Propulsion Systems Trends in Italian Space Agency ALCOR Program

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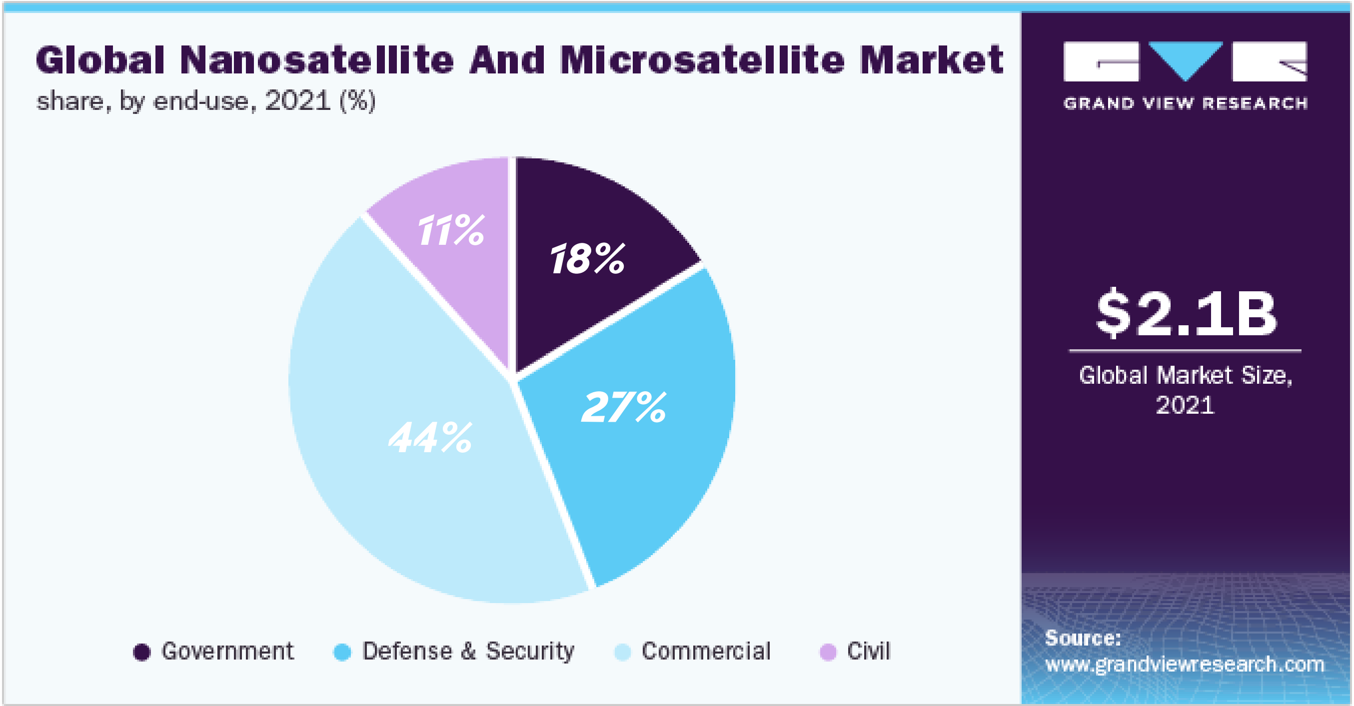
