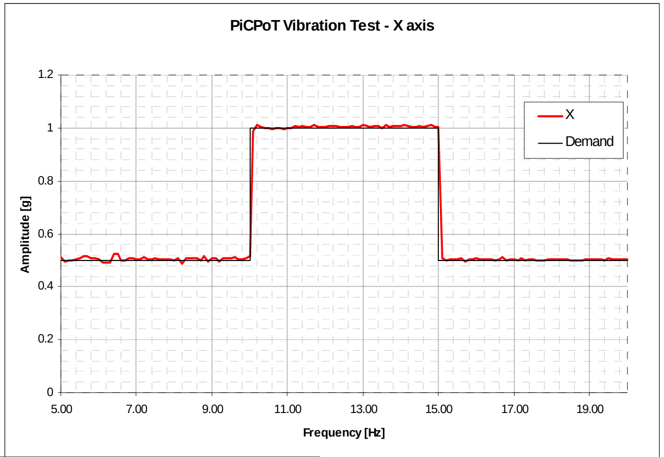
Campagna Sperimentale

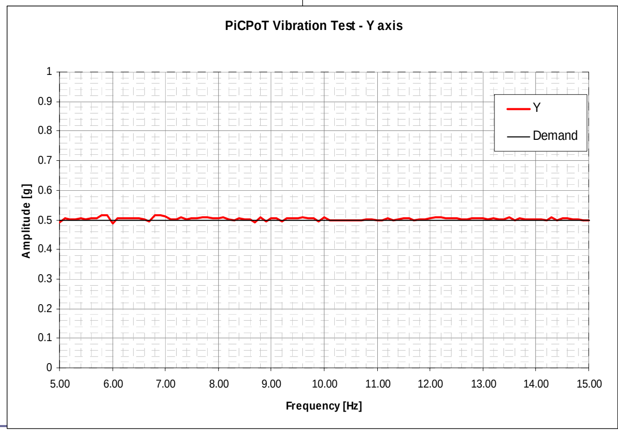
Test for Mechanical load: sinusoidal vibrations

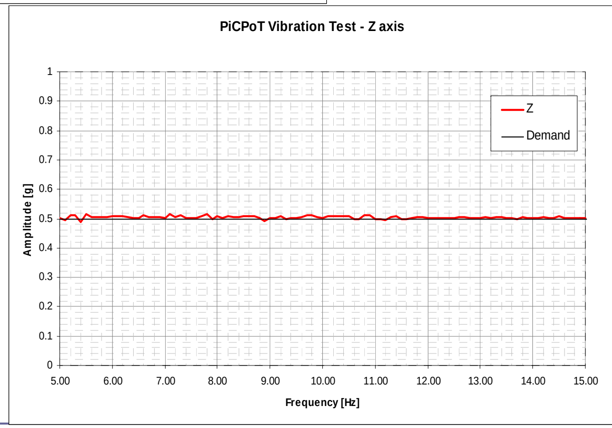




The SC has been put to test characterized by the recommended frequency spectra, for x, y and z orthogonal axes respectively.







Campagna Sperimentale

Requirements & verification: conclusions

- **The computations and tests which have been performed have shown that the spacecraft satisfies all the requirements with margin.**
- **At the moment PiCPoT is under testing to verify the electromagnetic compatibility.**
- **Shock and Acoustic loads tests have been performed by Yuzhnoye in Ukraine. PiCPoT has passed the tests successfully.**
- **Thermo-vacuum tests have already been performed on PiCPoT components. A complete thermo-vacuum test will take place next month at Università Federico II in Napoli, where the satellite will also be tested in a sun simulator.**

Contratto LANCIO

		DOC № DNR YZH ICD 001 00
Dnepr	YUZHNOYE design office	ISSUE: 1 DATE: PAGE 1 of 190

