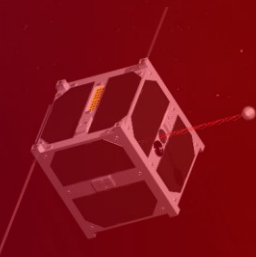


CubeSats Beyond LEO – 2021 Survey of MEO, GTO, GEO & Interplanetary Missions

Erik Kulu

Interplanetary Small Satellite Conference 2021

Uploaded: April 23, 2021



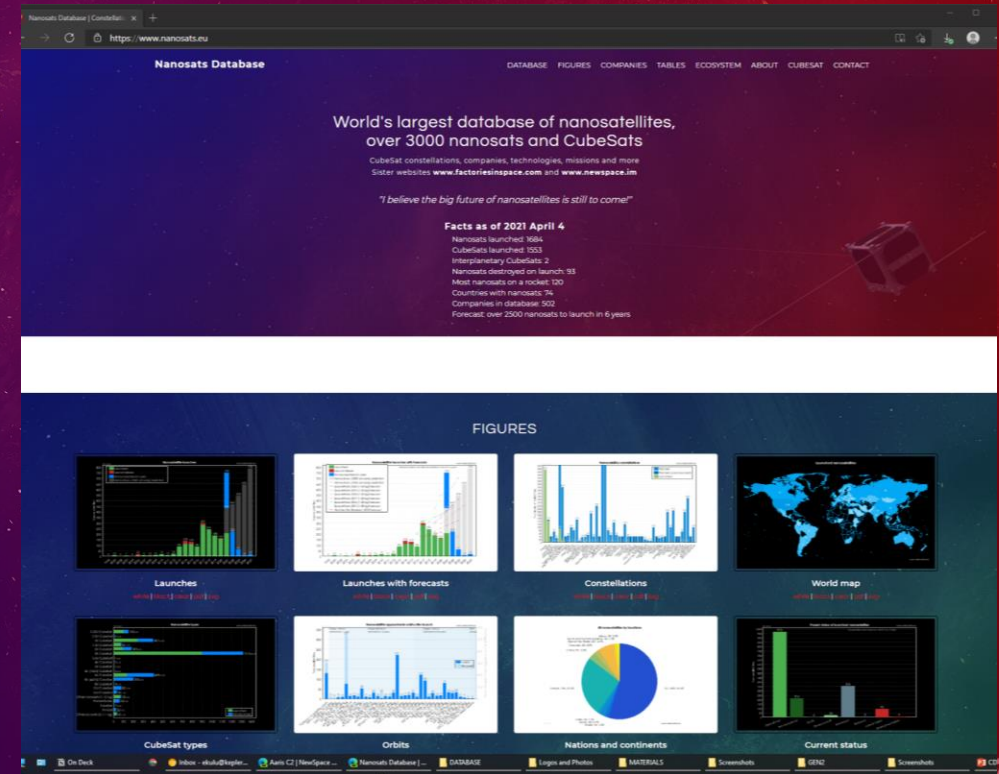
Agenda

- Nanosats Database
 - Definitions
- 2021 Statistics and Trends
 - Launches
 - Orbits/Destinations
 - Organisations
 - Form Factors
 - World Map
 - Missions
- Selected Spacecraft by Destinations
- Conclusion and Future Work
 - Sources & Acknowledgements



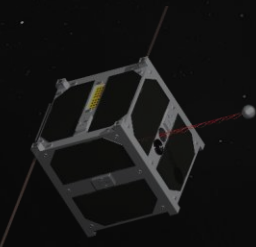
Nanosats Database

- Launched, planned and cancelled missions all included.
- Bigger and even more exciting future of nanosatellites is ahead.
 - Novel deployable technologies, new constellations and exploration missions.
 - Enable to visit many more moons and asteroids across the Solar System.
- Presenting “beyond LEO” CubeSats in a single source.
- Beyond LEO criteria:
 - Higher than 2000 km apogee.
 - MEO, GTO, GEO, Moon, Mars, interplanetary, deep space, asteroids.



“Nanosatellite” Broader Definition

- Included in Nanosats Database:
 - All CubeSats from 0.25U to 27U.
 - Nanosatellites from 1 kg to 10 kg (shown in kilograms).
 - Picosatellites from 100 g to 1 kg (shown in grams).
 - PocketQubes, TubeSats and ThinSats have own categories.
 - CAPSTONE (12U base, but microsatellite?).
- Not (yet) included:
 - Deep space inspection cameras, like flown on IKAROS & Tianwen-1.
 - Femtosatellites (10 g to 100 g), chipsats and suborbital launches.
 - CubeSats bolted to stages and not meant to be separate objects.
 - Data is since 1998 - at least 21 nanosats launched in the 1960s.
 - Many concept and study stage CubeSats.



