Overview of ESA Interplanetary CubeSat Missions & Enabling Technologies

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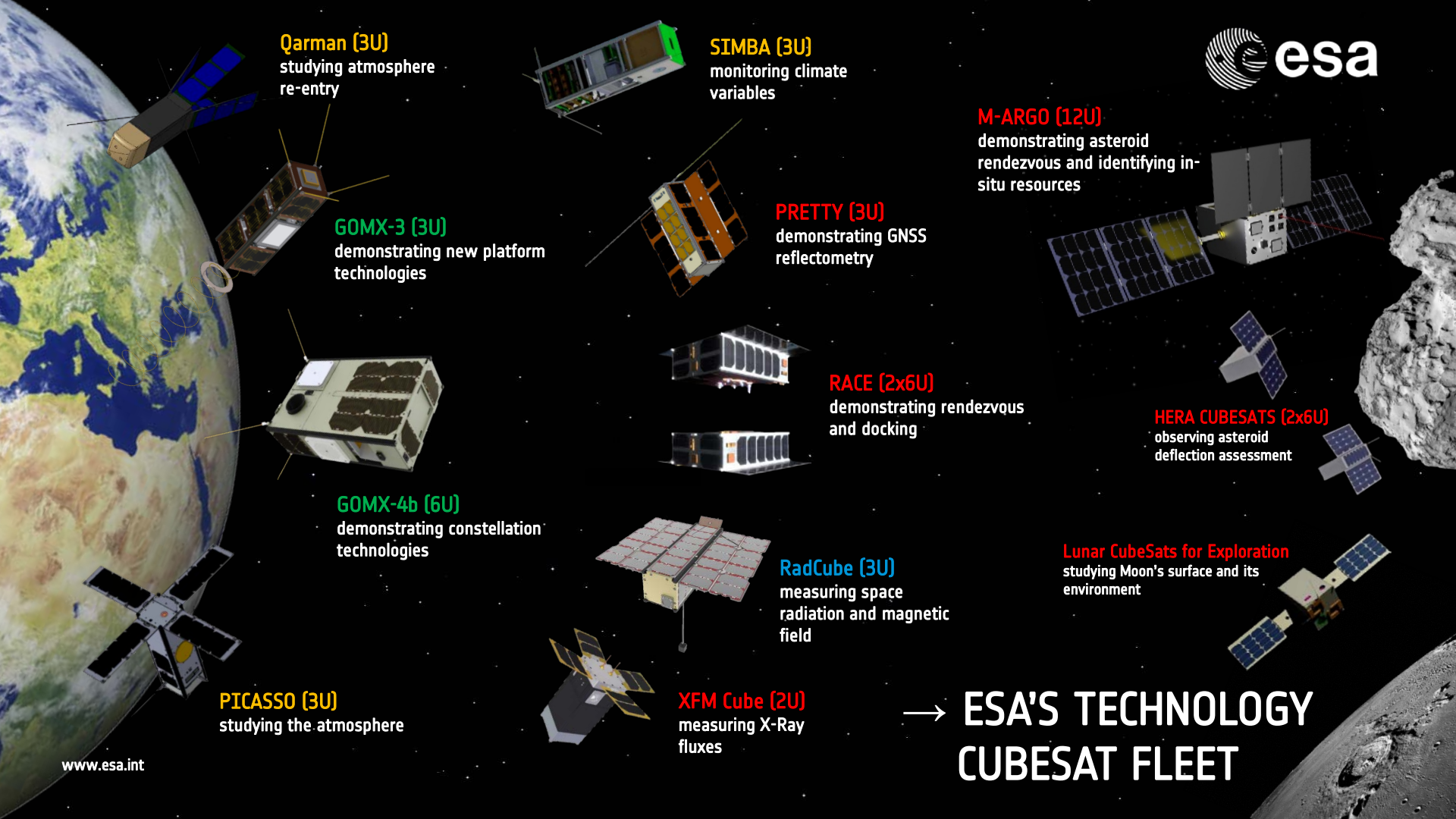
Directorate of Technology, Engineering & Quality