DNEPR PROGRAM

SPACE LAUNCH SYSTEM

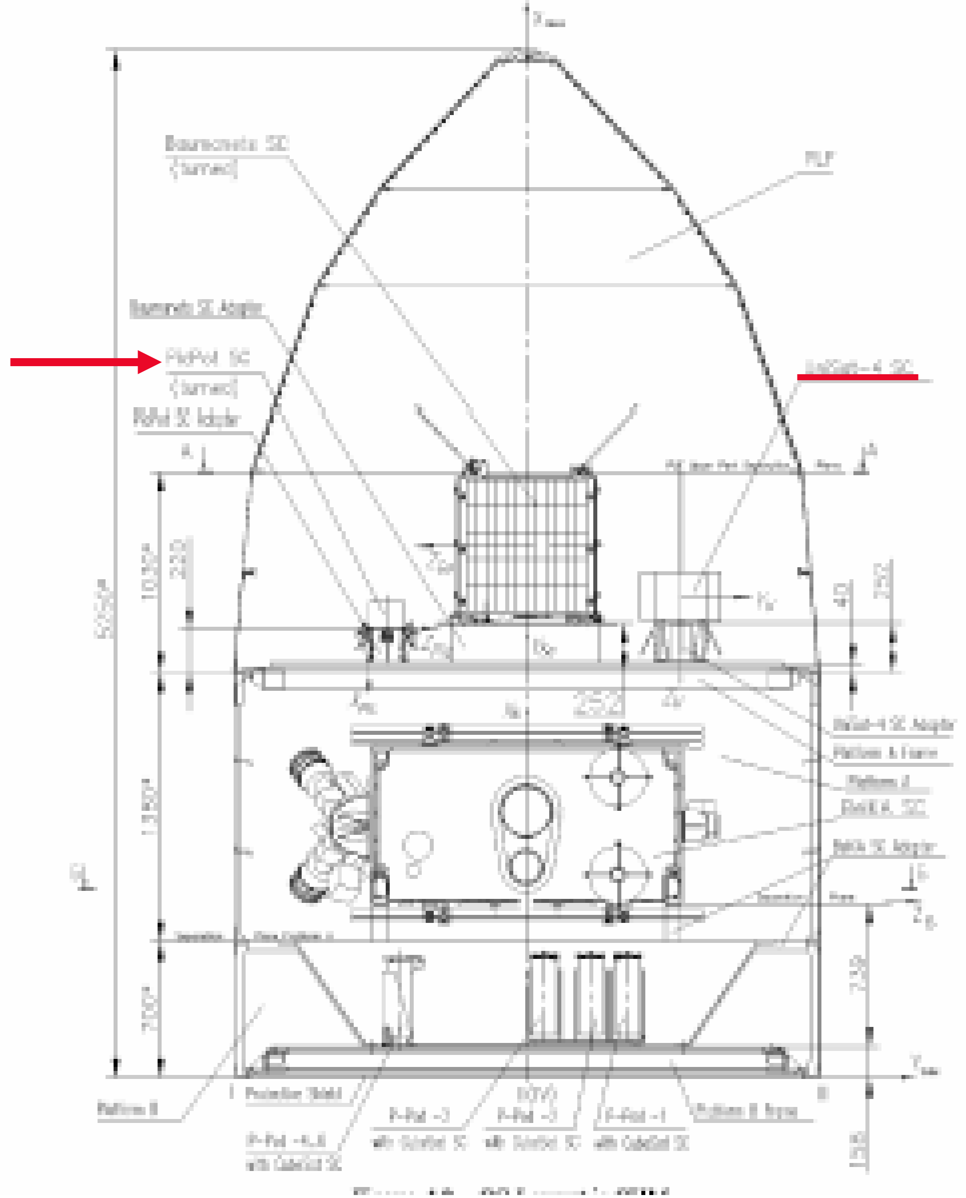
INTERFACE CONTROL DOCUMENT

For BelKA SC, Baumanets SC, UniSat-4 SC, PicPot SC, P-Pod Containers with CubeSat SC and Dnepr Launch Vehicle

Cal Poly State University Foundation, USA	University of Rome, Italy	First Deputy General Director of ISC Kosmotras	General Designer - General Director of Yuzhnoye SDO
Jill Keezer	F. Graziani	V.S. Mikhailov	S.N. Konyukhov