2021 Status

Beyond LEO CubeSats: MEO, GTO, GEO, Moon, Mars & Interplanetary Missions

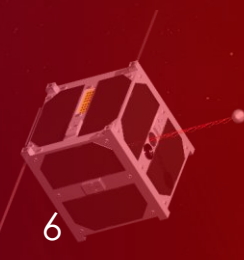


Count of “Beyond LEO” CubeSats

Beyond LEO
CubeSats in
Database:
64

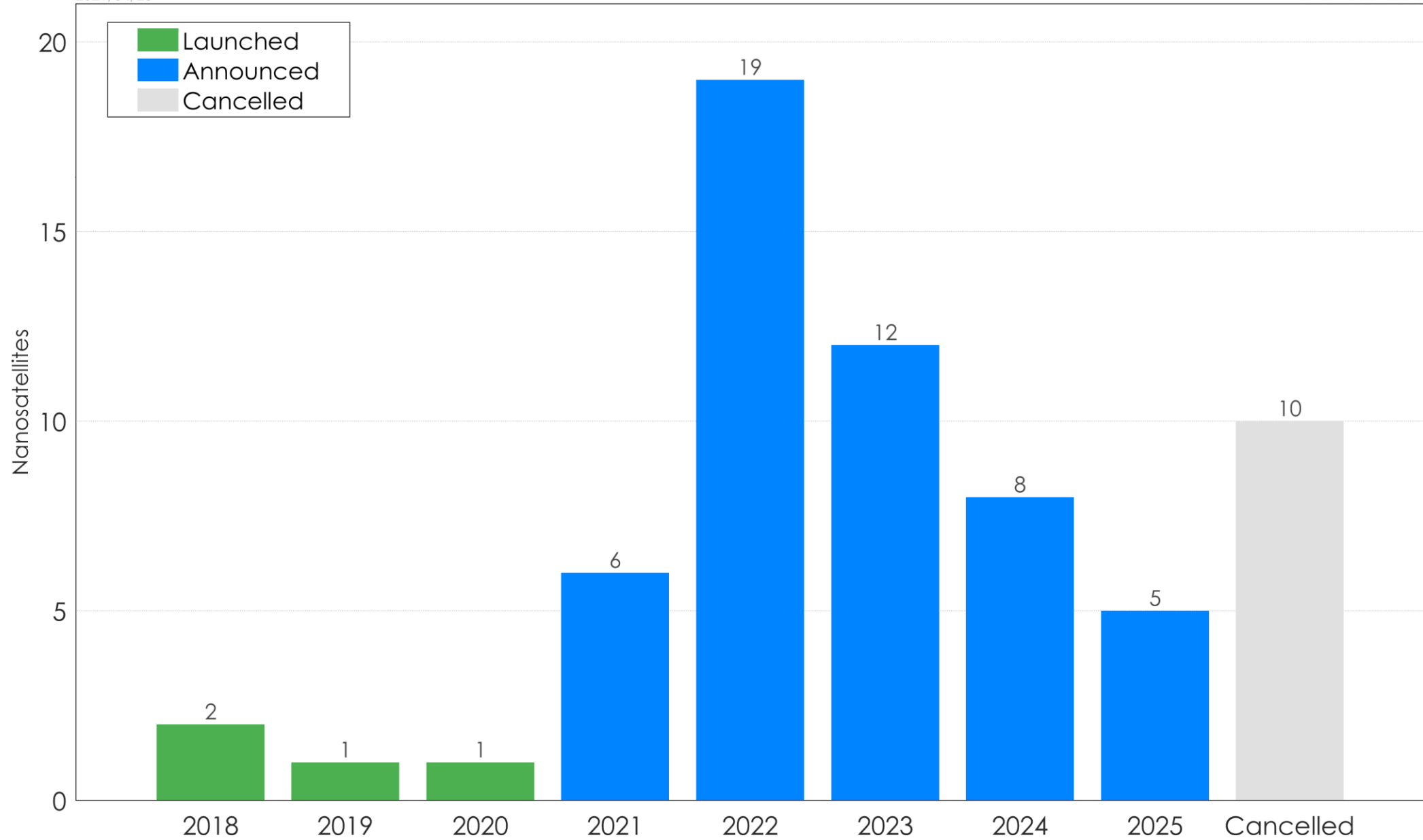
Interplanetary
CubeSats
Launched:
2

GTO
CubeSats
Launched:
2



CubeSat Launches Beyond LEO

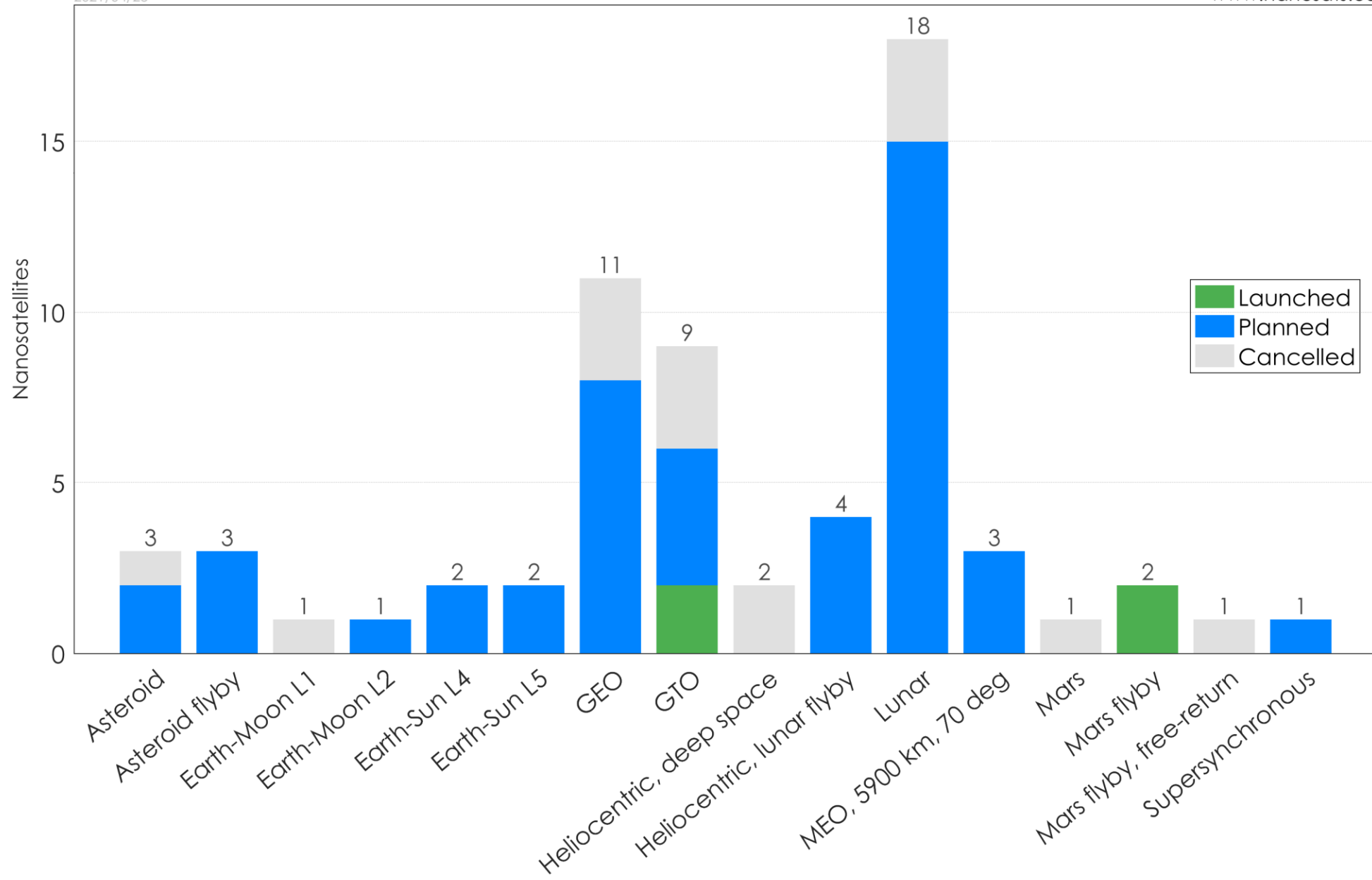
2021/04/23



Orbits of Beyond LEO CubeSats