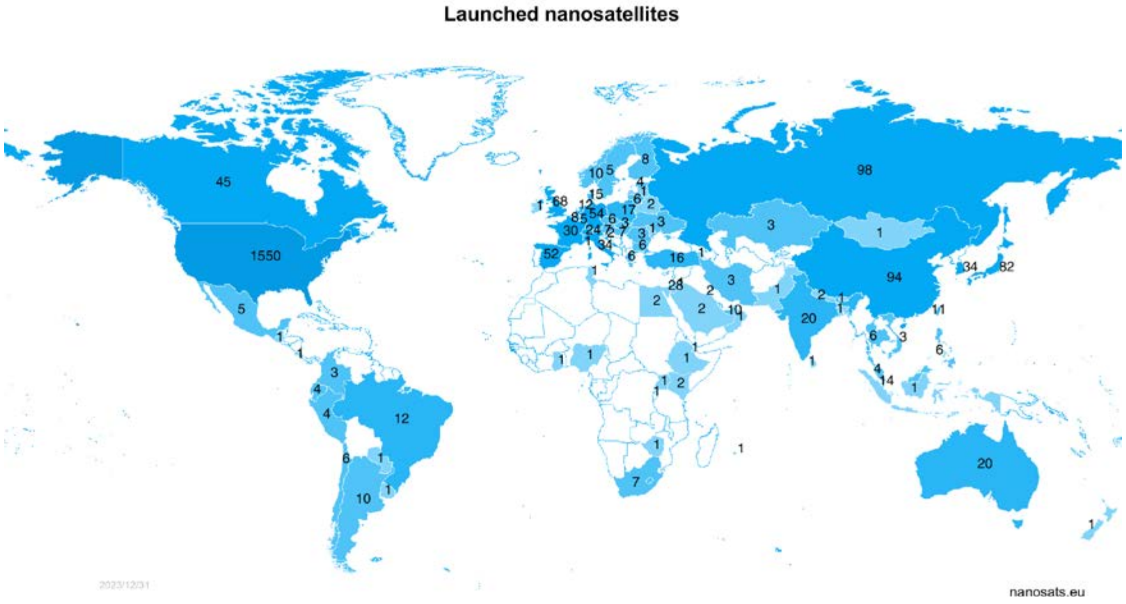
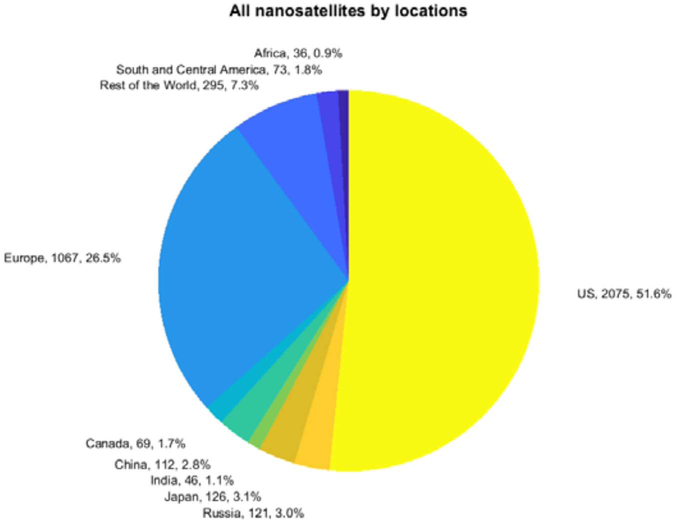
Micro- and Nano-Satellite Market