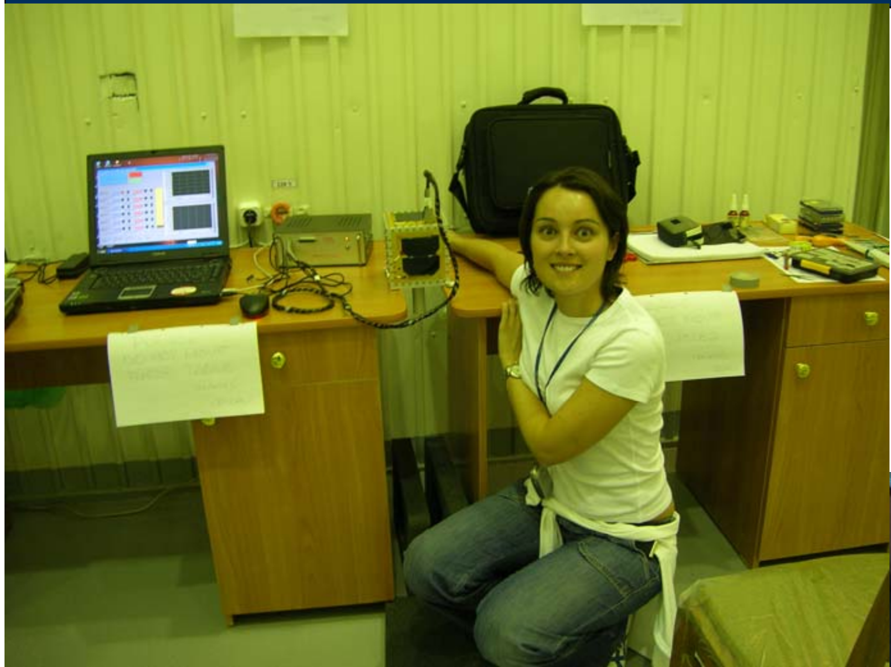
Chief Designer of Dnepr Program

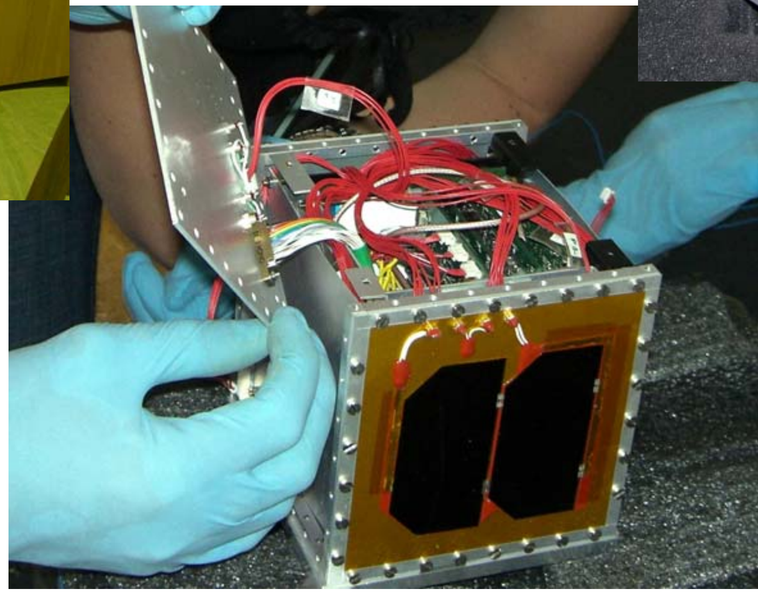
S.I. Us

