Filippo Graziani
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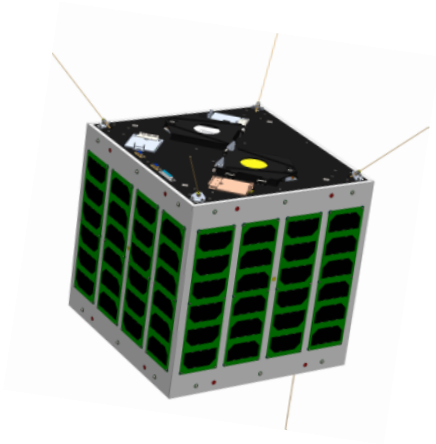
Member of IAA
Member of IAA Board of Trustees

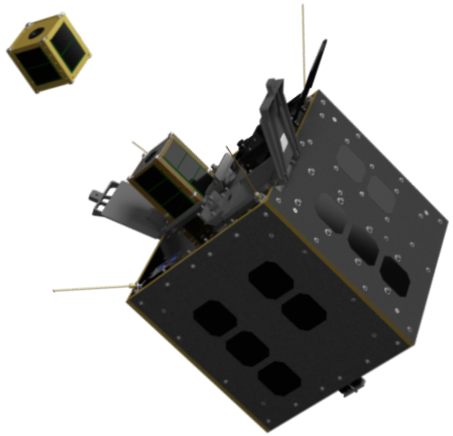
MICRO & NANO SATELLITES. PRESENT AND FUTURE

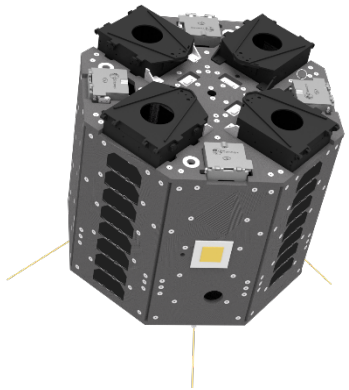
G.A.U.S.S. Srl – EUCASS 2017

GAUSS Srl

- The company name is an acronym for "*Group of Astrodynamics for the Use of Space Systems*".
- As a laboratory of Astrodynamics of Sapienza University of Rome, we have launched six microsatellites since 2000 (UNISAT-1, September 2000)
- GAUSS small satellites are used also as launch platforms for third-party satellites. As a private company (2012 on), we have successfully launched two small satellites, UniSat-5 (2013) and UniSat-6 (2014). UniSat-7 will be launched in 2018.

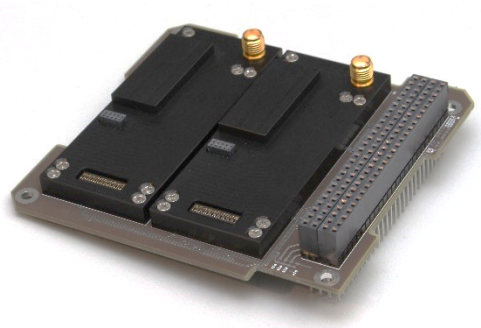


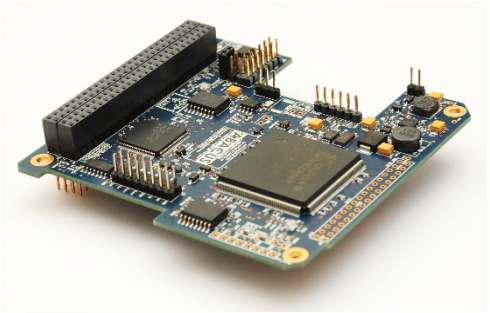


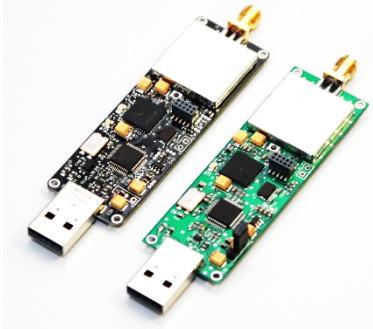


GAUSS Srl

- GAUSS Srl activities include:
  - NanoSatellite launch provider
  - Personalized Satellite bus for payloads
  - Mission analysis
  - Ground station services
  - Satellite subsystems:
    - OnBoard computers
    - Radio subsystem for TT&C
    - Power susbystem EPS

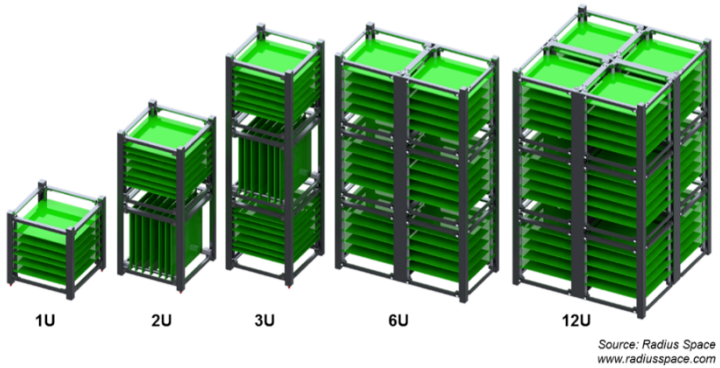






What's a Micro & Nano Satellite?

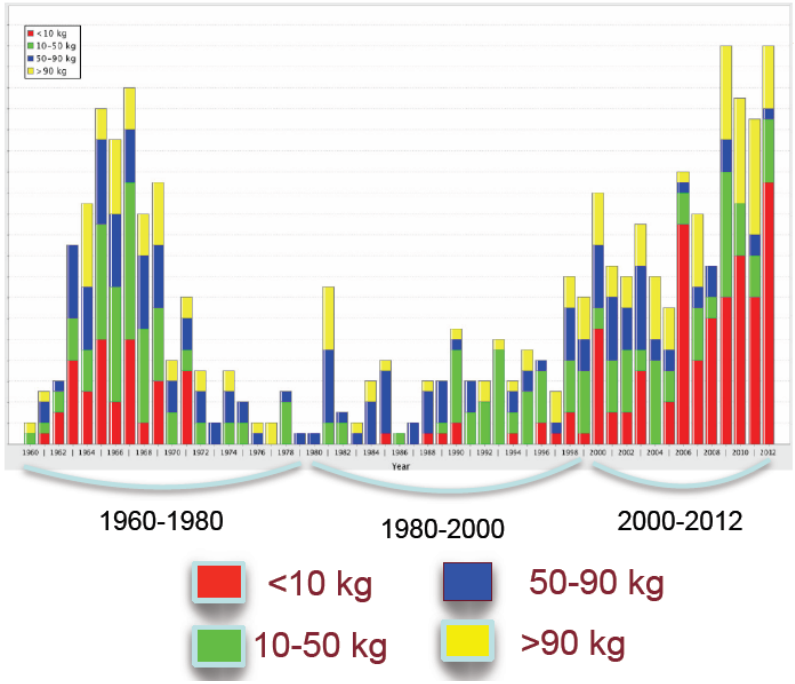
- Pico, Micro & Nano Satellites:
  - MicroSatellite: 10-100kg
  - NanoSatellite: 1-10kg
  - PicoSatellite: 0.1-1kg
  - Femto: 1-100g

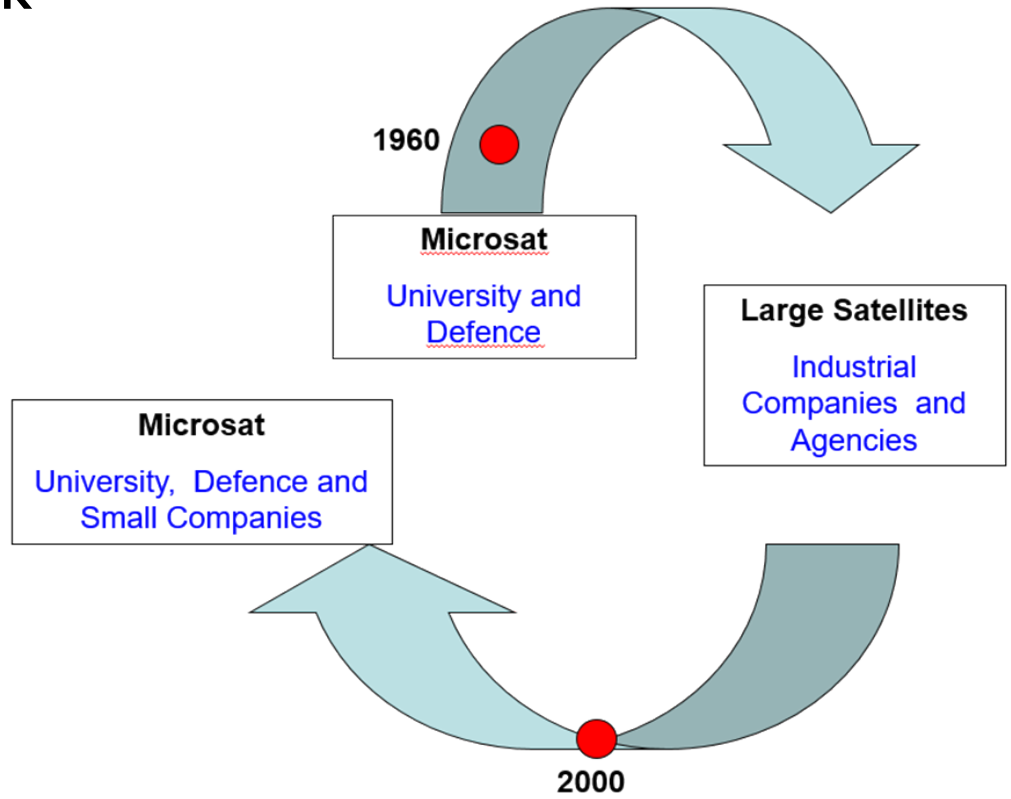


- What's a CubeSat?
  - Cube shape of 10x10x10cm (1l) with a maximum of 1.33kg. It is also called a CubeSat 1u.
  - In recent years other dimensions have become popular:
    - CubeSat 3U: 10x10x30cm, 4kg
    - CubeSat 6U: 10x20x30cm, 8kg