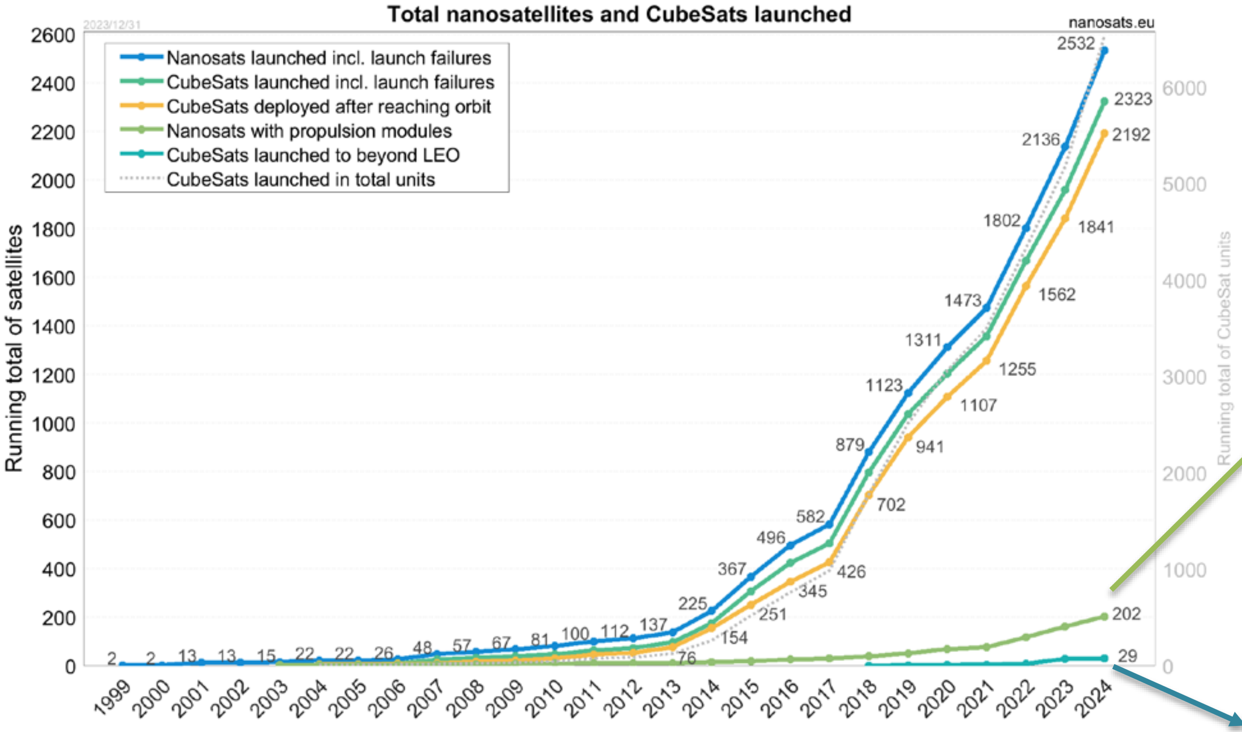
CAGR of 23.3%
13.8 B$ by 2030

Worldwide Distribution of Nano-Satellites





Expansion of the Nano-Satellite Field

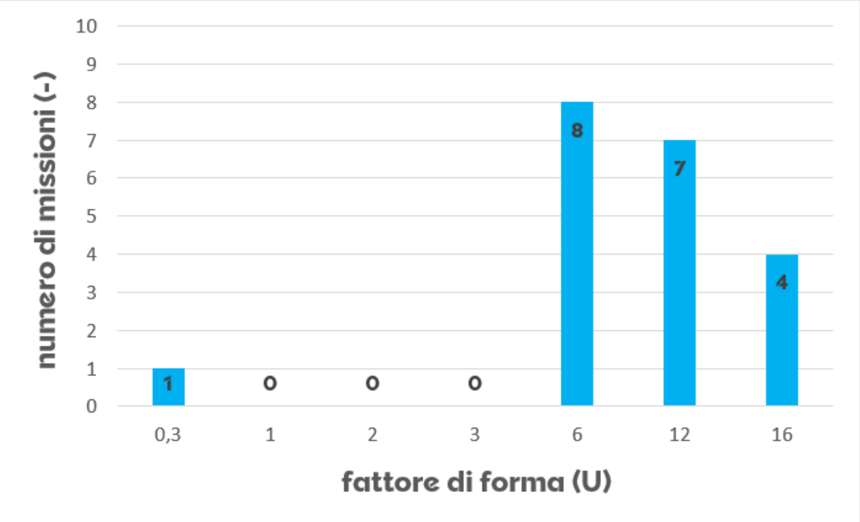


propulsion modules

beyond LEO missions

Agenzia
Spaziale
Italiana
SAILS (12U)
BOREALIS (6U)
CUSP (2x6U)
TASTE (12U+4U)
PICO-IOT (3x0.3U)
BISS (6U)
FUTURE (6U)
HENON (12U)
RODIO (4x16U)
SPEYE (6U)
Alcor
ANIME (12U)
VULCAIN (2x12U)
CHIPS (12U)
EARTHNEXT (16U)
INNOVATOR (2x6U)
E.CUBE (12U)
SEE (12U)
EXCITE (12U)
RAMSESS (6U)
SATURN (3x16U+)
EO/Geophysics
Telecommunications
In Orbit Demonstration
Astrophysics & Space Weather
Planetary Exploration
IOS & Autonomous Navigation
Astrobiology