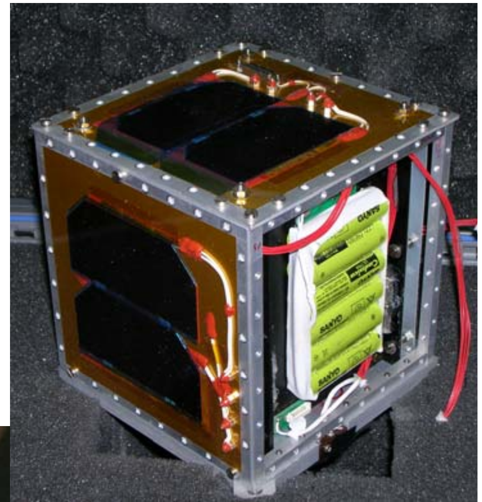


BAIKONUR

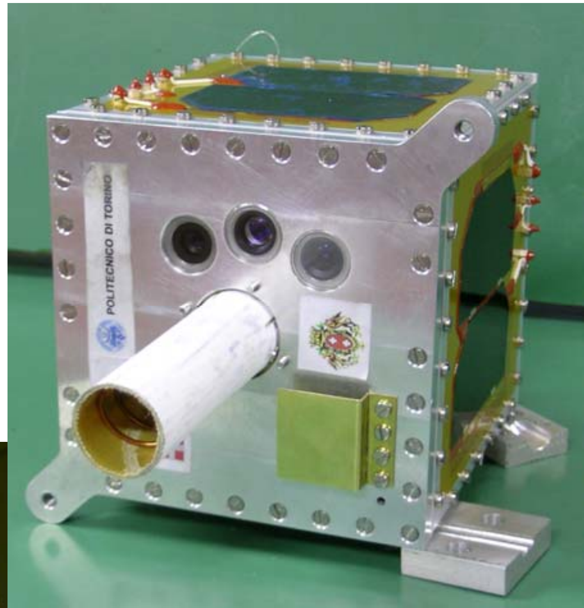
PiCPoT Integration