Microsatellites

- Microsatellites are back

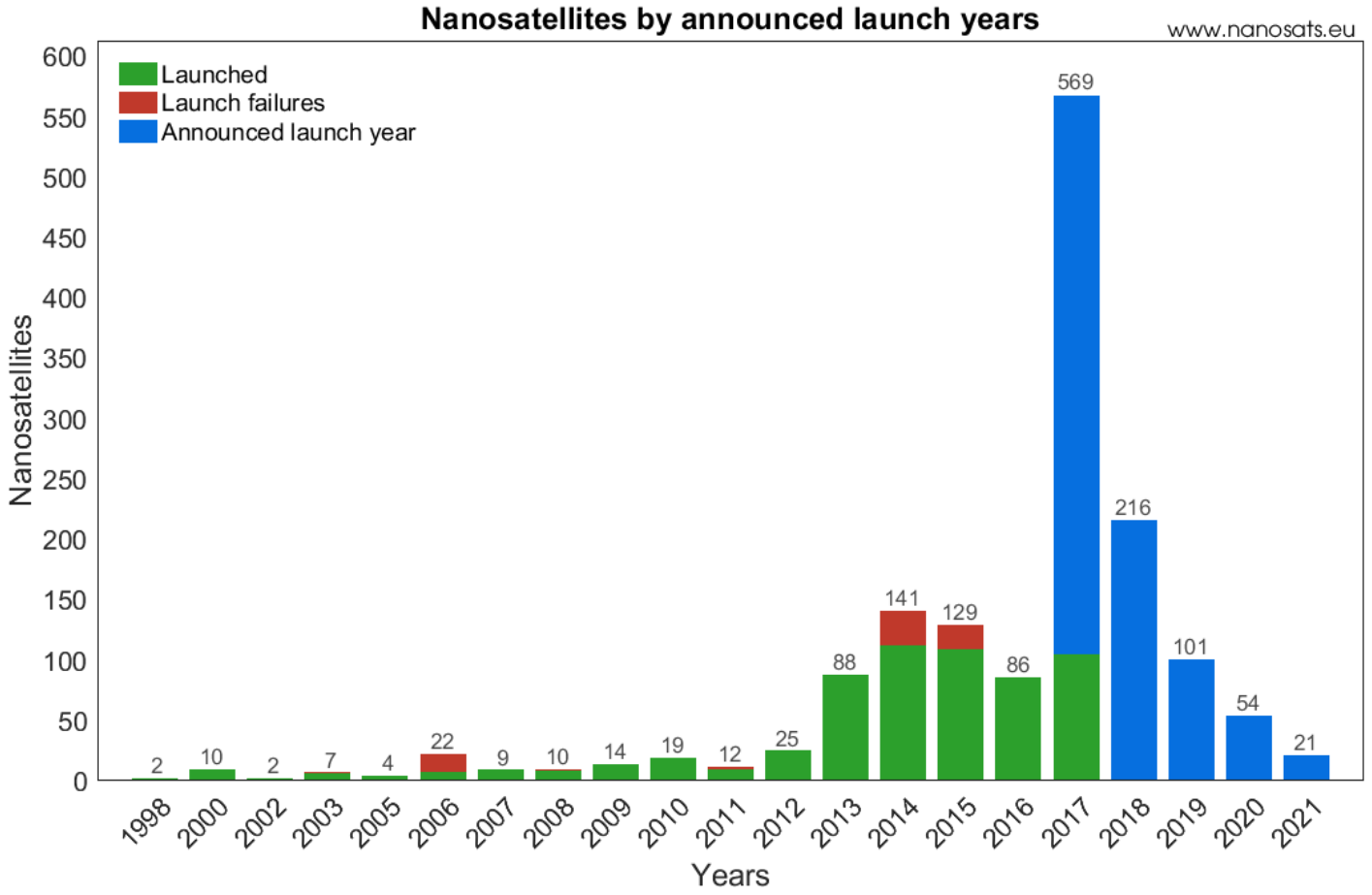




Why back to Microsatellites?

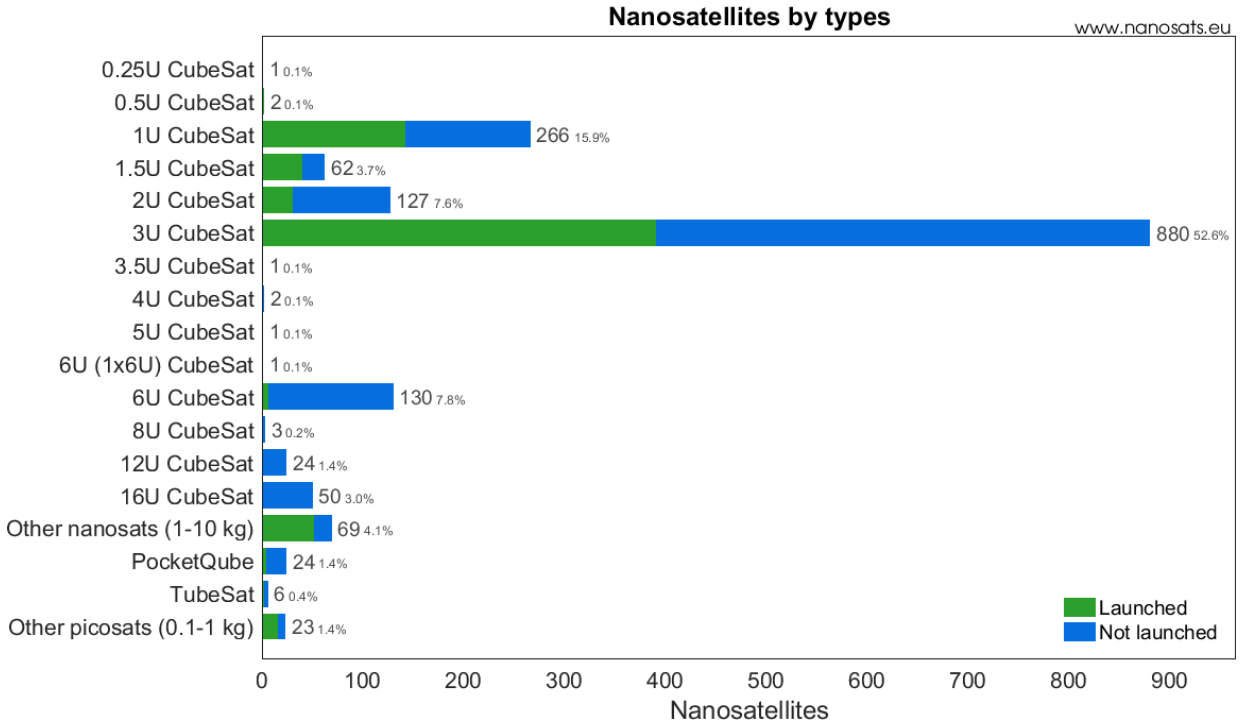
- **Miniaturization** of electronics has allowed developing high performance subsystems. (On board and payload computers, Radio, ADCS, Propulsion)
- **Reduced costs:** Mostly use of COTS electronics. Use of standards allow for a very fast construction.
- **Acceptable increased risk** of the mission: Losing one microsatellite will no longer geopardize the mission.
- Very **fast** reaction construction
- **Responsive space**, design and construction of microsatellites can be very fast and cheap in comparison with bigger satellites.