2021/04/23

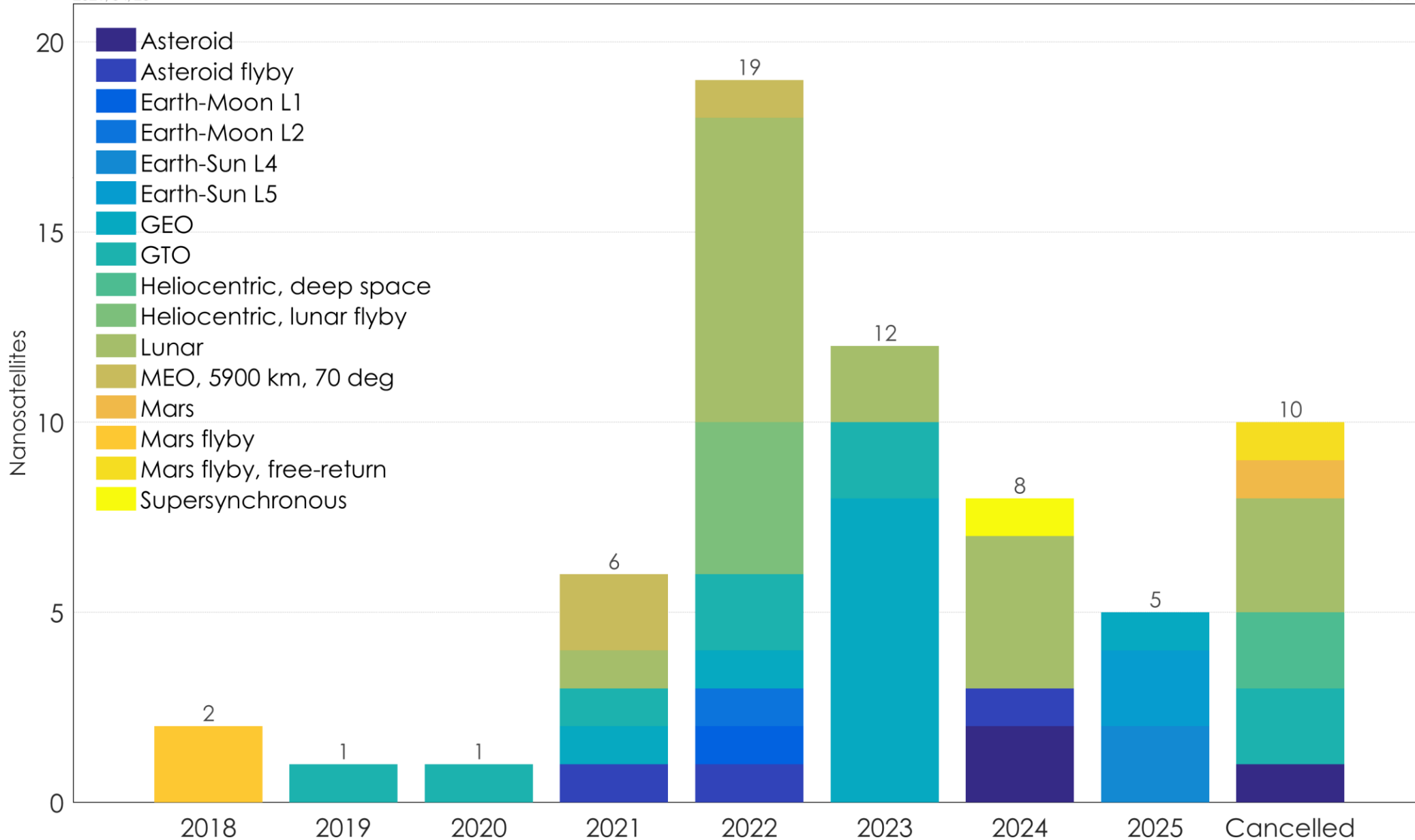
www.nanosats.eu



CubeSat Launches Beyond LEO By Orbits

2021/04/23

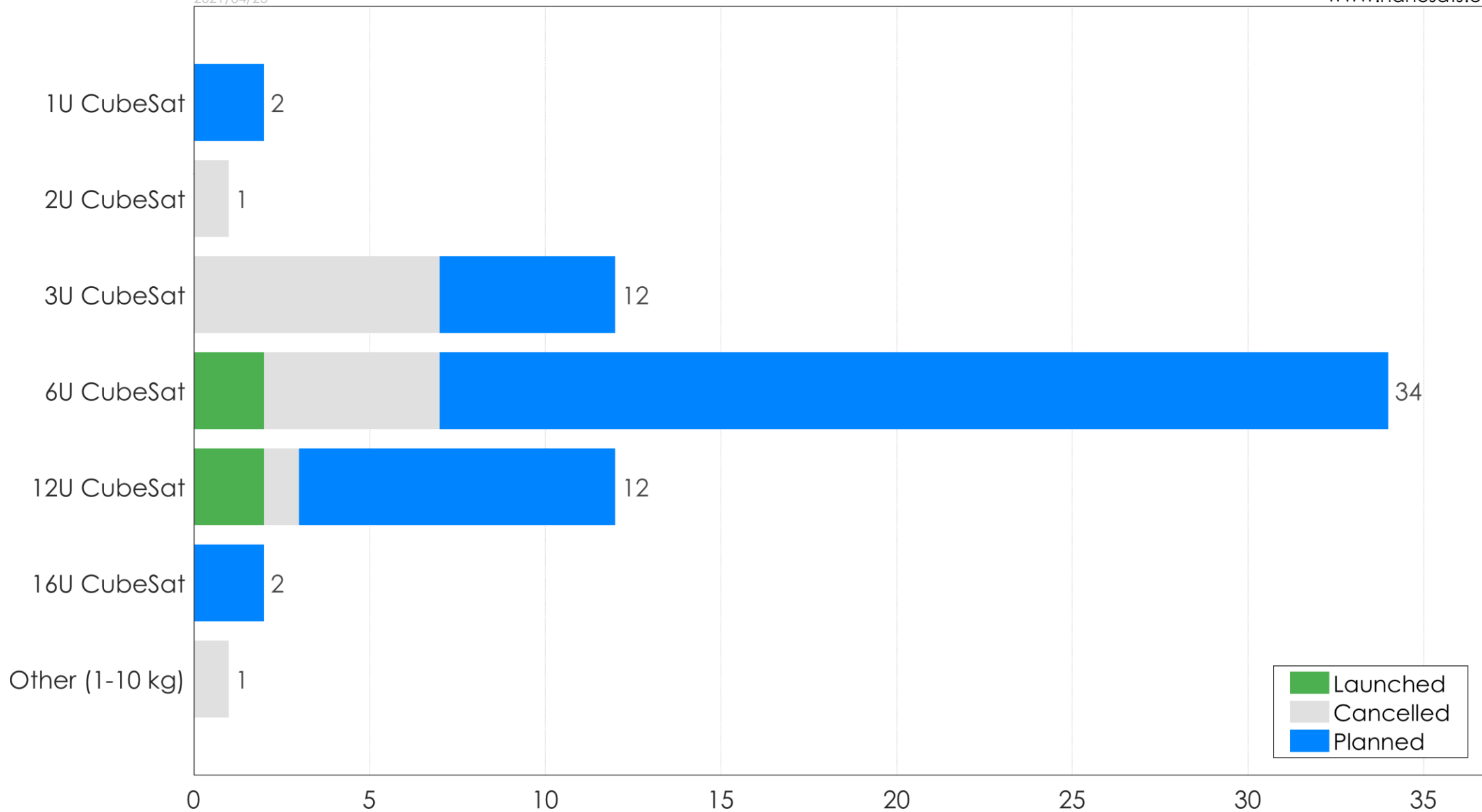
www.nanosats.eu



Beyond LEO CubeSat Form Factors

2021/04/23

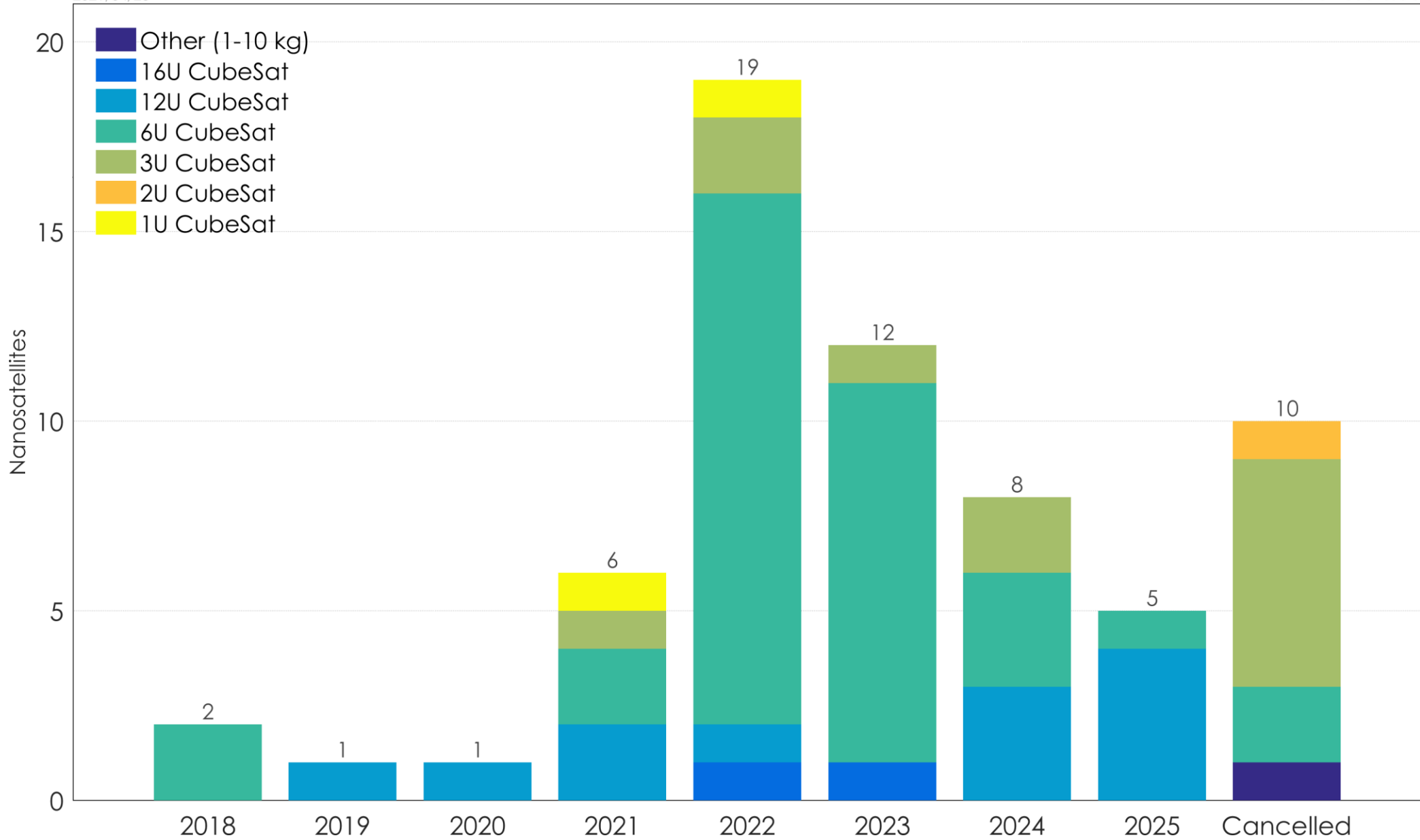
www.nanosats.eu



CubeSat Launches Beyond LEO By Form Factors

2021/04/23

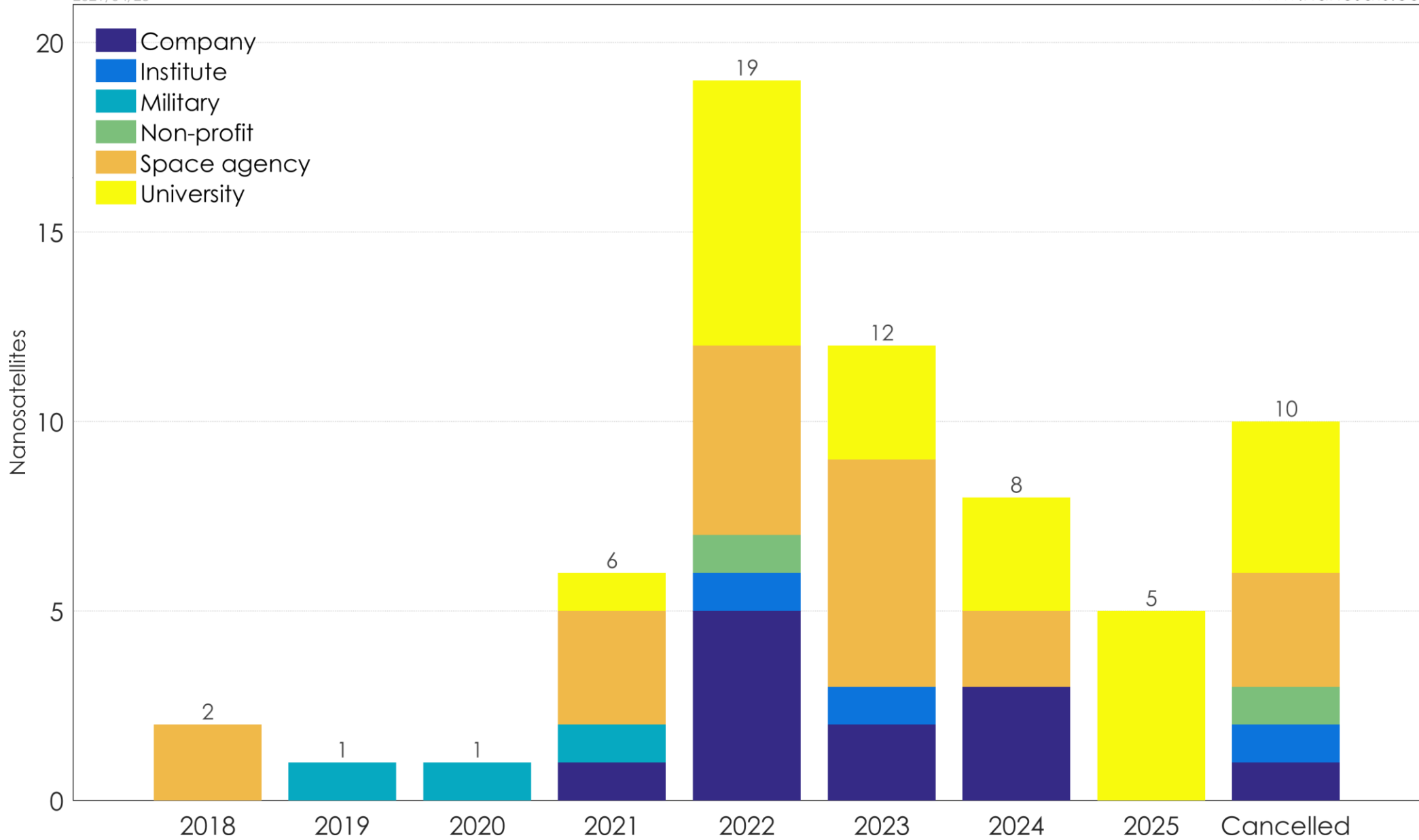
www.nanosats.eu