ISSC, 29 April 2019


Qarman (3U)
studying atmosphere re-entry
SIMBA (3U)
monitoring climate variables
M-ARGO (12U)
demonstrating asteroid rendezvous and identifying in-situ resources
GOMX-3 (3U)
demonstrating new platform technologies
PRETTY (3U)
demonstrating GNSS reflectometry
RACE (2x6U)
demonstrating rendezvous and docking
HERA CUBESATS (2x6U)
observing asteroid deflection assessment
GOMX-4b (6U)
demonstrating constellation technologies
RadCube (3U)
measuring space radiation and magnetic field
Lunar CubeSats for Exploration
studying Moon's surface and its environment
PICASSO (3U)
studying the atmosphere
XFM Cube (2U)
measuring X-Ray fluxes
→ ESA'S TECHNOLOGY CUBESAT FLEET
www.esa.int

ESA's First Technology CubeSat in Space

Project: GOMX-3

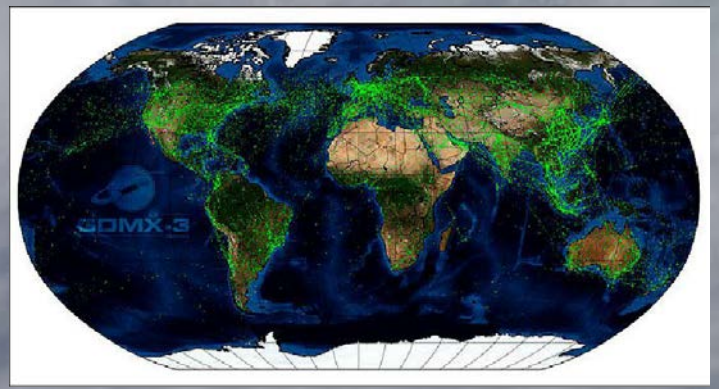
Contractor: GomSpace DK

Platform: 3U CubeSat (3 kg)

Duration: 1 year KO to flight readiness

Deployed from ISS: 5 October 2015

Status: 1 year of operation, mission successful



Achievements:

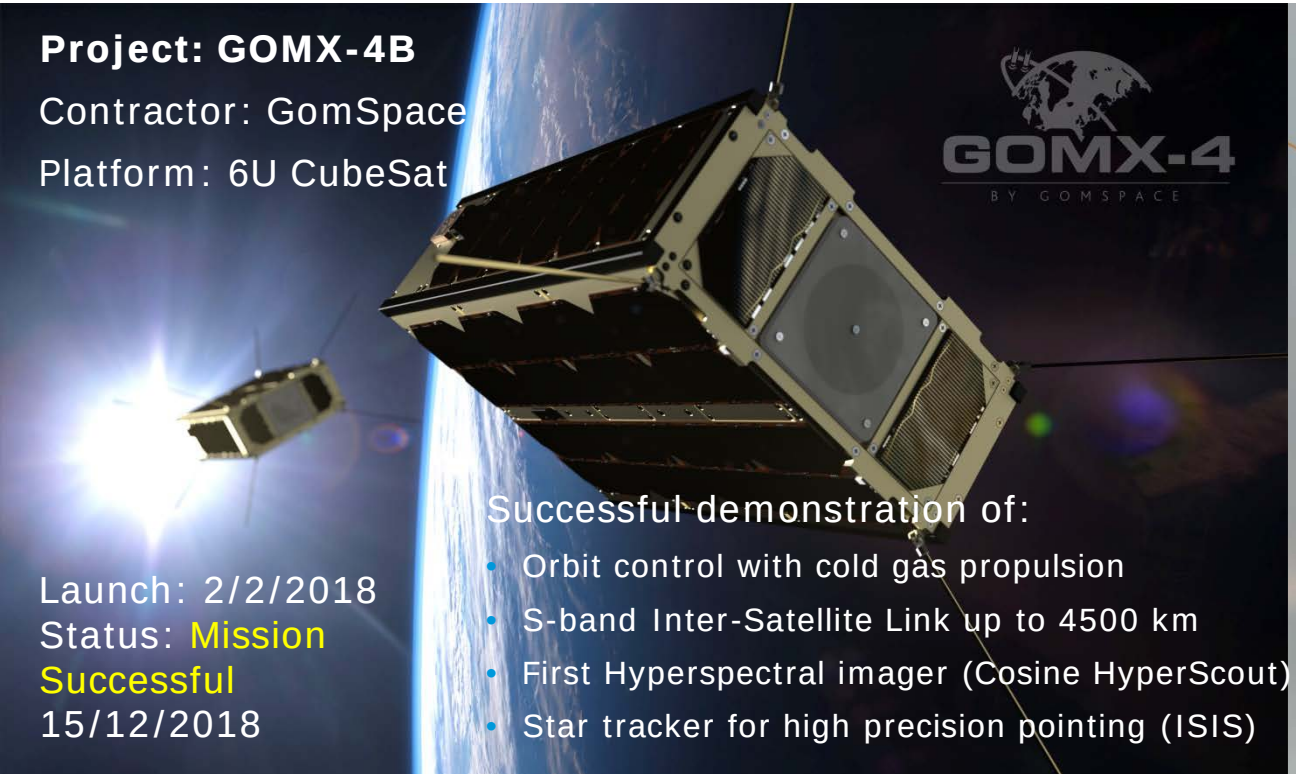
- 3-axis pointing acc. <2° (25° eclipse)
- X-band Downlink @ 3 Mbps
- Reconfigurable software-defined radio
- GEO Telecom L-band signal analysis
- ADS-B Aircraft tracking from a CubeSat
- Global wind data from ADS-B messages