Form Factors Distribution in ALCOR



Use of large form factors

- ✓ Higher volume, mass and power resources available for the propulsion system
- ✓ Higher thrust level needed to achieve an envisaged delta-v in a given firing time

A Quick Look into CubeSat Propulsion Systems

Main functions

- ✓ Orbit transfer
- ✓ Midcourse corrections
- ✓ Orbit insertion

Acquisition

- ✓ Station keeping
- ✓ Collision avoidance
- ✓ Pointing

Operations

- ✓ De-orbiting

Disposal

Ideal requirements

- ✓ Reduced envelope
- ✓ Reduced mass
- ✓ Suitable thrust level
- ✓ High specific impulse
- ✓ Low power consumption
- ✓ Reliability (TRL, flight heritage)
- ✓ Safety (low-hazard, low-toxicity)
- ✓ Low cost

Chemical vs. Electrical CubeSat Propulsion Systems

Chemical

Thrust level

Relatively high (10÷1000 mN), fast maneuvering but more demanding disturbance management needs

Main PRO

Lower power consumption

Main CON

Lower specific impulse

Cost driver

ensuring system safety, especially when high energy, high pressure and toxic propellants are considered

Electrical

Thrust level

Relatively low (0.01÷1 mN), slow maneuvering but less demanding disturbance management needs

Main PRO

Higher specific impulse

Main CON

Higher power consumption

Cost driver

developing small and reliable PPUs, especially in beyond LEO missions for radiation hardness reasons

Increasing Need for Propulsion Systems

12/20 of ALCOR missions employs propulsion systems on-board

seven years ago less than 10 CubeSats had flown with a propulsion system on-board *

Increase in the need for propulsion systems on-board

as a consequence of the increase in the variety of CubeSat mission applications, including:

- ✓ VLEO missions (e.g. EarthNext)
- ✓ beyond LEO missions (e.g. HENON, TASTE, ANIME)
- ✓ missions with formation flying (e.g. VULCAIN, SATURN, RODiO, INNOVATOR)

* K. Lemmer, *Propulsion for CubeSats*, Acta Astronautica, Vol. 134, pp. 231-243, 2017

Share of Propulsion System Families in ALCOR

Higher share of electric propulsion systems in ALCOR missions

10/15 electric vs. 5/15 other propulsion systems on-board *

In spite of lower thrust levels, leading to long maneuvering times, thus often long mission operations and payload unavailability periods, as well as of a higher power consumption, electrical propulsion systems appear to be preferred in ALCOR missions. Possible reasons for this preference could be found in CubeSat demanding envelope constraints (higher specific impulse, thus higher total impulse for a given propellant mass) and poor parasite torques management capabilities (lower thrust level, thus lower angular momentum increase for a given thrust misalignment).

* among the 12 ALCOR missions with propulsion, 3 rely on a dual propulsion system, for a total of 15 propulsion systems on-board

Propulsion System Technologies in ALCOR

Electric

- ✓ 5 MEPT (Magnetic-Enhanced Plasma Thruster)
- ✓ 3 ion engines
- ✓ 1 FEEP (Field Emission Electric Propulsion)
- ✓ 1 PPT (Pulsed Plasma Thruster)

Others

- ✓ 2 cold-gas thrusters
- ✓ 1 resistojet
- ✓ 1 mono-propellant thruster
- ✓ 1 hybrid bi-propellant thruster