Microsatellites



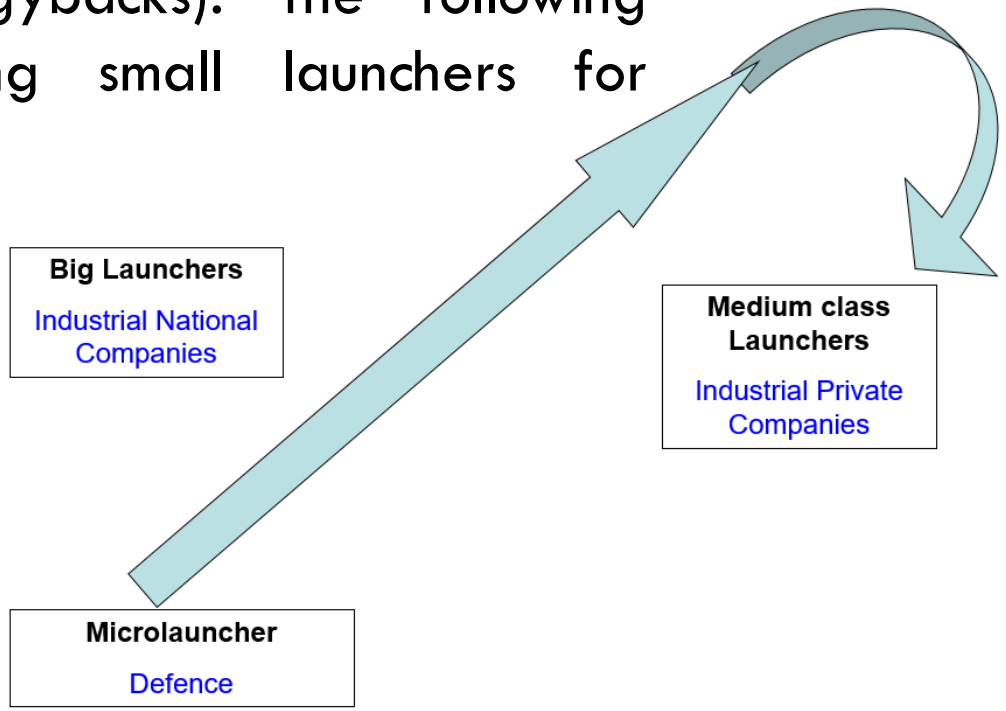
Microsatellites

- 1U and 3U CubeSats are the most popular sizes while the 6U is increasing in interest:

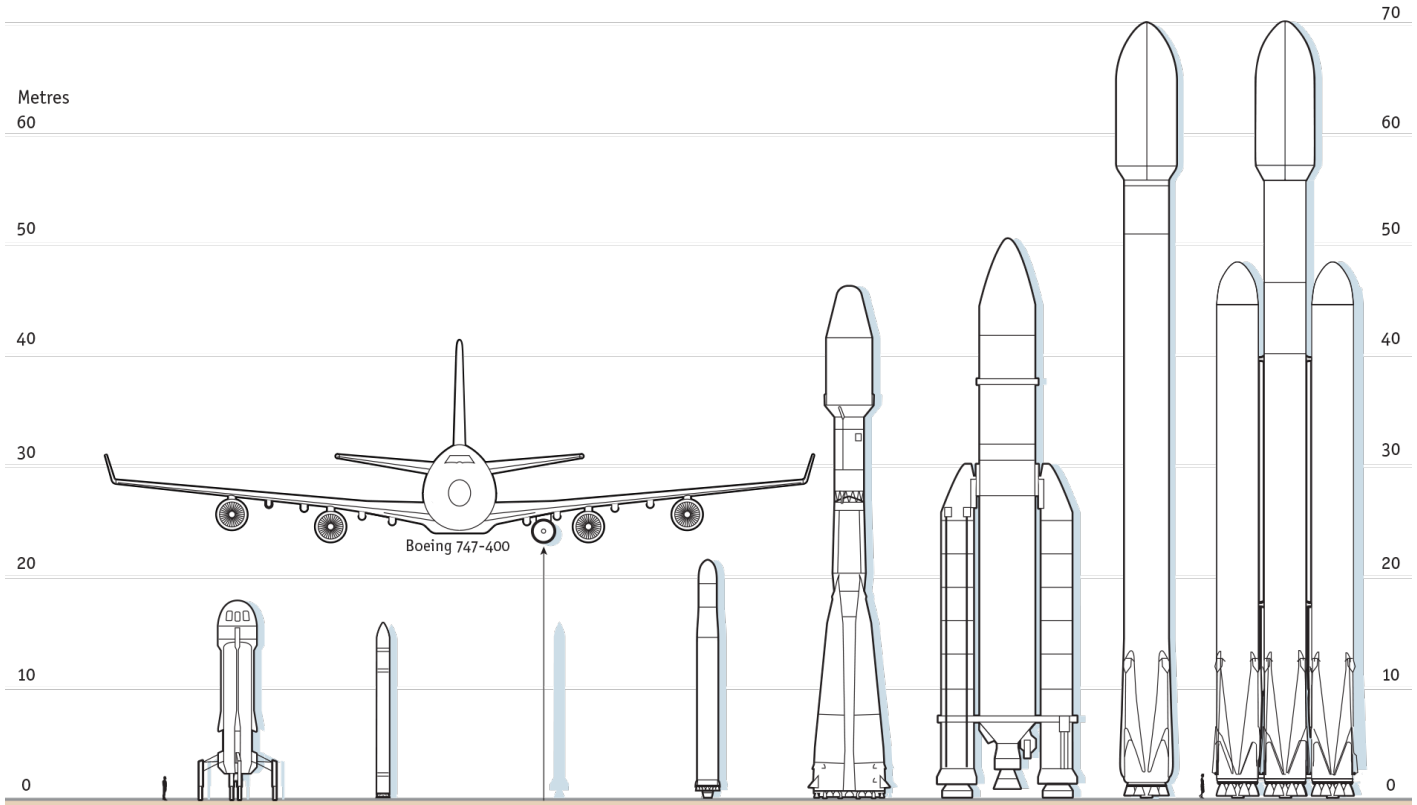


Small launchers are back

- Small launchers are back. There is a new need to launch smaller satellites without depending on bigger satellites (launch as piggybacks). The following companies are developing small launchers for microsatellites:
  - RocketLabs
  - PLD Space
  - Virgin Orbit
  - Vector Space Systems
  - Super Strypi
  - Vega



Small launchers are back

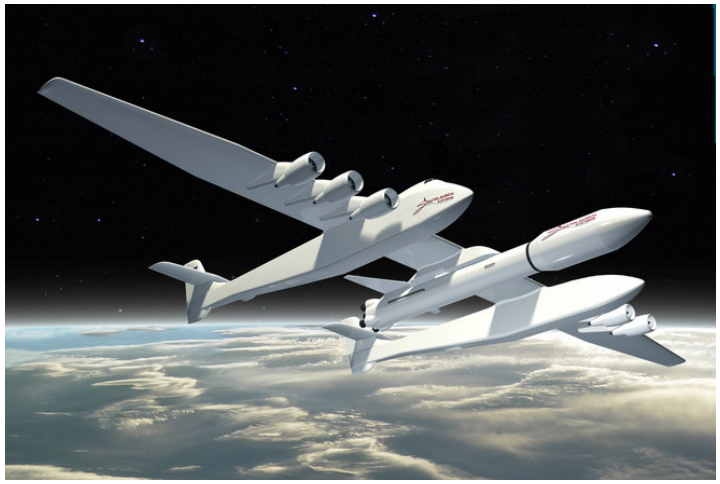


Carrier rocket Organisation	New Shepard Blue Origin	Electron Rocket Lab	LauncherOne Virgin Galactic	Alpha Firefly	Soyuz-2.1a Russia	Ariane 5 ArianeSpace	Falcon 9 SpaceX	Falcon Heavy SpaceX
Height, metres	18.0*	16.0	16.0*	21.6*	46.1	50.5	70.0	70.0
Payload to LEO†, kg	n/a	150	500	200	7,800	20,000	22,800	54,400

*Estimated †Low-Earth orbit

Small launchers are back

- Air-launched rockets are back into business:
  - LauncherOne by Virgin Orbit
  - StratoLauncher by Scaled Composites
  - GOLauncher by Generation Orbit
- Readiness to launch on demand