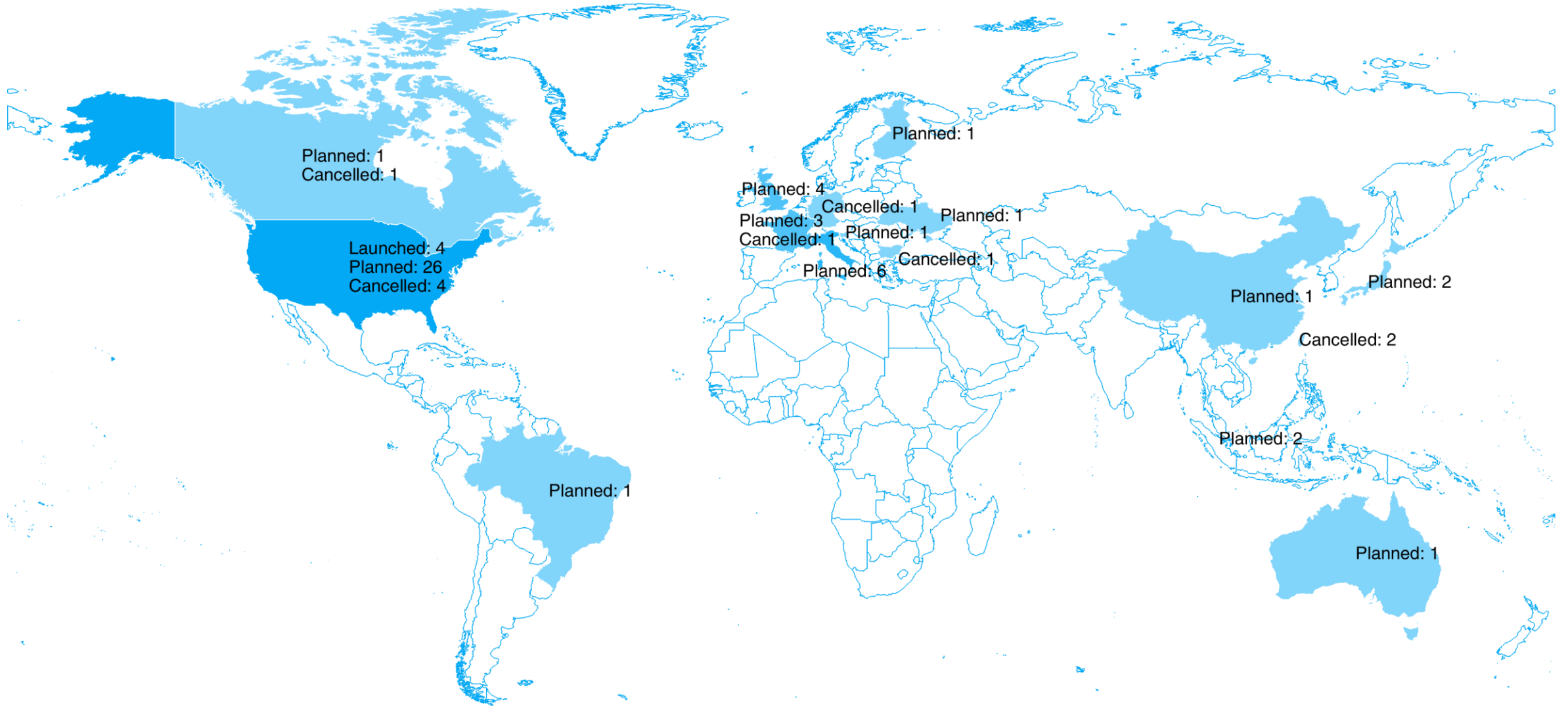
CubeSat Launches Beyond LEO By Organisations

2021/04/23

www.nanosats.eu



Map of CubeSats Beyond LEO

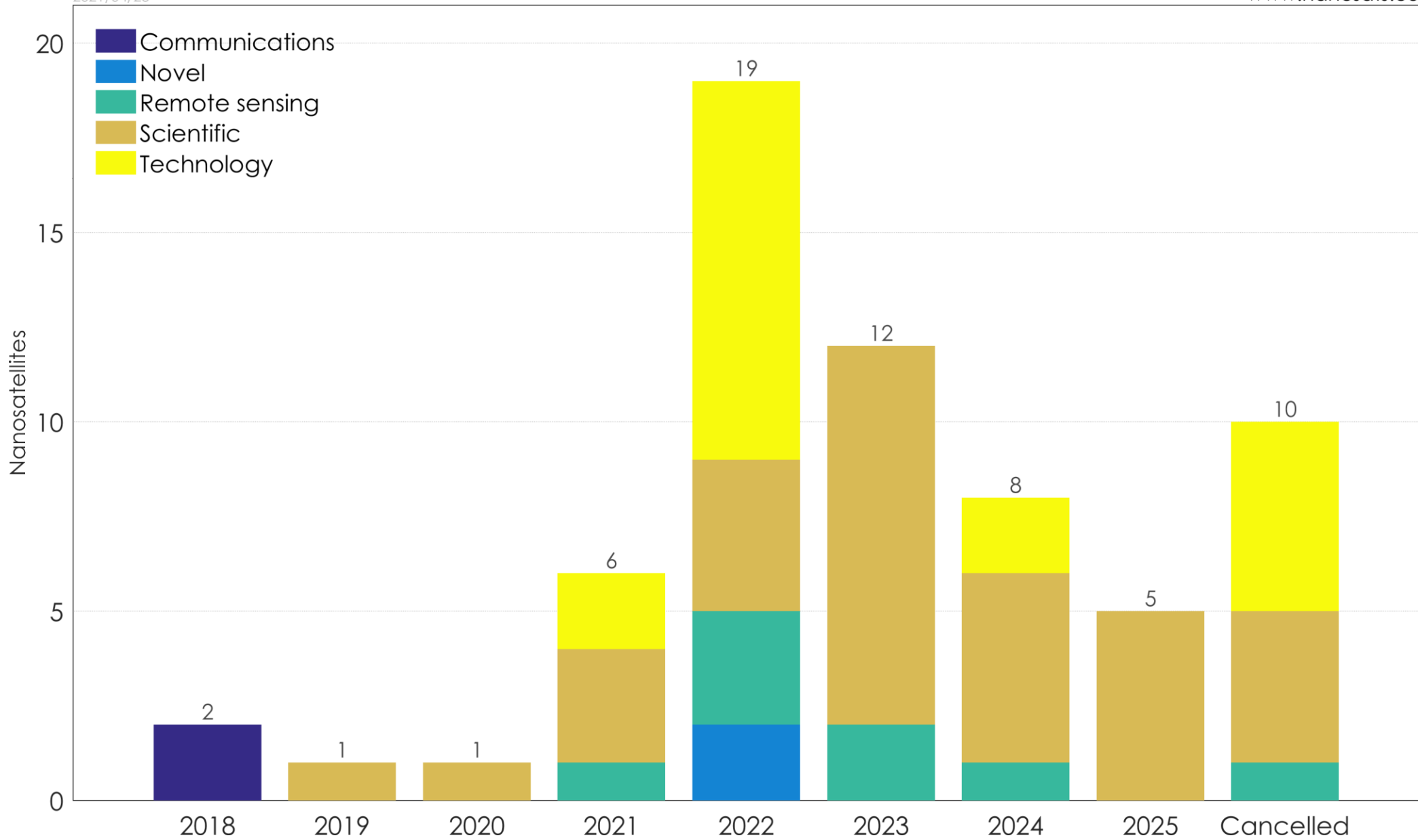


www.nanosats.eu

CubeSat Launches Beyond LEO By Missions

2021/04/23

www.nanosats.eu



Selected Examples

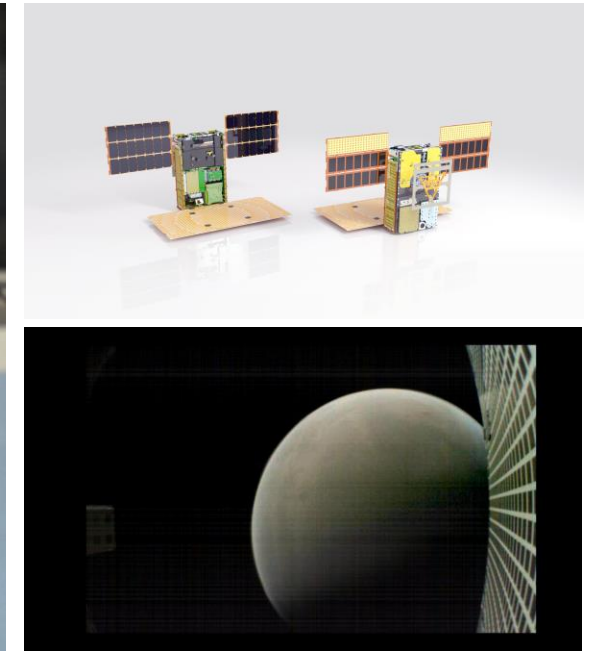
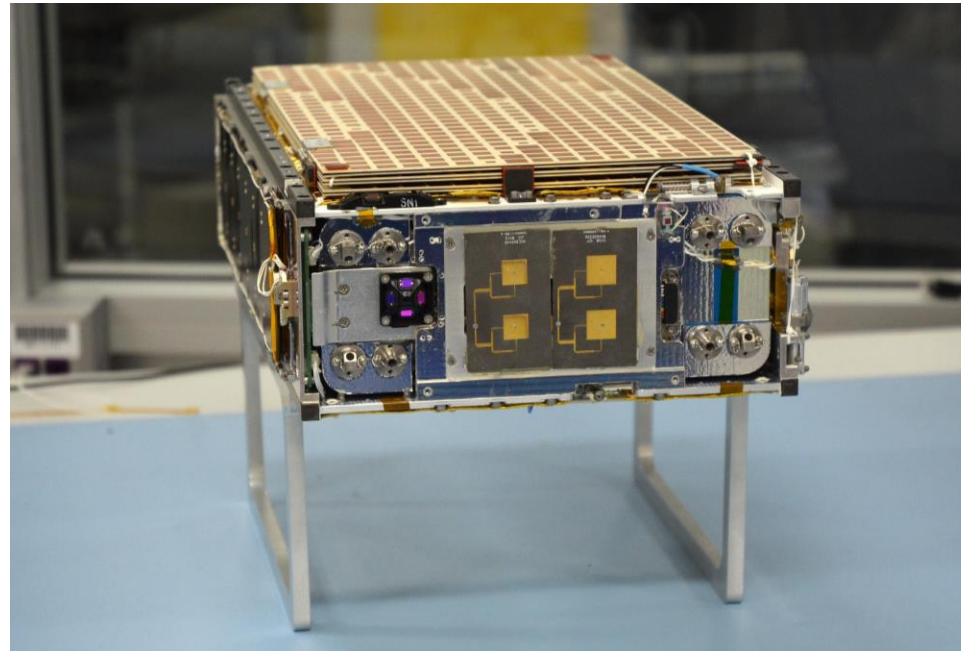
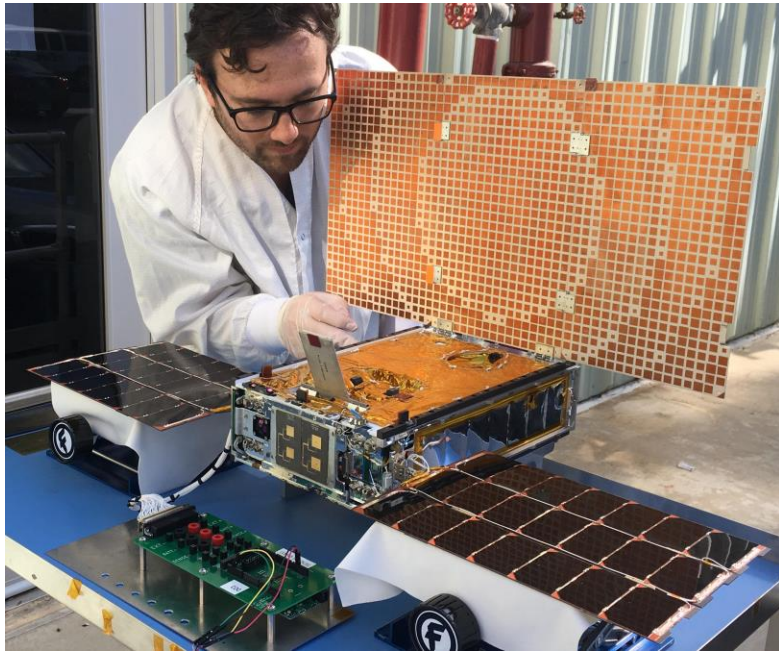
Beyond LEO CubeSats:

MEO, GTO, GEO, Moon, Mars &
Interplanetary Missions



MarCO - Mars Cube One

- Two 6U Mars flyby CubeSats launched in 2018.
- First interplanetary / deep space CubeSats beyond LEO orbit.
- Mission: Relay data in real-time during InSight landing on Mars.
- Status: Mission successfully completed and signals lost about 1 month later.

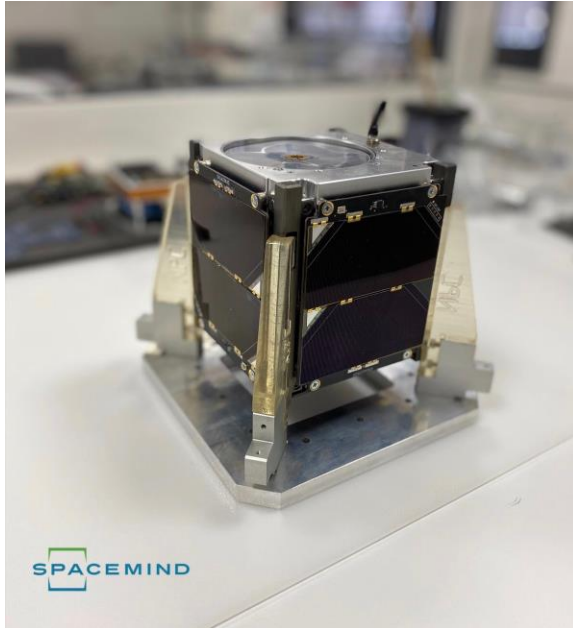


TDO and TDO-2

- Launched in 2019 and 2020 to GTO.
- Developed by Georgia Institute of Technology for Space and Missile Systems Center (SMC) and sponsored by Air Force Research Laboratory (AFRL).
- Status: Passive object?
- Mission: Support space domain awareness through optical calibration and satellite laser ranging.



MEO CubeSats



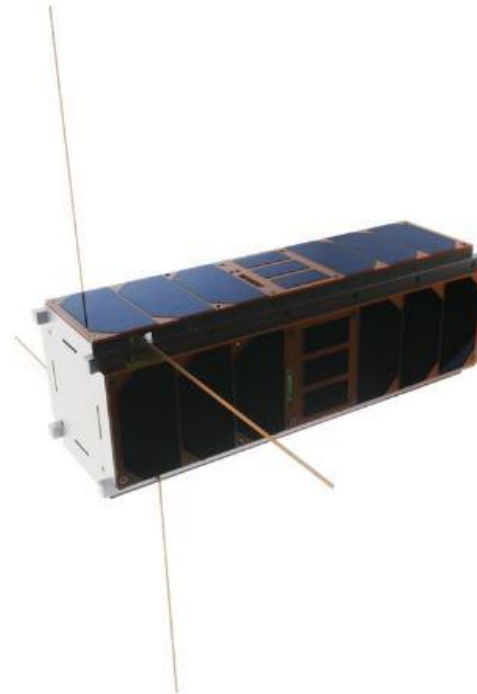
ALPHA

2021

Vega-C, 6000 km, 70 deg

1U

Tech demo



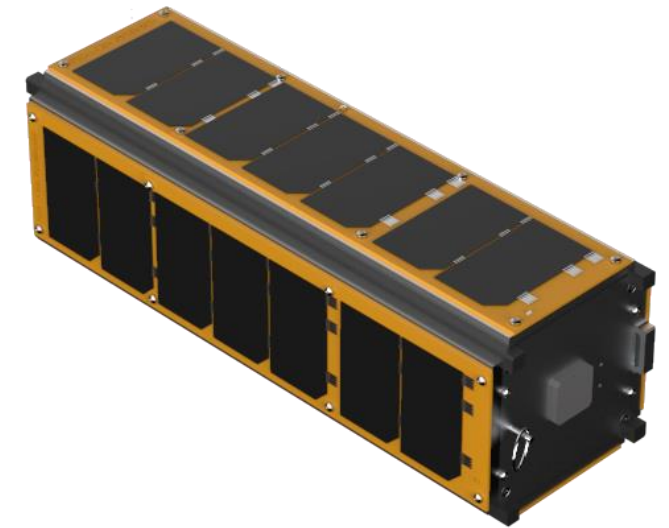
AstroBio CubeSat (ABCS)

2021

Vega-C, 6000 km, 70 deg

3U

Lab-on-a-chip



TRISAT-R

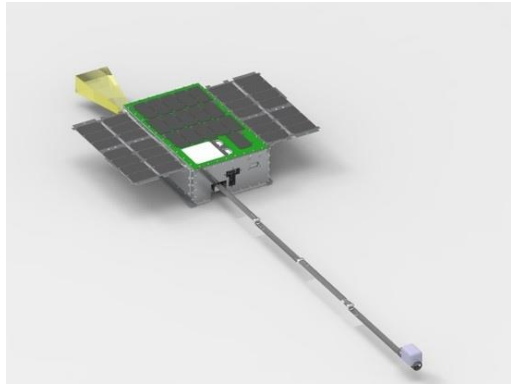
Unknown?

Vega-C?

3U

Radiation measurements

GTO CubeSats (1)

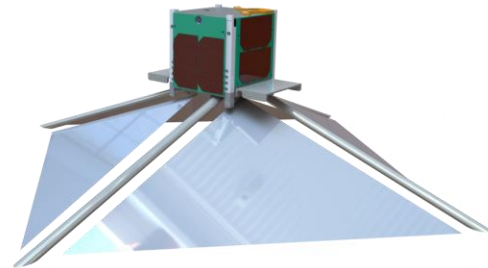


GTOSat

2021?

6U

Detecting high energy particles

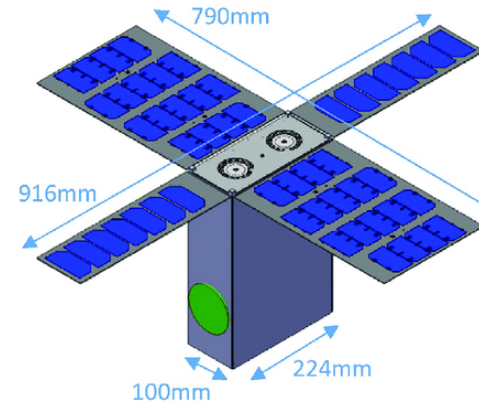


CP14 (ADE)

2022?

1U

De-orbit sail



SpectroCube

2022?

6U

Astrochemistry and radiation research



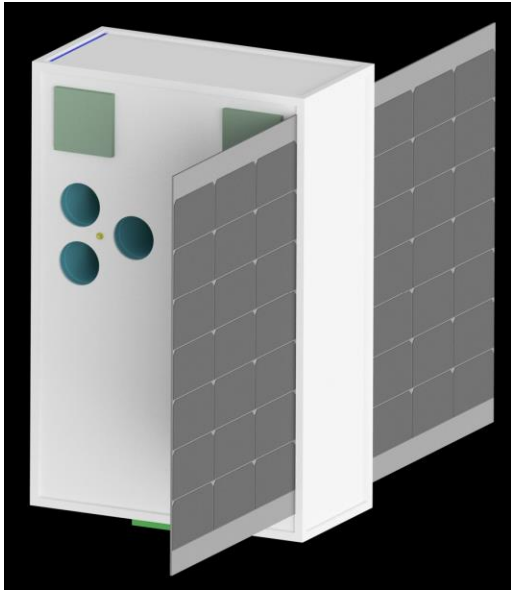
Foresail-2

2023

6U

Coulomb drag experiment and characterize ULF waves

GTO CubeSats (2)



OSC (Optics Space Craft, Virtual Telescope for X-Ray Observations, VTXO)

2024

6U

Supersynchronous orbit



LACCE (Louisiana Coronal mass ejection Correlation Experiment)

2023 or Concept?

3U

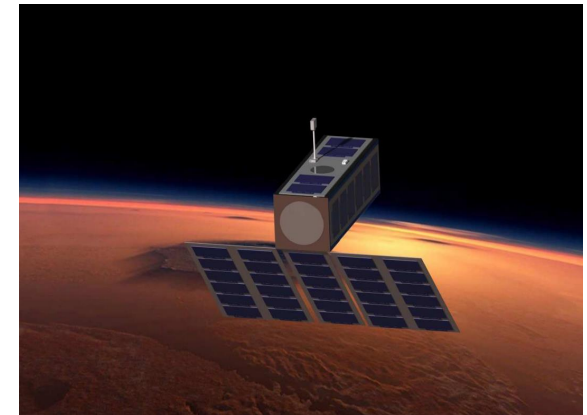
Study solar storms



DSM-BRAC
Cancelled?