1st Gen. Constellation Technology Demonstration

Project: GOMX-4B

Contractor: GomSpace

Platform: 6U CubeSat



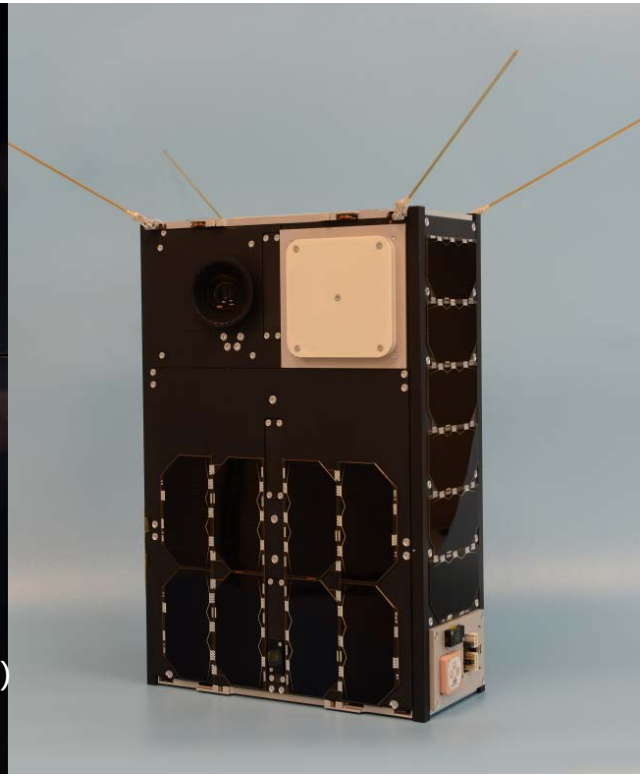
Launch: 2/2/2018

Status: Mission Successful

15/12/2018

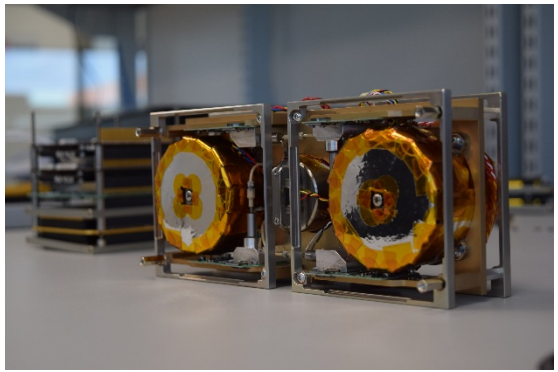
Successful demonstration of:

- Orbit control with cold gas propulsion
- S-band Inter-Satellite Link up to 4500 km
- First Hyperspectral imager (Cosine HyperScout)
- Star tracker for high precision pointing (ISIS)



Technologies Demonstrated on GOMX-4B

All relevant to deep space missions



Cold gas propulsion
(Gomspace Sweden)

Orbit control manoeuvres
(10 m/s @ 70 s)

Star tracker
(ISISpace NL)

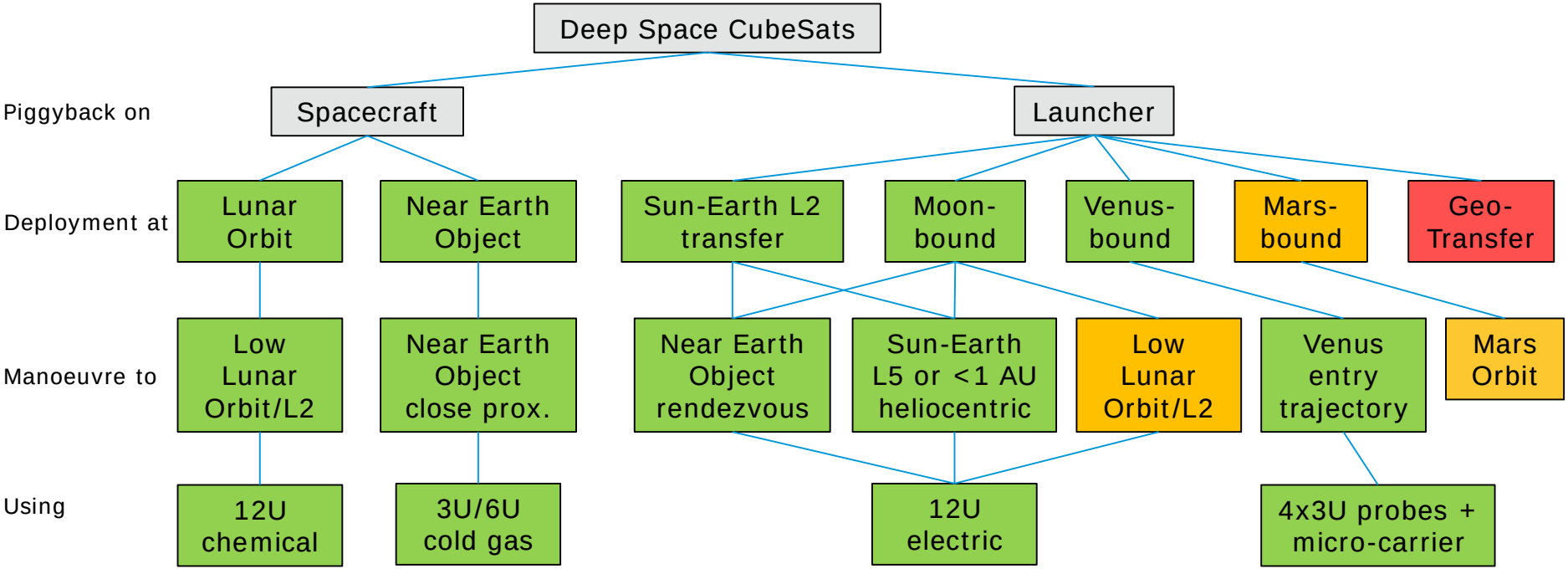
Precise attitude determination
(30” @3-sigma)

S-band Inter-Satellite Link
(Gomspace)