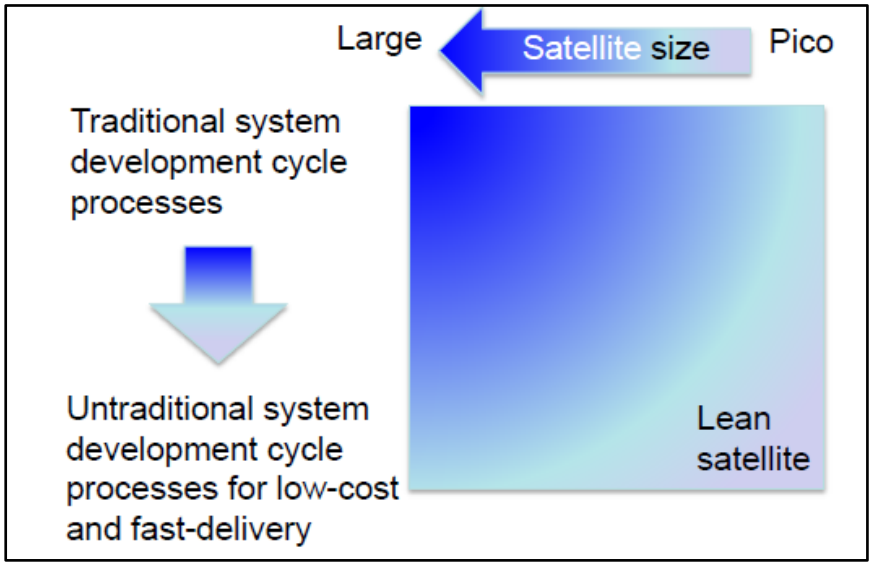


NETS Project and Lean Satellites

- NETS project is an international collaborative effort to establish an international standard for testing of nano-satellites.
- The project was initiated in 2011 by Prof. Mengu Cho from Laboratory of Spacecraft Environment Interaction Engineering of Kyushu Institute of Technology (Japan) who decided to create a new international standardization (ISO) focusing on:
  - Environment Tests of Nanosatellite System
  - Documentation of Nanosatellite Environment Tests
  - Environment Tests of Nanosatellite Components/Units
- The idea started from the consideration that Nanosatellites have to deal with the international standards created for bigger satellites, meaning they have to comply with expensive tests and assurance criteria which, for the purpose of Nanosatellites, may seem unnecessary.
- The standard will:
  - Promote worldwide trade of small-scale satellite products by providing the minimum level of assurance that the product made of non-space-qualified COTS parts and units can work in space.
  - Serve as a guideline of testing for new-comers to space (e.g. small business, developing countries, etc.)
- The standard will help strengthening and expanding the space industry base worldwide.
- Several experts both from industry and from academia have been involved in drafting and promoting the NETS Project and various activities carried out including some workshops through international collaboration.

NETS Project and Lean Satellites

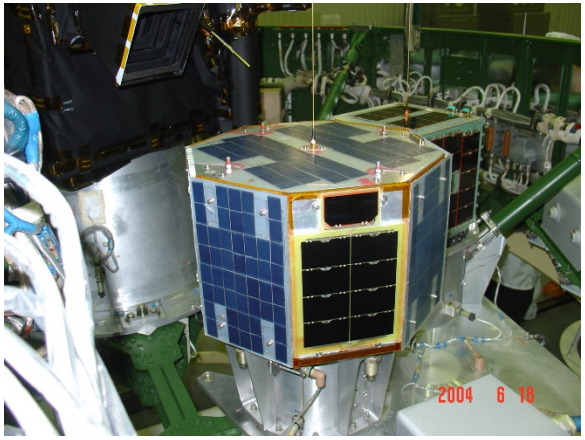
- Since the very beginning, the necessity emerged to define «what is a small satellite»?
- In 2014, during the International Workshop on Small-Scale Satellite Standardization held in Kitakyushu (Japan), a round table of experts from all over the world finally agreed on the word «LEAN SATELLITE».
- «*A Lean Satellite is a satellite that utilizes non-traditional, risk-taking development and management approaches with the aim to provide value of some kind to the customer at low-cost and without taking much time to realize the satellite mission.*»

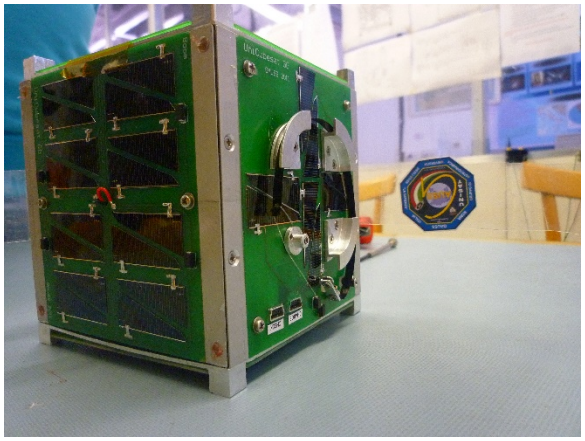


- The Project has been carried on also at IAA Study Group 4.18, where a final report will be soon issued.
- Many concepts are still under evaluation and new workshop will be held to promote international discussion on the topic so, stay tuned: http://cent.ele.kyutech.ac.jp/nets_web/nets_web.html

History of Microsatellites

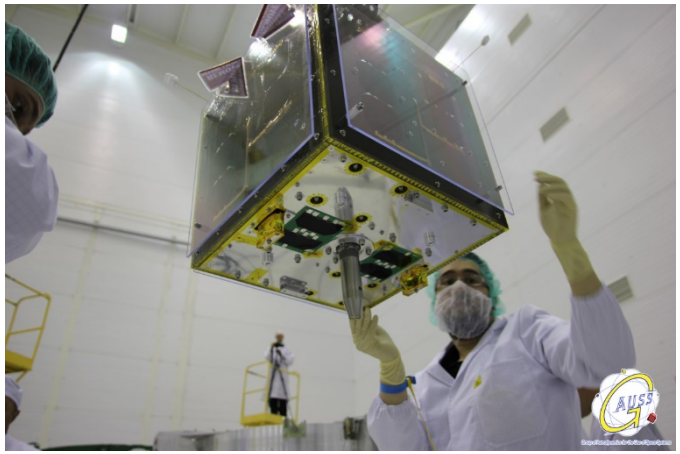
- Educational purpose:
  - CubeSats: Proposed by professors Bob Twiggs and Jordi Puig-Suari in 1999. Launched already more than 500 CubeSats.
  - GAUSS Lab from the School of Aerospace Engineering of La Sapienza launched:
    - Five microsatellites (EduSat, UniSat)
    - One Nanosatellite: 1u CubeSat