2U

Tech demo for a future time capsule

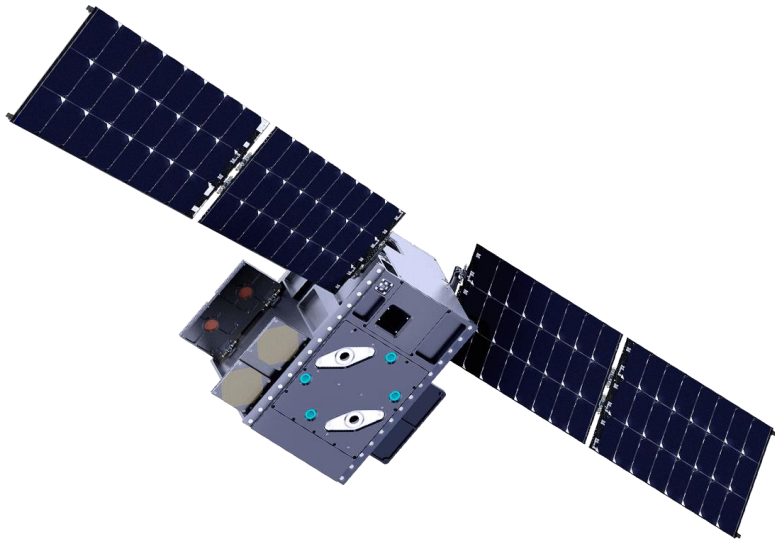


BIRDY-GTO
Cancelled

3U

Tech demo for a future Mars flyby free return spacecraft

GEO CubeSats (1)

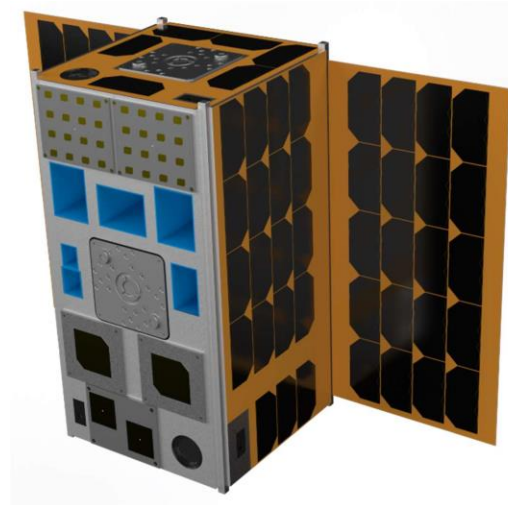


ASCENT

2021?

12U

Technology demo
of CubeSats in GEO



GS-1 (Gravity Space)

2022

16U

Hosted payloads incl.
radios and space
situational awareness



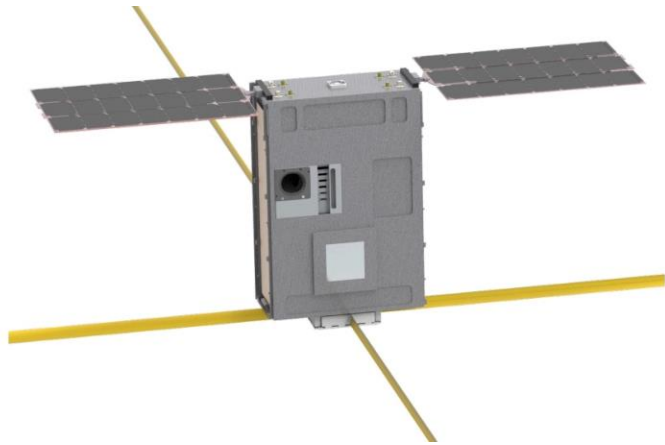
SWIMSat

2023 or Concept?

6U

Network for space hazards

GEO CubeSats (2)

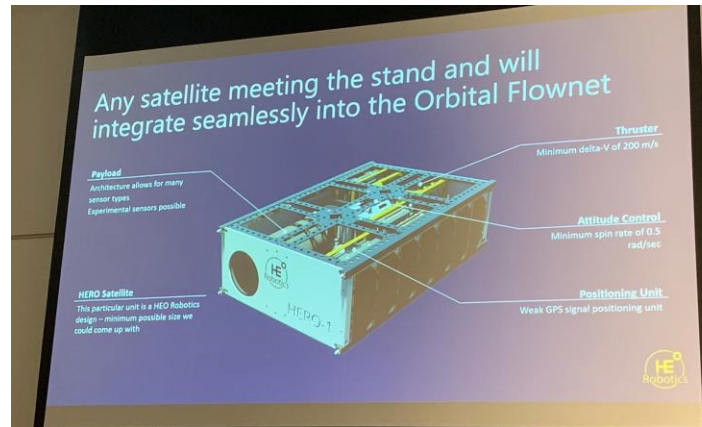


SunRISE (Sun Radio Interferometer Space Experiment)

2023

6x 6U

One very large radio telescope to study Sun in RF

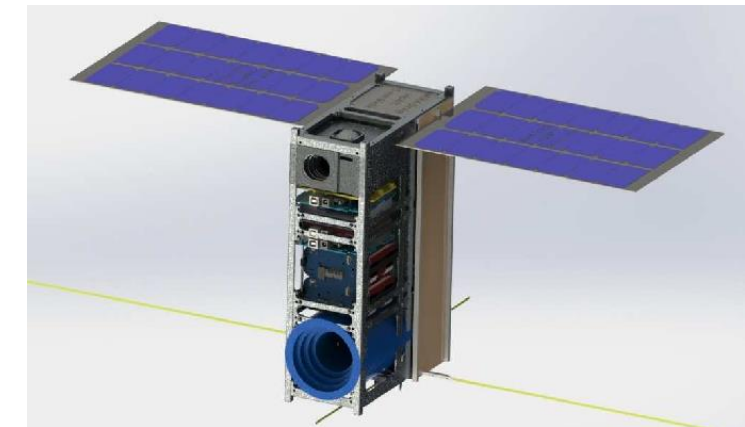


Hero-1

2023?

6U

Track GEO assets with optical imagers



mDOT Telescope-CubeSat (Miniaturized Distributed Occulter/Telescope)

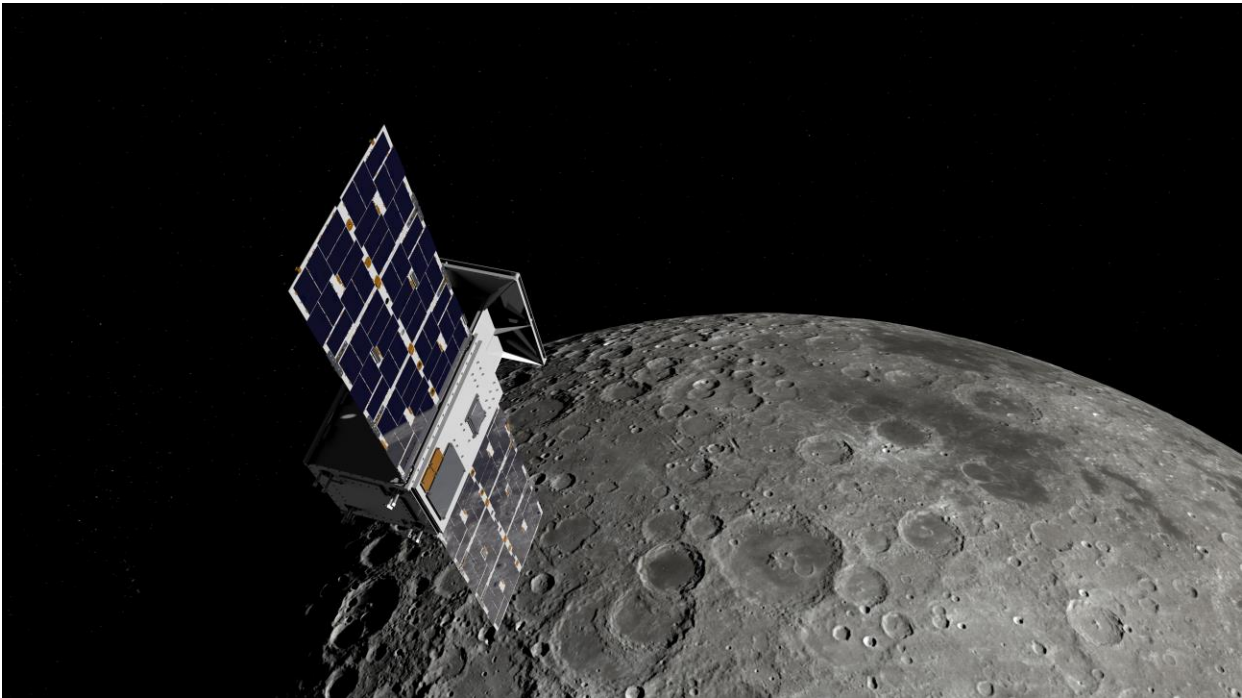
2025 or Concept?

6U

Demonstrate occulter and telescope

Lunar CubeSats (1) - CAPSTONE

- Launching in 2021 with Rocket Lab and Photon Lunar space tug.
- 12U base with special modifications?
- Demonstrate stability of the Moon's near-rectilinear halo orbit for Gateway and spacecraft-to-spacecraft navigation.