Very diversified technologies involved

seven years ago the majority of CubeSats used only cold-gas technologies *

* *K. Lemmer, Propulsion for CubeSats, Acta Astronautica, Vol. 134, pp. 231-243, 2017*

Emerging Trends of Propellants

Use of green propellants in resistojet and mono-propellant thrusters

Resistojet and mono-propellant thrusters in ALCOR only use H2O and H2O2, respectively, according to the demand for low toxicity substances

Use of solid state sublimating propellants in electric propulsion systems

Electric propulsion systems in ALCOR mainly use solid state sublimating Iodine, Indium or Teflon, according to high density and non-pressurized propellant advantages

COTS, Delta-Design and New Developments

COTS in 11 ALCOR missions

COTS considered as flight proven “plug-and-play” units

Delta design frequently needed mainly because of total impulse and I/F adaptation

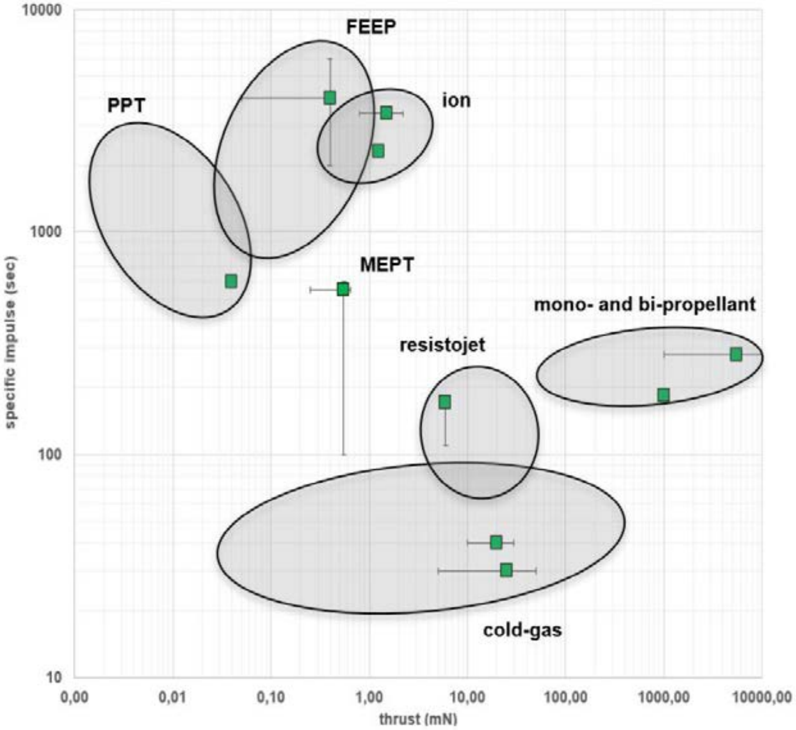
New development in 4 ALCOR missions

New developments from technology demonstration projects

Supplier involved or taken into consideration

T4i, Busek, Mars Space, Enpulsion, SteamJet

Propulsion System Performance in ALCOR



Very distributed range of performance *

Thrust levels between 0.04 and 10000 mN

Specific impulses between 30 and 6000 sec

* D. Krejci and P. Lozano, *Space Propulsion Technologies for Small Spacecraft*, Proceeding of the IEEE, Vol. 106, n. 3, 2018

Concluding Remarks

- ✓ *The variety of CubeSat applications bring an increasing need for propulsion systems on-board*
- ✓ *60% of ALCOR missions foresees a propulsion system*
- ✓ *Higher share of electric propulsion systems in ALCOR missions*
- ✓ *About 70% of ALCOR missions adopting propulsion consider electric propulsion systems*
- ✓ *Use of green mono-propellants and solid sublimating propellants for electric propulsion*
- ✓ *Predominance of COTS propulsion systems but frequently with delta-design involved*
- ✓ *Very diversified propulsion technologies involved*
- ✓ *Very distributed range of performance*
- ✓ *Interest and potential further expansion of electrothermal thrusters*

Thank you for your attention

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