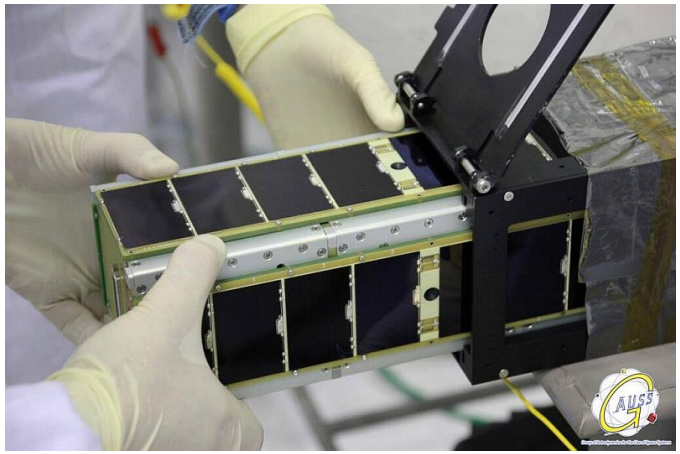




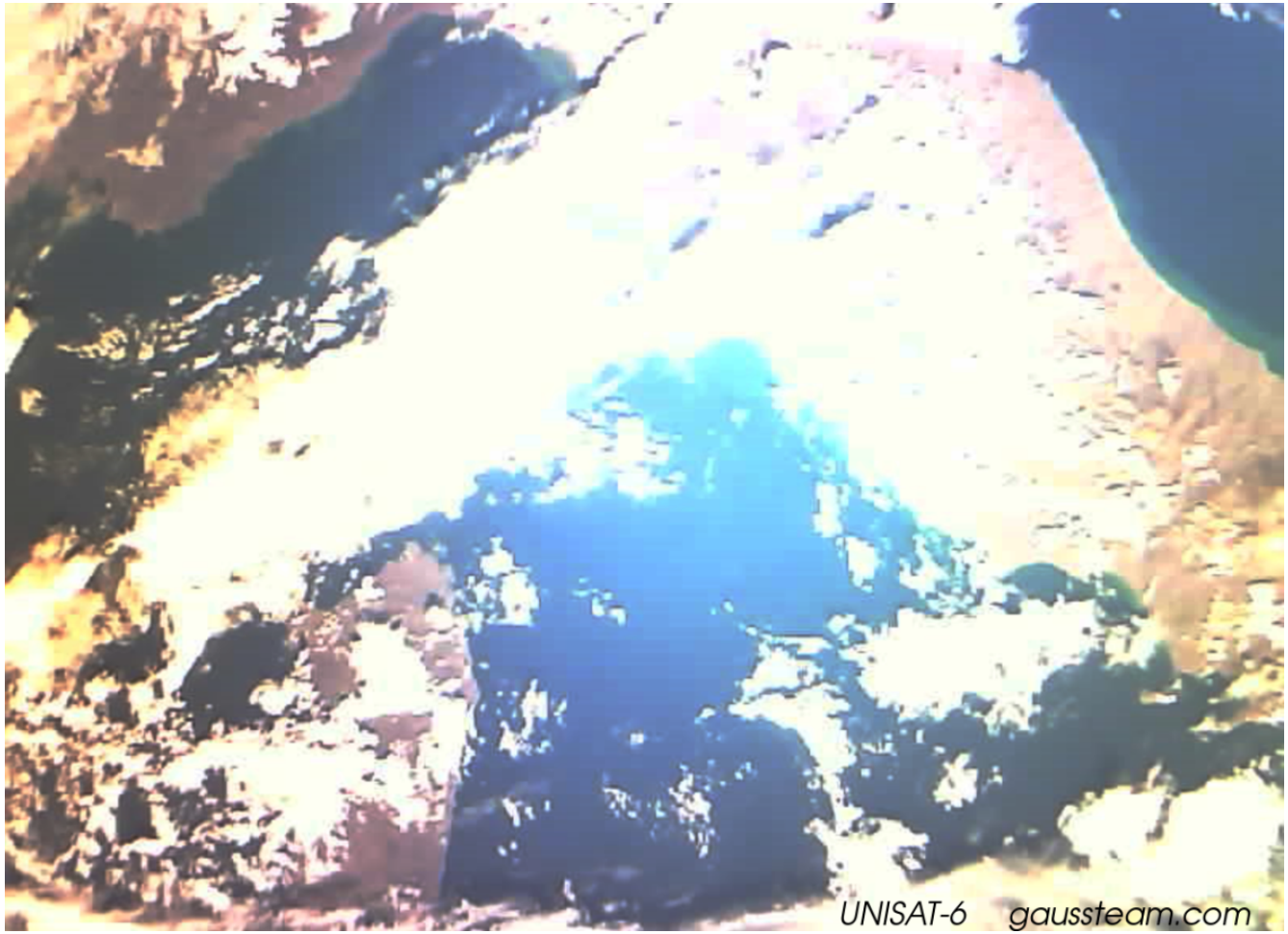
Present of Microsatellites in LEO

- Technology test: **UniSat-6** is a satellite developed by GAUSS Srl used for testing new electronics in orbit. It was launched in 2014 and it is currently operative.
- Educational: **Tigrisat** is a satellite built by The School of Aerospace La Sapienza with students of Irak with the scope of training new engineers in building satellites. The scope of the satellite is to observe the dust storms over Irak. Launched in 2014.



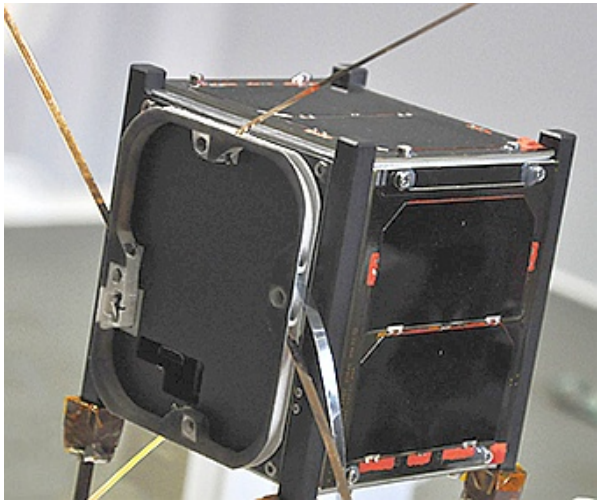


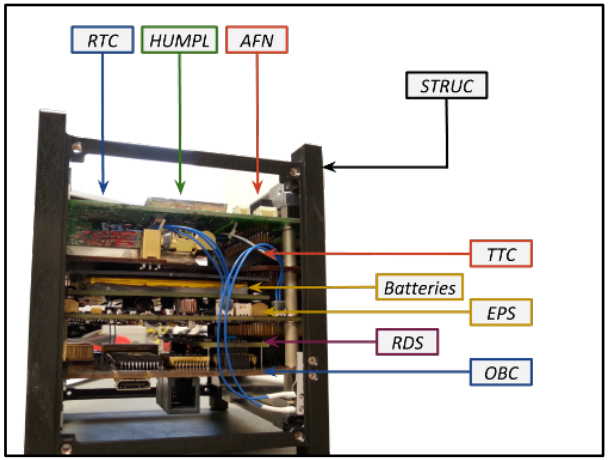
Present of Microsatellites in LEO



Present of Microsatellites in LEO

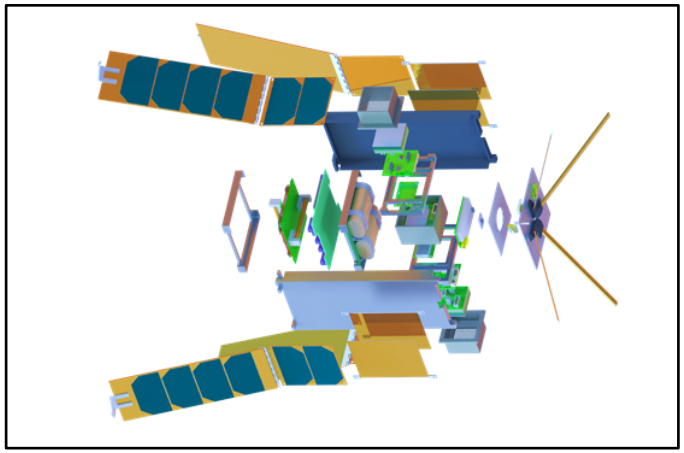
- Communication: **HumSat** (Humanitarian Satellite Constellation). Developed by the University of Vigo, is a satellite constellation providing worldwide communication capabilities to areas without infrastructure. The overall objective of the HumSat constellation is to provide messaging services through small user terminals on the basis of the store-and-forward concept.





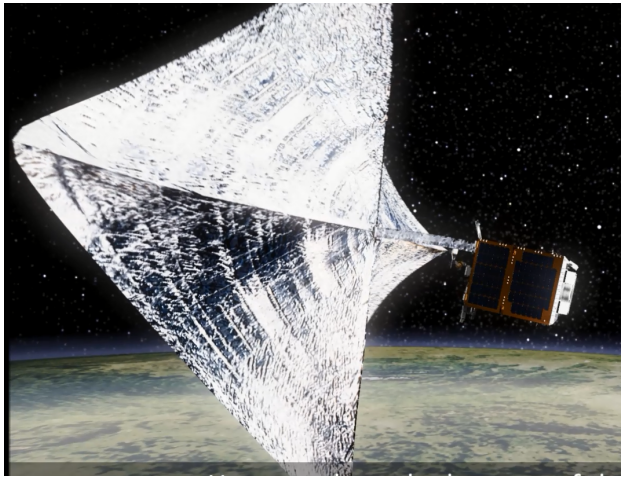
Present of Microsatellites in LEO

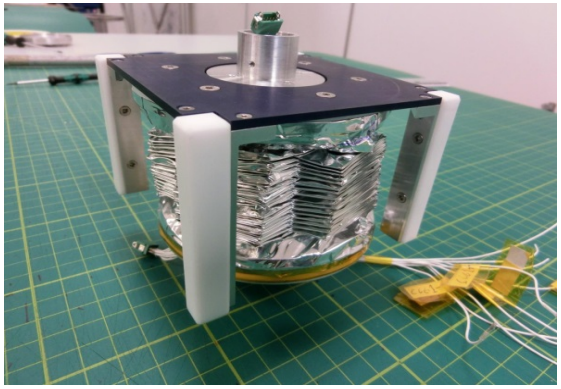
- Astrophysics: **CXBN-2** is a satellite developed by the Morehead State University with the scope of increasing the precision of measurements of the Cosmic X-Ray Background in the 30-50 keV range as well as to provide flight heritage for innovative CubeSat technologies and X-Ray-Gamma Ray Detectors. Already delivered to the launch provider, currently ready for launch.

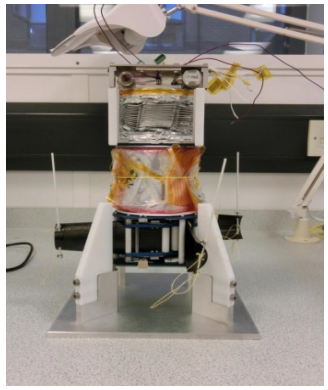


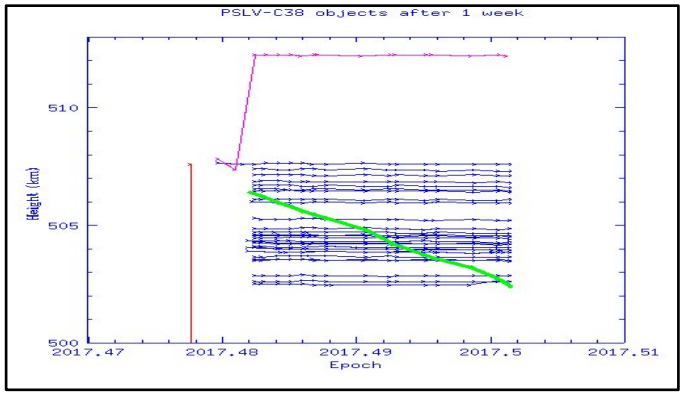
Present of Microsatellites in LEO

- Debris Removal: **RemoveDEBRIS DragSail** is a satellite developed by the University of Surrey and SSC to demostrate a inflatable mast deployment and a sail of 9m2 in a LEO orbit that will help deorbiting a satellite in a few days after deployment of the sail.