Lunar CubeSats (2)

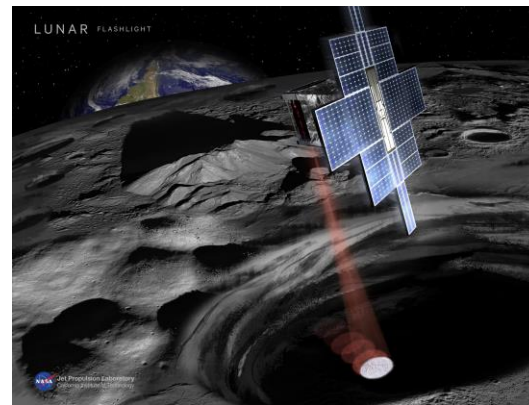


LunaH-Map

2022? (SLS)

6U

Map hydrogen content



Lunar Flashlight

2022? (SLS)

6U

Illuminate craters
and detect water



Lunar IceCube

2022? (SLS)

6U

Prospect for water
and other volatiles



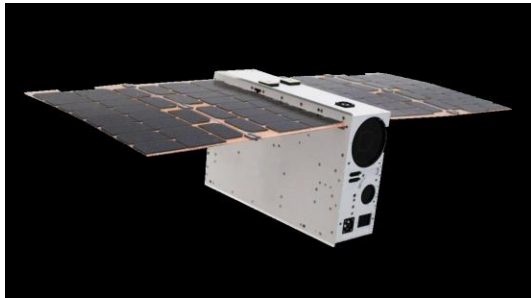
Miles

2022? (SLS)

6U

Tech demo with
propulsion

Lunar CubeSats (3)

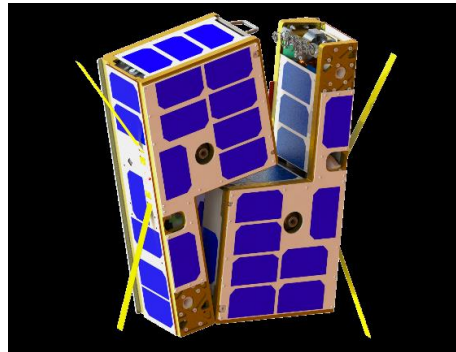


ArgoMoon

2022? (SLS)

6U

Image Artemis-1 and
tech demo

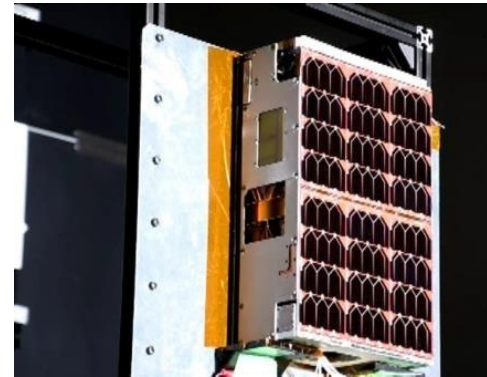


Cislunar Explorers

2022? (SLS)

6U

Electrolysis propulsion
& optical navigation
tech demo

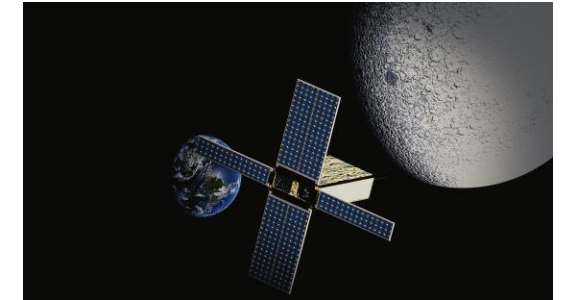


OMOTENASHI

2022? (SLS)

6U

Demonstrate low
cost lunar surface
landing probe



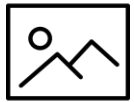
Garat a-L (Garatea-L)

2022 (PSLV?)

6U

Study the effects of
microgravity of
different lifeforms

Lunar CubeSats (4)



Seven Sisters 1

2023

6U

Searching water

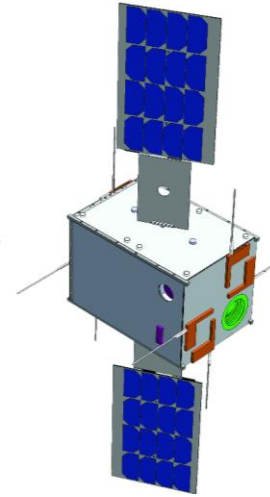


RADMIA

2023 or Concept?

16U

Hyperspectral imager
and radiation sensor



LUMIO

2024

12U

Detect bright flashes
to map meteoroid
bombardments



VMMO

2024

12U

Search water from
permanently
shadowed craters

Lunar CubeSats (5)



Zeus-MS

2024

2x 12U

Multiple payloads,
using Momentus
transportation service



ALCEK

Cancelled

6U

Spectroscopic
research of surface

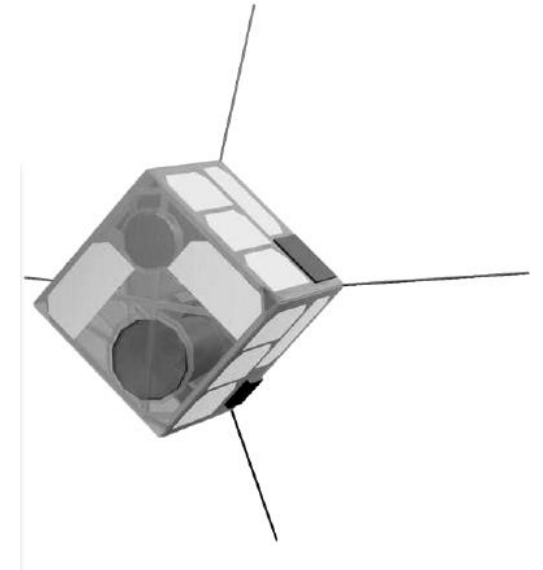


LIS-1

Cancelled

3U

Take photos of
Moon's surface



Lunette

Cancelled

6 kg

ESMO subsatellite
for gravity mapping

Mars CubeSats (+MarCO)

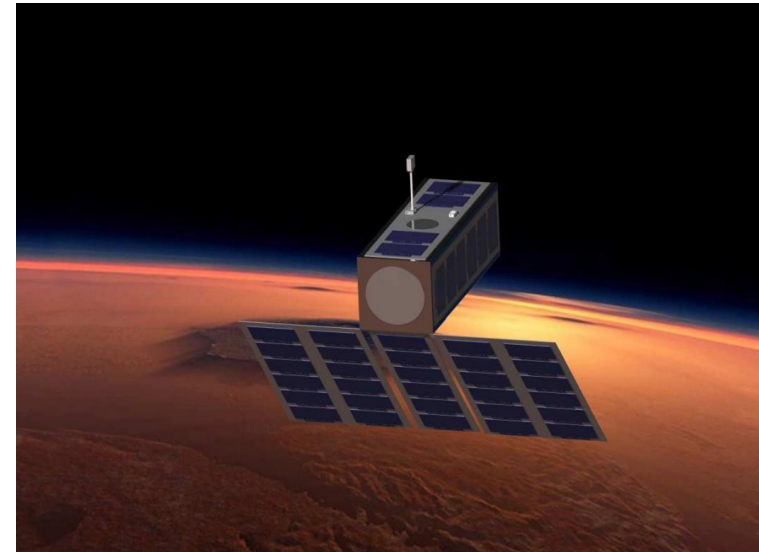


Cubeallute

Cancelled

3U

Probe Mars atmosphere with hypersonic drag balloon



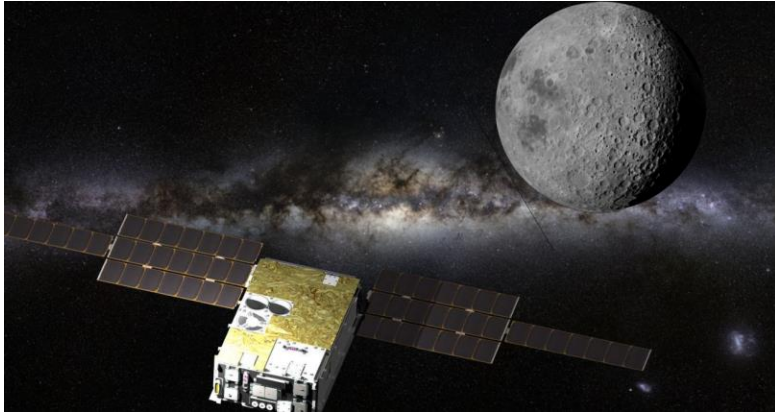
BIRDY

Cancelled

3U

Mars free-return to collect radiation data

Earth-Moon Lagrange CubeSats



EQUULEUS (Equilibrium Lunar-Earth point 6U Spacecraft)

2022? (SLS)

6U

Lunar L2 orbiter to demonstrate technologies and characterize environment.



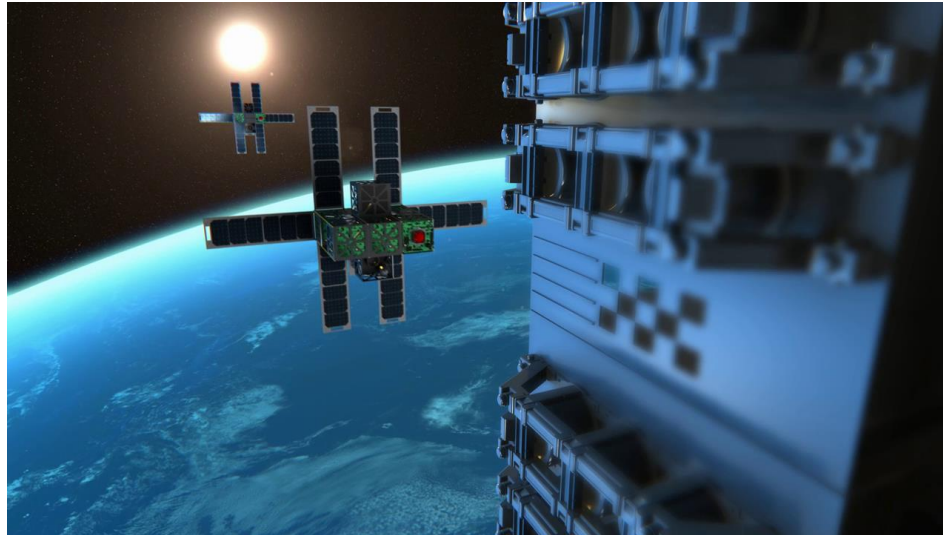
Hypergiant Lagrange CubeSat

2022?

12U

Demonstrate interplanetary network and Earth's data archive in Lunar L1.