High rate comms @ short range (few 10s km) / low rate @ long range

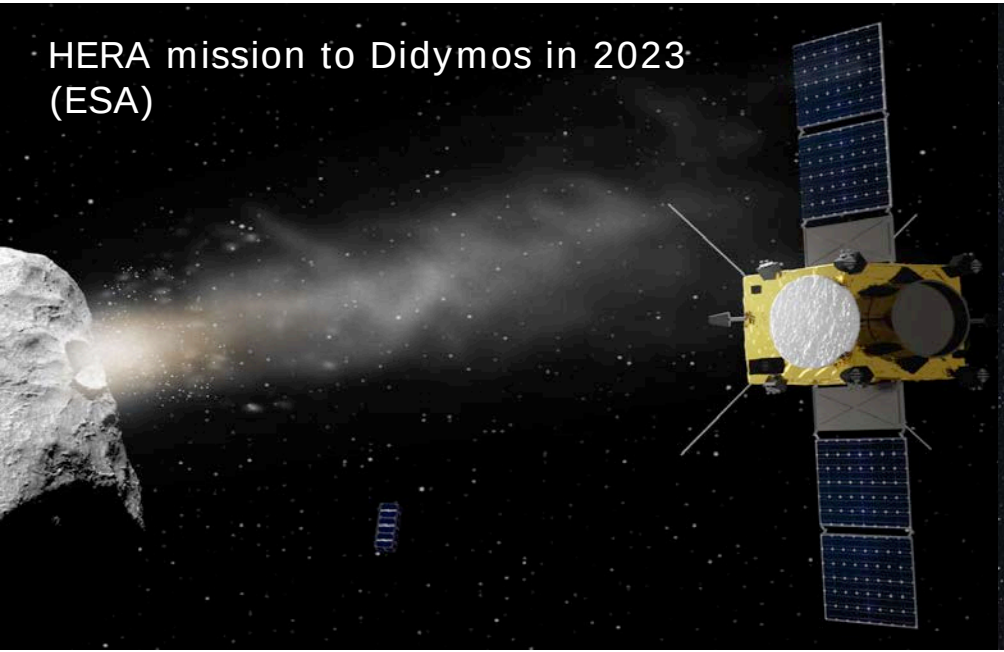
Interplanetary Mission Scenario Assessment

How far can the CubeSat paradigm be extended from the safety of LEO out to lunar and deep space? What unique new missions can be performed?



Mother-daughter architectures at single targets

Deployment of a swarm of CubeSats by a larger mothercraft



Transportation & data relay provided by larger mothercraft
Deep investigation of a single target body with multi-point measurements

Juventas Cubesat on the Hera mission

Industrial Consortium led by GomSpace (DK)
GMV(RO), Astronika(PL), Brno University(CZ), CSRC(CZ)

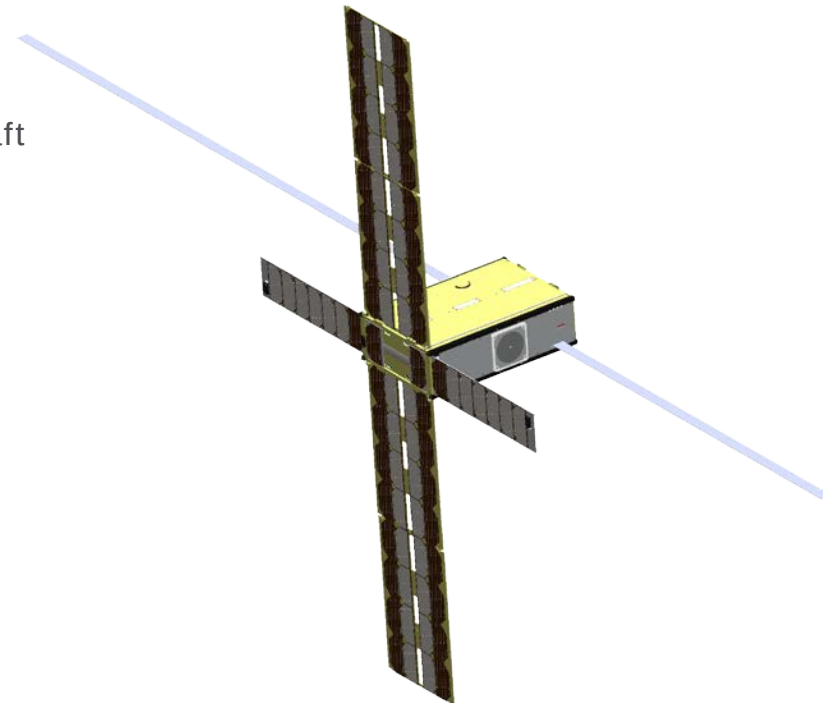
Platform: 6U CubeSat deployed at asteroid by Hera spacecraft
Scientific objectives:

- 1: Characterize the gravity field
- 2: Characterize the internal structure
- 3: Determine the surface properties
- (4): Determine the dynamical properties

Payloads focused on geophysical investigations:

- Low frequency Radar
- 3-axis Gravimeter
- ISL radio link
- Visible camera for context
- Accelerometers and gyros

Status: Phase A/B ongoing



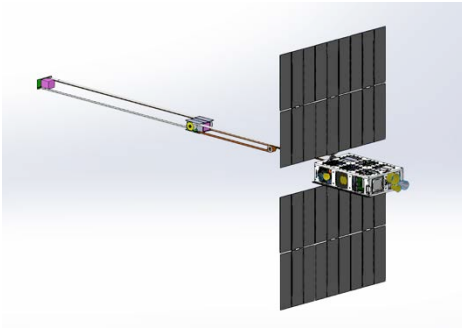
APEX CubeSat on the Hera mission

Surface composition

- *SIMA* – elemental composition from sputtered material from surface
- *ASPECT* – Mineral composition (Fabry-Perot imaging spectrometer)
- Infer variations between Didymos I and II

Internal structure

- *MAG* – Intrinsic magnetization
- Determination of Fe-Ni content and homogeneity



APEX
asteroid prospection explorer

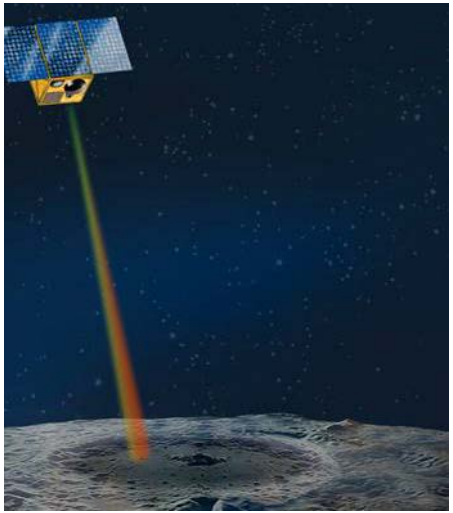
Swedish Institute of Space Physics (IRF),
V-kvadrat AB,
Royal Institute of Technology (KTH),
OHB Sweden,
Reaktor Space Lab (RSL),
Aalto University,
VTT Technical Research Centre of Finland Ltd,
University of Helsinki,
DLR Bremen,
Space Systems Czech (SSC)

Status: Phase A/B ongoing

LUnar Cubesats for Exploration (LUCE)

LUMIO (Lunar Meteoroid Impacts Observer)

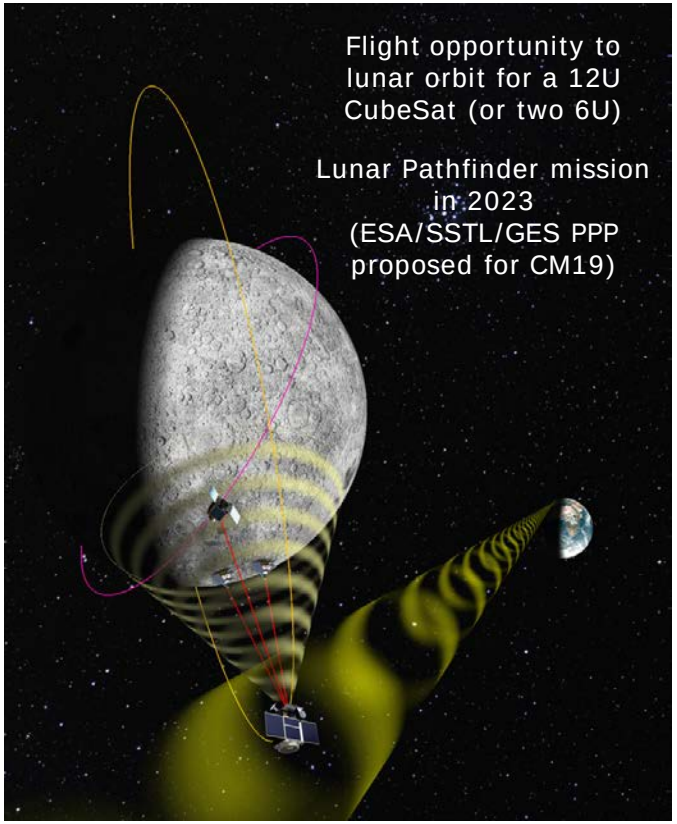
Carrying sophisticated camera to capture flashes of meteoroids impacting the far side