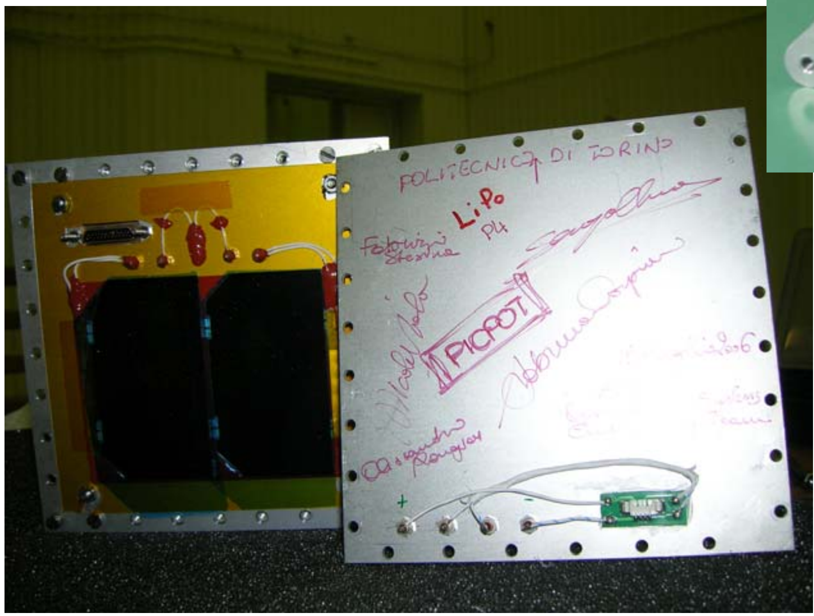


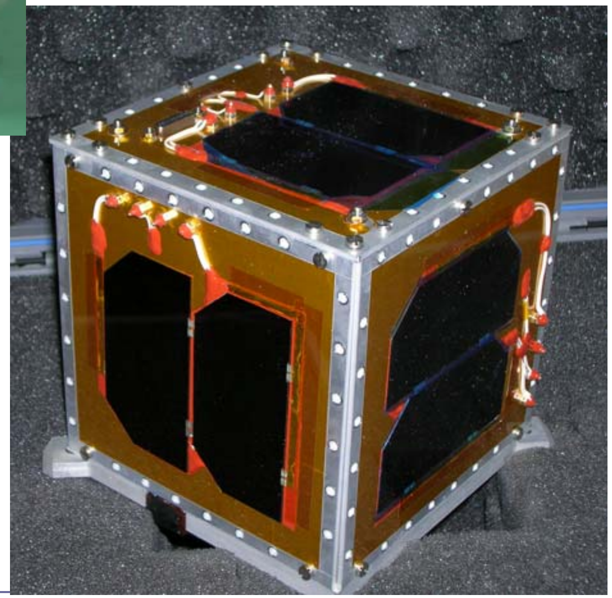




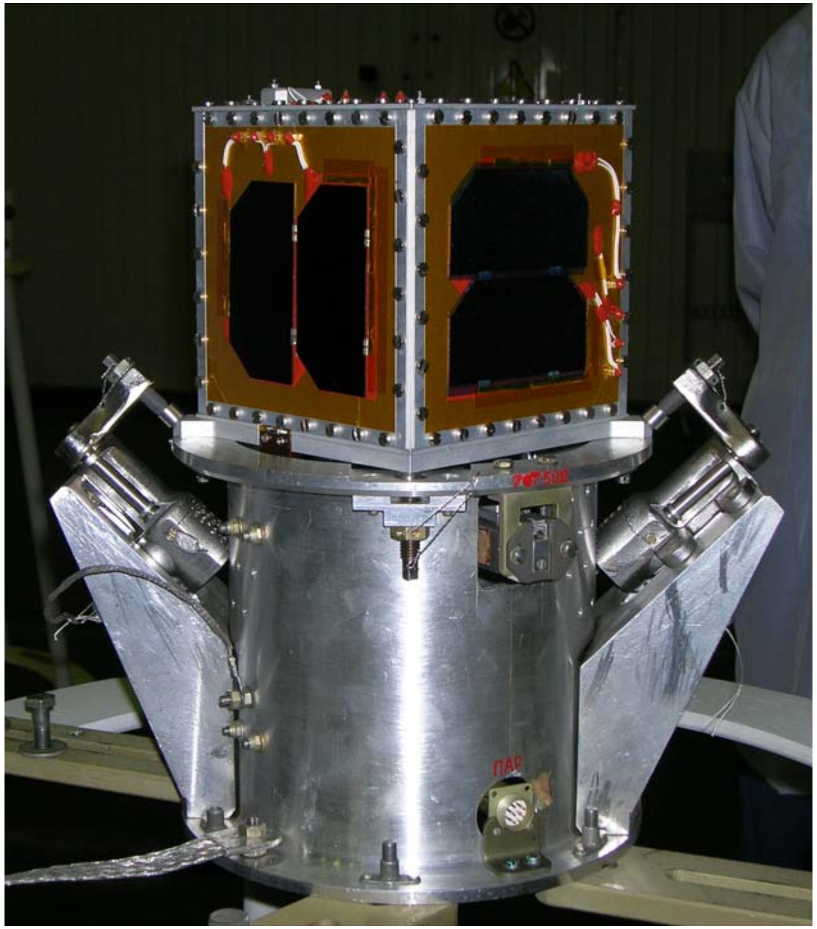
Here is PiCPoT !