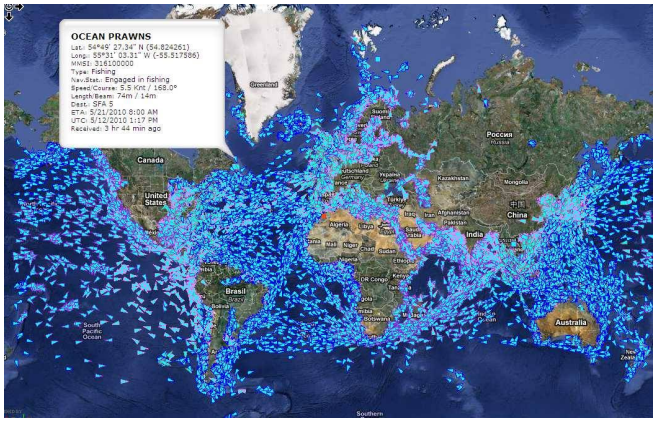






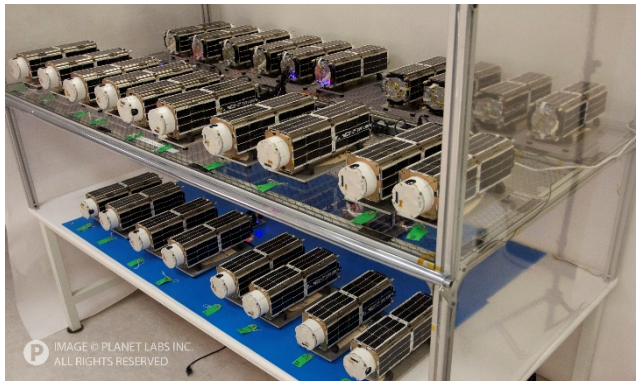
Present of Microsatellites in LEO

- Maritime Zone Monitoring: The **AprizeSat** satellites (12) were built by LinaSpace LLC. The are equipped with AIS Receivers to monitor maritime vessels. If coupled with imaging capability, the spacecraft can identify and image fishing vessels operating in marine protected zones, and publish their information to the public.

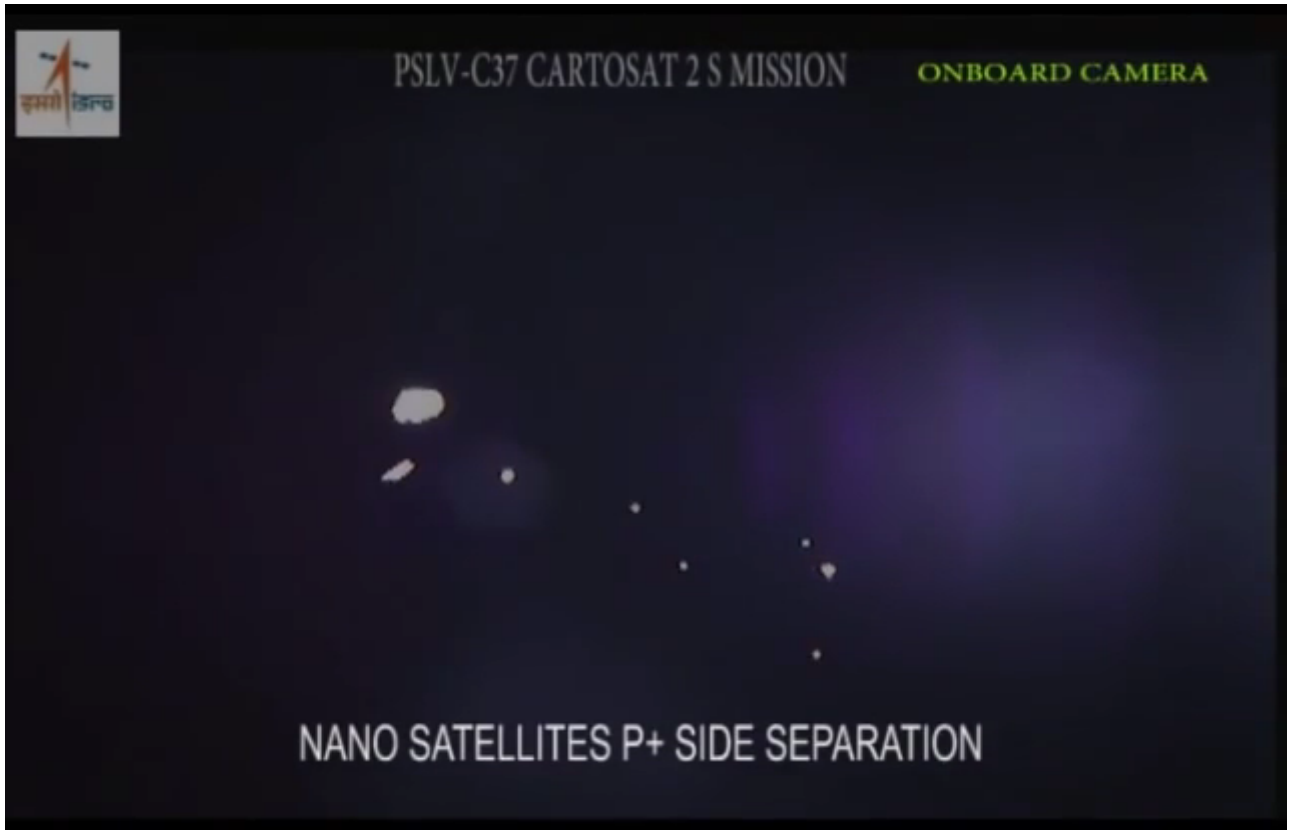


Present of Microsatellites in LEO

- Constellations:
  - **Planet:** Earth Observation constellation with a 10 to 15m resolution. Launched more than 150 satellites.
  - **Spire:** Weather monitoring using the GPS signals. Launched more than 40 satellites.

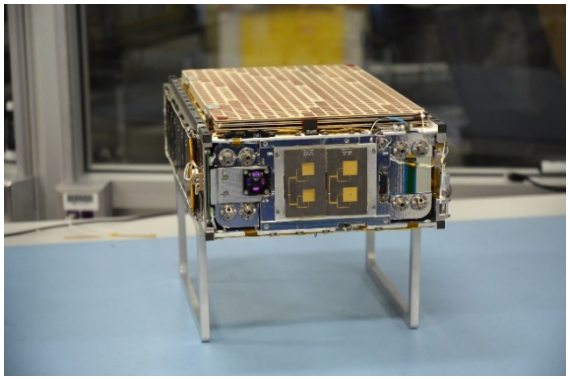


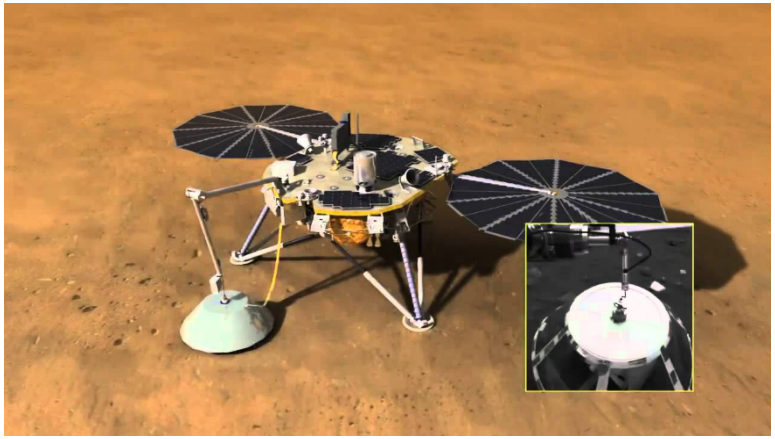
Present of Microsatellites in LEO

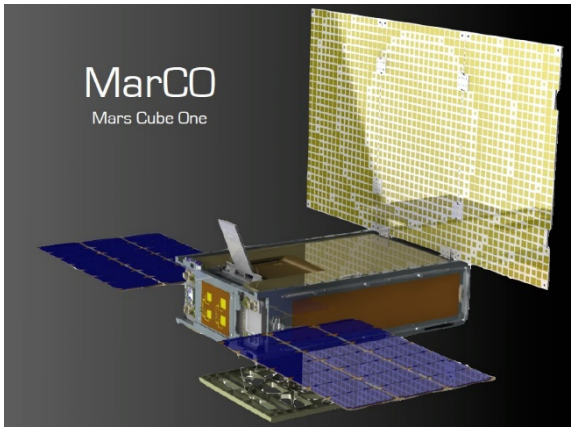


Present of Microsatellites on Deep Space missions

- **MarCO**: (Mars Cube One) Developed and built by NASA. MarCO is composed by a couple of 6U Cubesats that will provide both UHF and X-band functions capable of immediately relaying information received over UHF during the EDL of the NASA's Insight lander mission in 2018.