Earth-Sun Lagrange CubeSats



SULIS-A (Solar cUbesats for Linked Imaging Spectropolarimetry)

2025?

2x 12U

Earth-Sun L4

3 pairs of formation-flying coronagraphs within CubeSats in 1AU orbits around the Sun for Sun magnetic field observations.

SULIS-B (Solar cUbesats for Linked Imaging Spectropolarimetry)

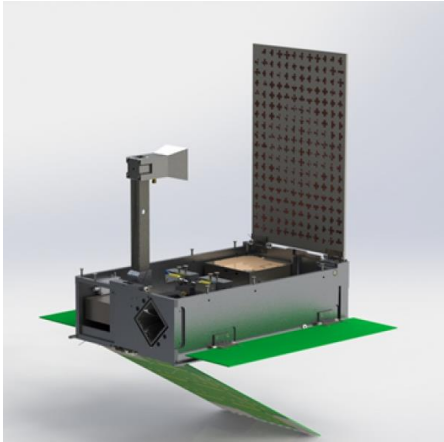
2025?

2x 12U

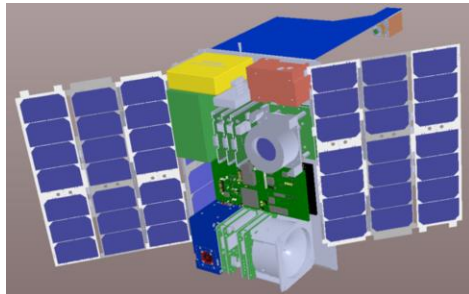
Earth-Sun L5

3 pairs of formation-flying coronagraphs within CubeSats in 1AU orbits around the Sun for Sun magnetic field observations.

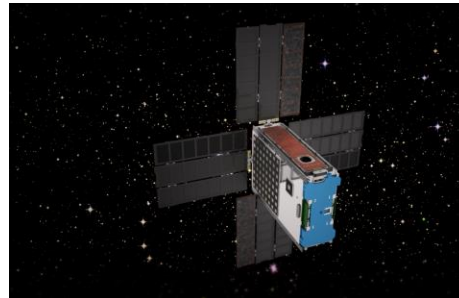
Heliocentric CubeSats



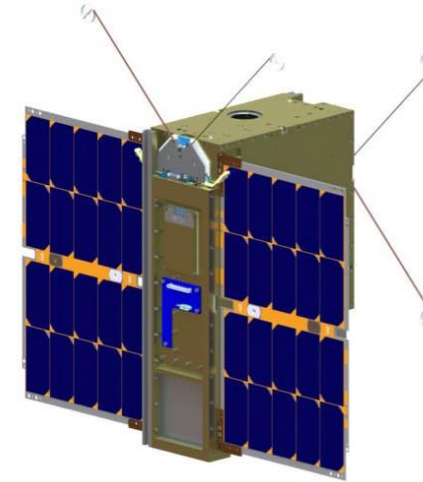
CU-E3
2022? (SLS)
6U
High-data rate
communications



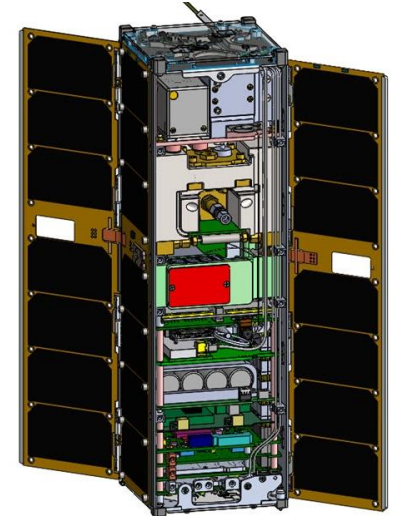
CuSP
2022? (SLS)
6U
Space weather
station to study
solar particles



BioSentinel
2022? (SLS)
6U
Tech demo and
radiation biosensor



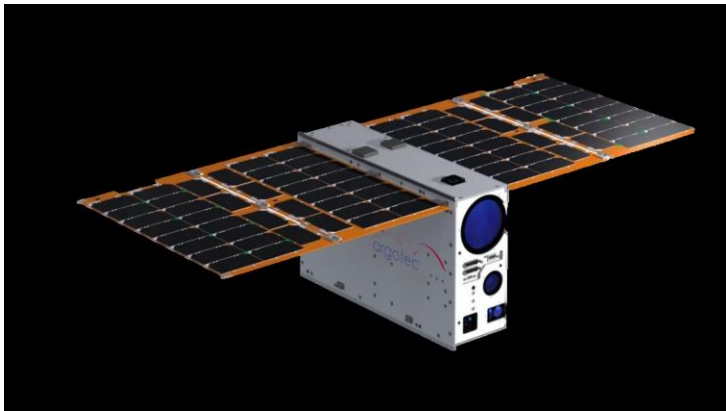
LunIR
2022? (SLS)
6U
Lunar fly-by for
spectroscopy and
thermography
using MWIR sensor



Detailed CAD Model
Apr 2014

INSPIRE
Cancelled
2x 3U
Tech demo,
planned to be
first in deep
space

Asteroid CubeSats (1)

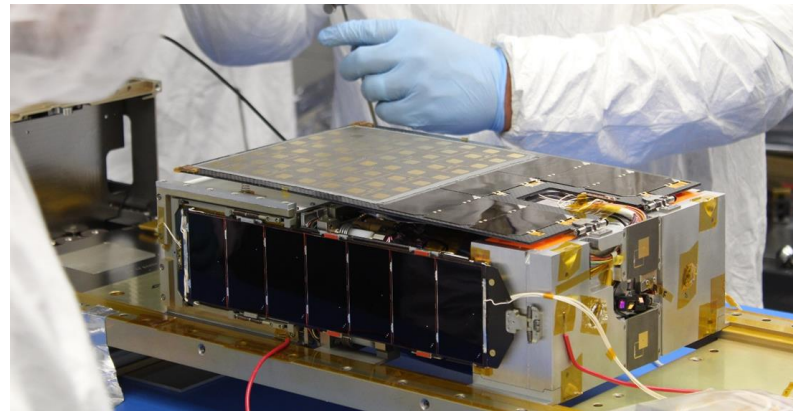


LICIA Cube

2021

6U

Travel with DART and monitor crater and plume after the impact

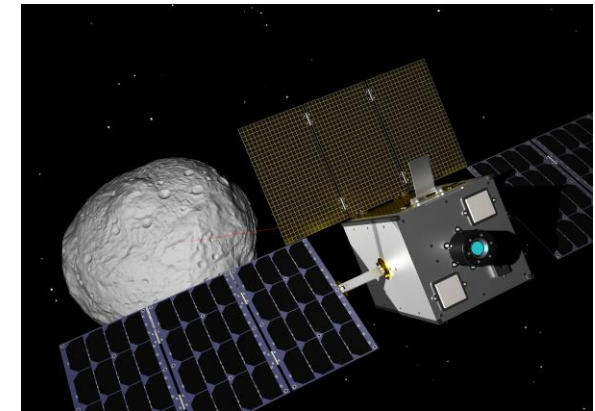


NEA Scout

2022? (SLS)

6U

Flyby an asteroid slowly with a solar sail and gather detailed imagery



M-ARGO

2024

12U

Orbit and characterise using multispectral camera and laser altimeter

Asteroid CubeSats (2)



Juventas

2024

12U

Subsurface sounding and gravity measurements

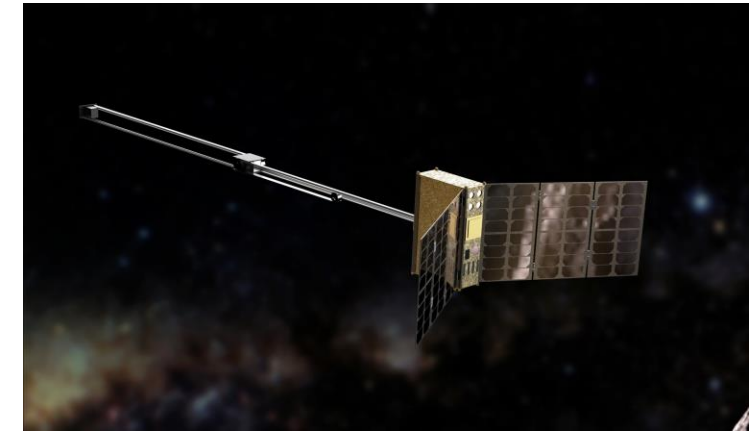


Milani

2024

12U

Map asteroids and determine compositions.



APEX

Cancelled?

12U

Mineral prospector in deep space

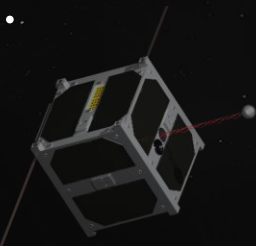
Conclusions and Future Work

- Interplanetary, MEO, GTO, GEO and other “beyond LEO” CubeSats are still in the early days, but starting to take off.
- 2021 status:
 - Beyond LEO CubeSats in the database: 64
 - Interplanetary CubeSats launched: 2
 - GTO CubeSats launched: 2
- Future work:
 - Add concepts/studies as a new category (Europa, Neptune etc).
 - Differentiate and collect further deep space technologies.



Sources & Acknowledgements

- Information & photos should have references on www.nanosats.eu.
- Launch schedules and manifests such as [Gunter's Space Page](#).
- [Jonathan McDowell's Space Reports](#) and [Master Satellite List](#).
- Websites [IARU](#), [Space-Track](#), [NASA Spaceflight](#), [NewSpace Hub](#).
- Official publications, websites, news articles and social media posts.
- Presentations and proceedings from related conferences incl ISSC.
- Radio amateurs such as [DK3WN](#), [JA0CAW](#) and [SatNOGS](#).
- Other databases such as [M. A. Swartwout](#) for some cross-checking.
- Databases [SPOON](#) (parts on orbit) and [PMPedia](#) (radiation tested).
- Occasional emails and self-additions. Thank you!





Nanosats Database

www.nanosats.eu

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