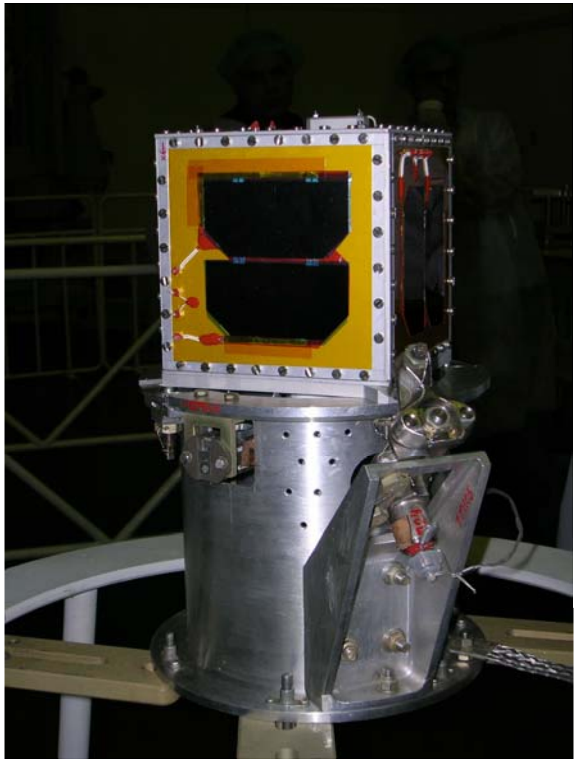




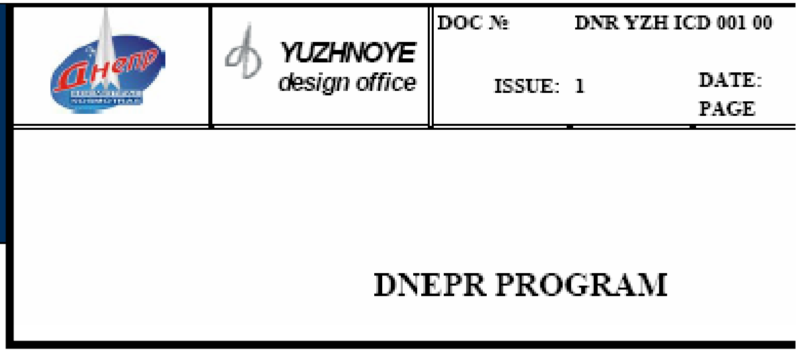
PiCPoT Launch Tests



BAIKONUR:integration on Launcher



Previsione del volo



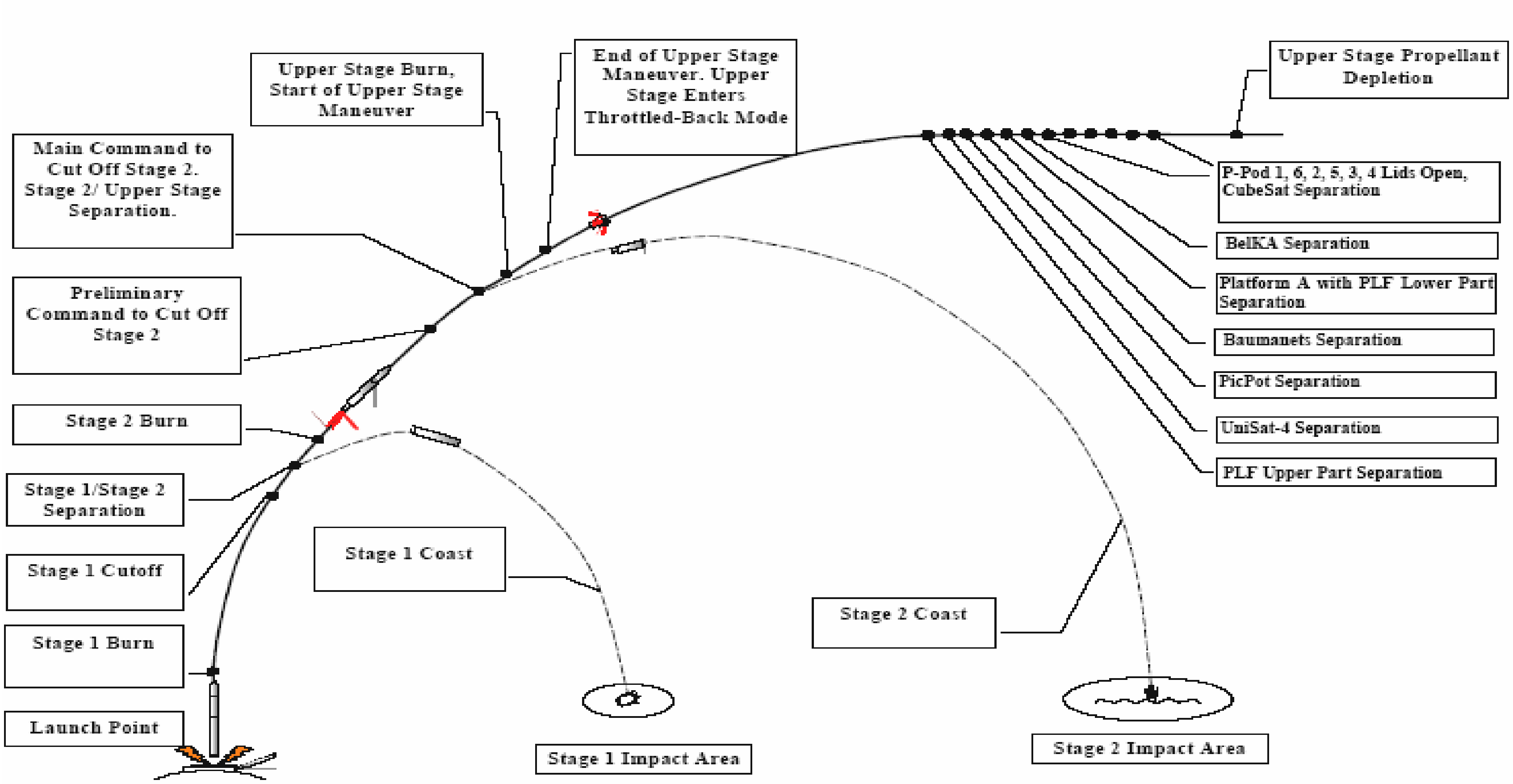


Figure 4.12. Multiple-Satellite Injection Profile (Launched by RS-20)