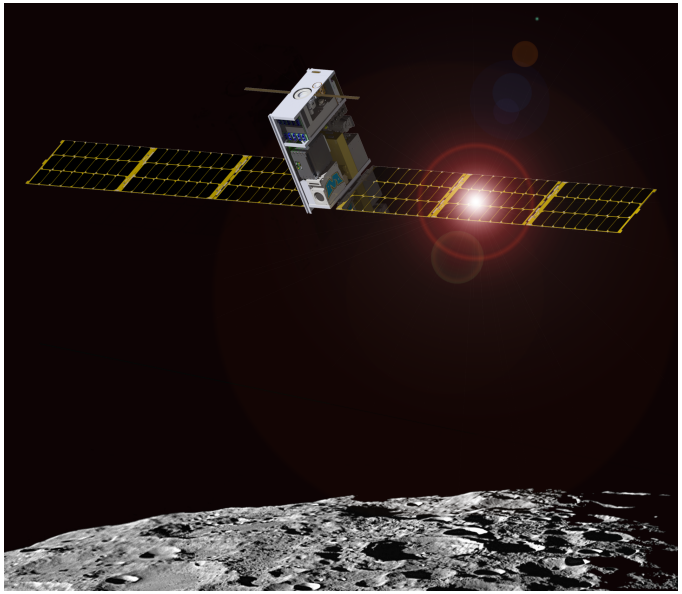






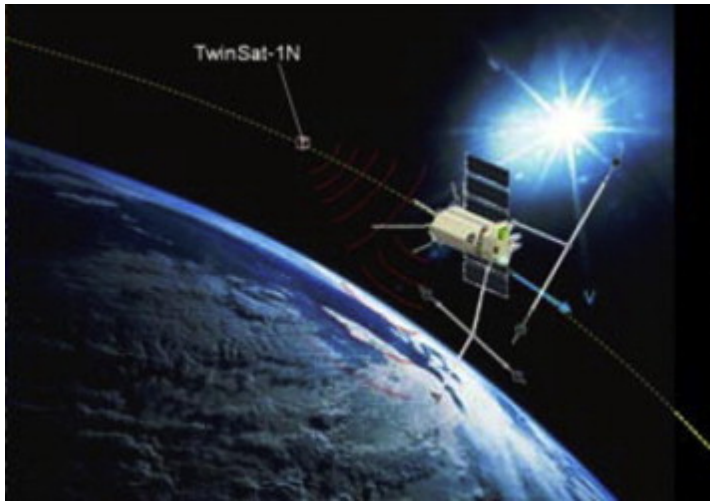
Present of Microsatellites on Deep Space missions

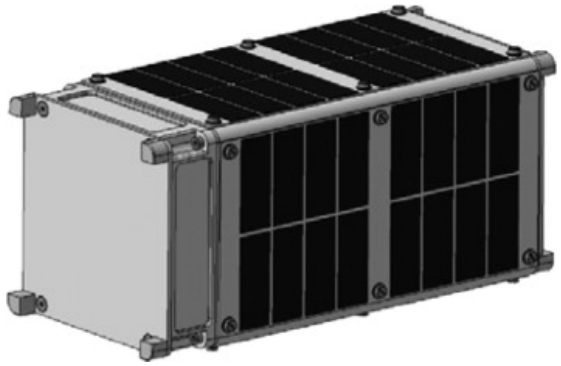
- **Lunar IceCube:** Designed and built by Morehead State University
  - Lunar IceCube is a 6U small satellite whose mission is to prospect for water in ice, liquid, and vapor forms and other lunar volatiles from a low-perigee, inclined lunar orbit using a compact IR spectrometer.
    - **1.)** Lunar IceCube will be deployed by the SLS on EM-1 and
    - **2.)** use an innovative RF Ion engine combined with a low energy trajectory to achieve lunar capture and a science orbit of 100 km perilune.
  - Its CDR was on the 28th of June, it will be launched on the 15th of October 2018



Future of Microsatellites on LEO

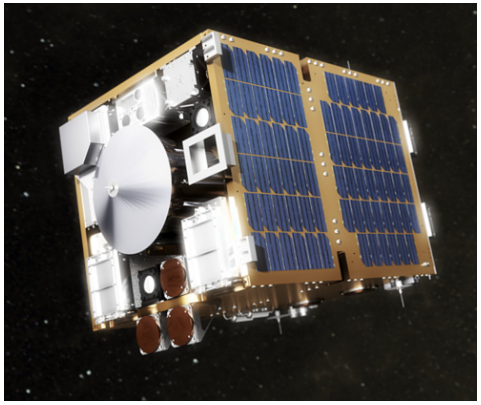
- Earthquake monitoring: **TwinSat**, a couple of Russian-UK satellites co-orbiting to monitor ionosphere changes prior to earthquake events. It is composed by two satellites:
  - Microsatellite TwinSat-1M
  - Nanosatellite TwinSat-1N
- The nanosatellite is considered to be a subpayload from the Microsatellite, allowing measurements from two different angles of the same region and communicating between them with an intersatellite system.

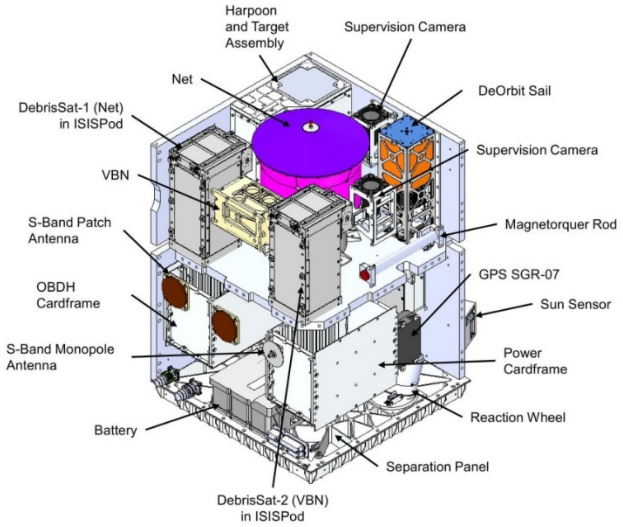




Future of Microsatellites

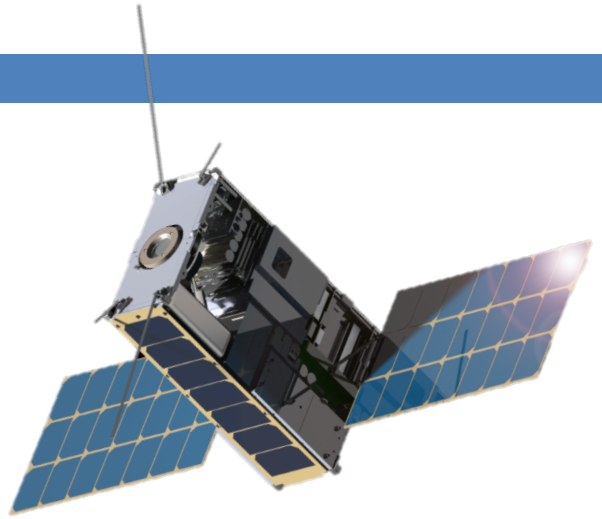
- Space debris observation and removal
  - Microsatellites could be launched to observe non operational satellites in order to asses its status and possibility of docking in the future with bigger satellites in order to remove it.
  - SSC is launching RemoveDEBRIS satellite with two onboard DebriSats and one DragSail to test different debris removal technologies.
  - Microsatellites could clamp space debris and open drags in order to reduce the lifetime of the orbit of the target debris

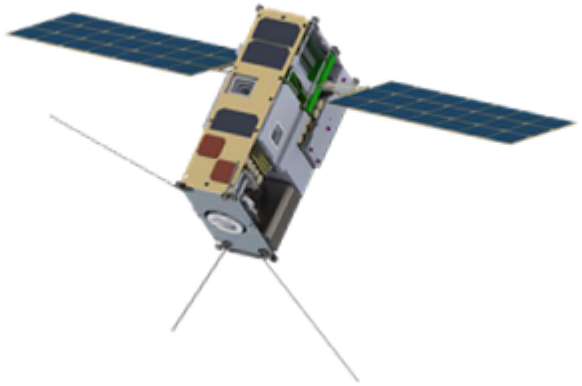




Future of Microsatellites

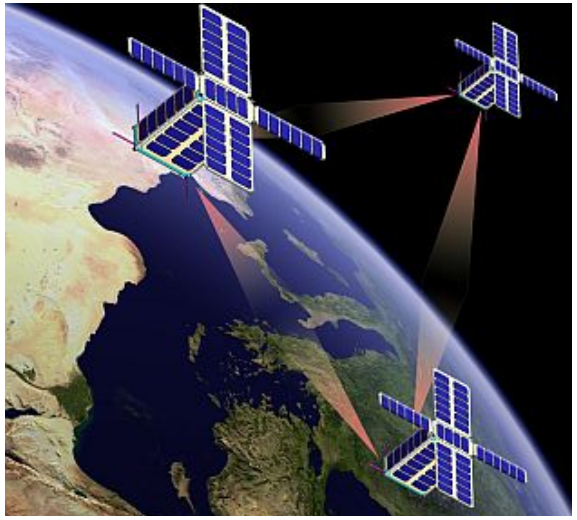
- Interplanetary missions:
  - Expendable, used for risky maneuvers.
  - **LuniSat**: A 50kg Satellite developed by GAUSS to fly CubeSats to the Moon
  - **NEA Scout**: Flyby of an asteroid, launch in 2018
  - **DARCSIDE**: Study of the Europa Moon together with Europa Clipper.
  - **AIM** CubeSats: Study the Didymos asteroid.