LANCIO

La strage degli Innocenti

July

Date	Site	Launcher	Payload	Country	Mission	Operator	Prime	Platform	Mass	Orbit
04	Kennedy	Discovery	STS-121	U.S.	Manned	NASA/JSC	Boeing	OV-103	121,094 kg	LEO/ISS
			Leonardo	U.S.	ISS Cargo	NASA/JSC	Alcatel Alenia Space	MPLM	9,500 kg	LEO/ISS
04	Musudan-ri	Pekdosan 2?	Test Payload?	North Korea	Technology	CMIK	n.a.	n.a.	n.a.	Failure
09	Balasore	Agni 3	[Dummy Warhead]	India	Technology	DRDO	DRDO?	-	n.a.	Failure
10	Sriharikota	GSLV	Insat 4C	India	Communications	ISRO	ISRO	I-3K	2,168 kg	Failure
12	Yasny	Dnepr 1	Genesis PF1	U.S.	Technology	Bigelow	Bigelow	-	1,360 kg	LEO
20	Vandenberg	Minuteman 3	GT-192GM	U.S.	ICBM	U.S. Air Force	Sandia?	-	n.a.	Suborbital
21	Plesetsk	Molniya M	Kosmos	Russia	Early Warning	VKS	NPO Lavochkin	Oko	1,750 kg	HEO
26	Baykonur	Dnepr 1	BelKA	Belarus	Remote Sensing	Nat. Ac. Sciences	RKK Energia	Viktoria	250 kg	Failure
			Baumanets	Russia	Technology	Roskosmos	NPO Mash	n.a.	80 kg	Failure
			Unisat 4	Italy	Science	Un. La Sapienza	Un. La Sapienza	-	12 kg	Failure
			PicPot	Italy	Science	Un. Torino	Un. Torino	-	3 kg	Failure
		P-Pod-A	ION	U.S.	Technology	Un. Illinois	Un. Illinois	Cubesat x 3	3 kg	Failure
		P-Pod-A	Sacred	U.S.	Technology	Un.Ariz. Tucson	Un.Ariz. Tucson	Cubesat	1 kg	Failure
		P-Pod-B	KUTESat	U.S.	Technology	Kansas Univ.	Kansas Univ.	Cubesat	1 kg	Failure
		P-Pod-B	ICEcube 1	U.S.	Science	Cornell Univ.	Cornell Univ.	Cubesat	1 kg	Failure
		P-Pod-B	Rincon	U.S.	Technology	Un.Ariz. Tucson	Un.Ariz. Tucson	Cubesat	1 kg	Failure
		P-Pod-C	SEEDS	Japan	Technology	Nihon University	Nihon University	Cubesat	1 kg	Failure
		P-Pod-C	HAUSat 1	South Korea	Technology	Hankuk Av. Un.	Hankuk Av. Un.	Cubesat	1 kg	Failure
		P-Pod-C	Ncube 1	Norway	Technology	Norsk Romsenter	Norsk Romsenter	Cubesat	1 kg	Failure
		P-Pod-D	Merope	U.S.	Technology	Montana St. Un.	Montana St. Un.	Cubesat	1 kg	Failure
		P-Pod-D	AeroCube 1	U.S.	Technology	AeroSpace Corp.	AeroSpace Corp.	Cubesat	1 kg	Failure
		P-Pod-D	PolySat 2	U.S.	Technology	Cal Poly	Cal Poly	Cubesat	1 kg	Failure
		P-Pod-E	PolySat 1	U.S.	Technology	Cal Poly	Cal Poly	Cubesat	1 kg	Failure
		P-Pod-E	ICEcube 2	U.S.	Science	Cornell Univ.	Cornell Univ.	Cubesat	1 kg	Failure
		P-Pod-E	Voyager	U.S.	Technology	Un. Hawaii	Un. Hawaii	Cubesat	1 kg	Failure

“Lessons learned”... Prospettive ...

- **Complessità del Programma di realizzazione e messa in orbita di un satellite, anche se “nano”**
- **Necessità di uno sviluppo organizzato, ben pianificato e necessità di rigorosa osservanza delle tempistiche.**
- **Prove, prove, prove. . .**
- **Prove funzionali, anche con satellite già integrato su lanciatore, tramite connettore di test**
- **volontà di effettuare tutte le prove su PiCPoT “spares”, in vista di eventuali possibilità di un altro lancio**
- **Prospettive, da esaminarsi, su nuove più razionali architetture e tecnologie elettroniche**
- **Prospettive interessanti per vari tipi di utilizzazioni dei nano-satelliti, in particolare per campo Radio-Amatoriale**