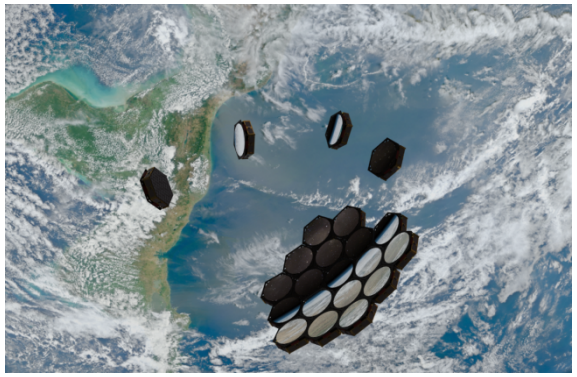




Future of Microsatellites

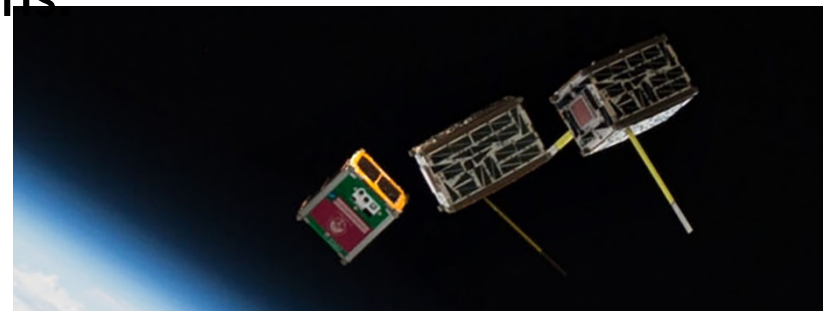
- Formation flying:
  - It will allow emulating bigger SAR antennas, having greater resolution than its big counterparts.
  - It will allow continuous coverage of a target on ground from LEO orbits.
  - Multiple small satellites will allow the construction of gigantic, reconfigurable structures, telescopes and radiotelescopes (ie AAReST from SSC).



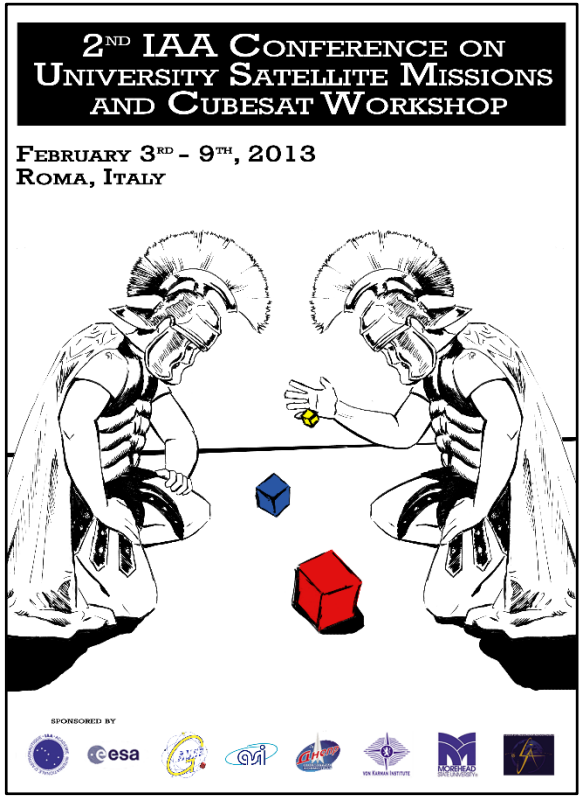


Future of Microsatellites

- Microsatellites might never fully replace bigger satellites, but they will offer **new services** or **increase the capabilities** of them when used in coordination.
- Microsatellites also allow for a very **responsive** access to space.
- Microsatellites are the **future** in both, commercial and science missions.

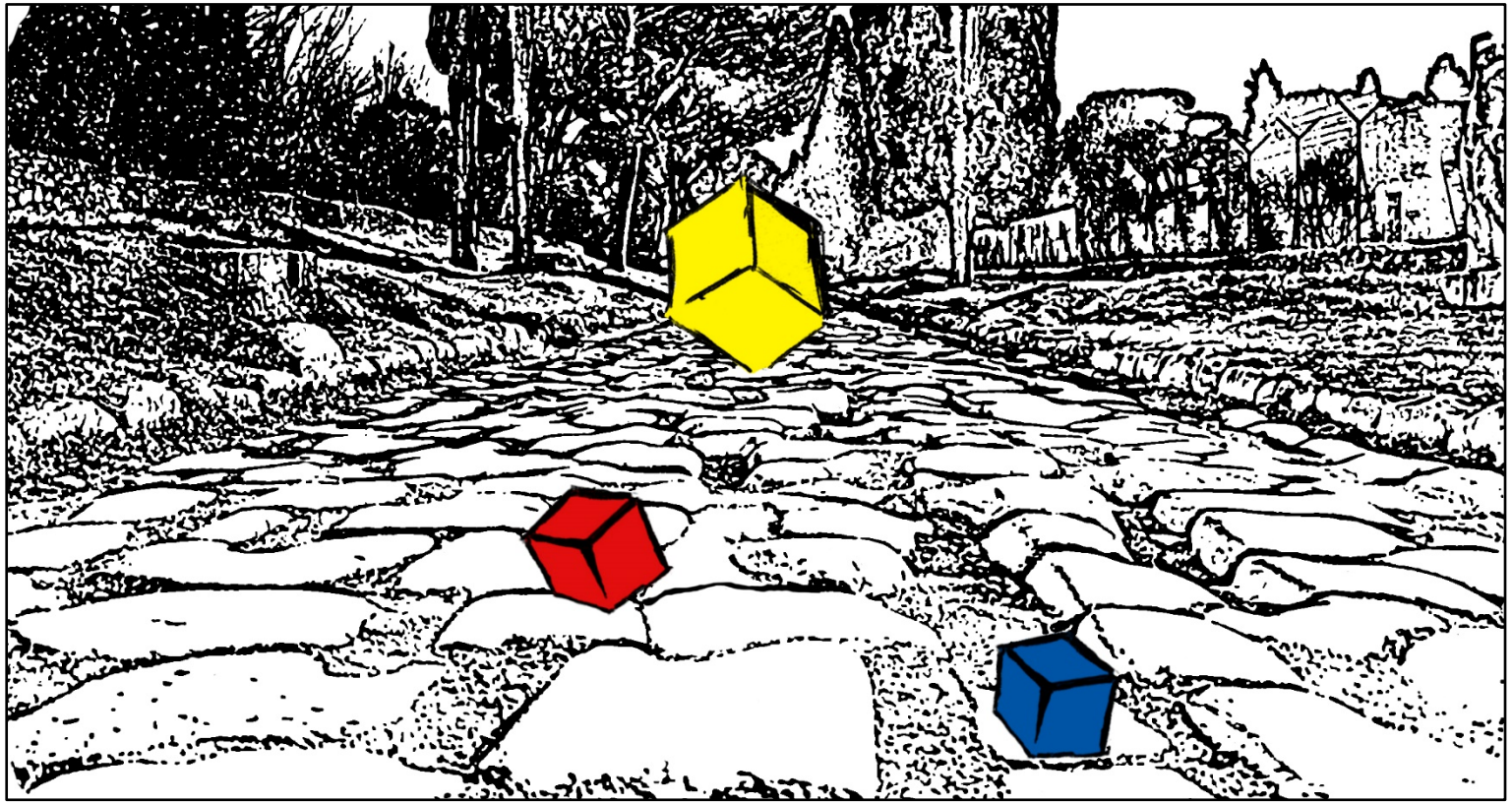


CubeSat Workshops



CubeSat Workshop 2011 - CubeSat Workshop 2013 - CubeSat Workshop 2015

Next CubeSat Workshop



A Road Towards the Future

A Road Towards the Future

- 4° CUBESAT WORKSHOP:
  - **Conference in Roma,**

    4th-7th December 2017

Palazzo Rospigliosi

Thank you

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