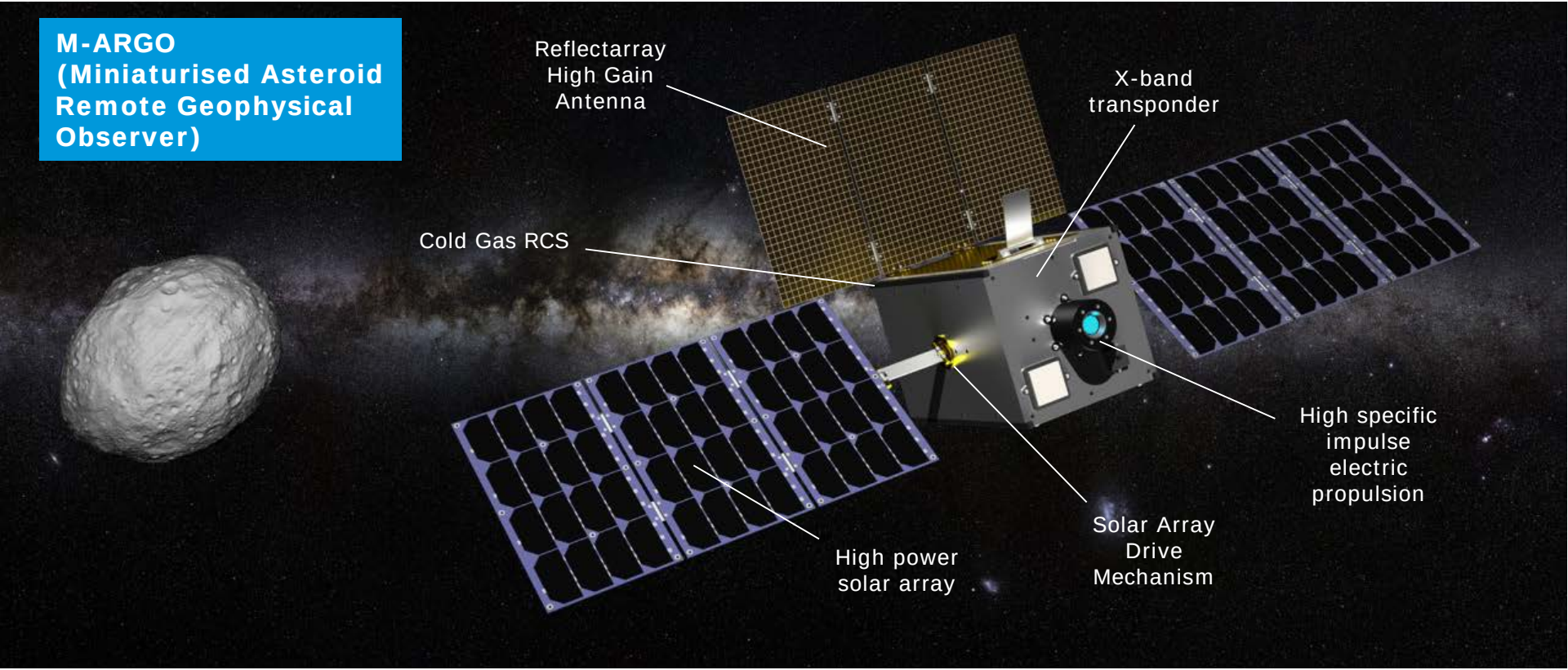
VMMO (Volatile and Mineralogy Mapping Orbiter)

Charting the Moon's water ice in permanently shadowed polar regions using active fibre laser

Industrial Phase A studies planned KO in Q3 2019



Stand-alone Deep Space CubeSats

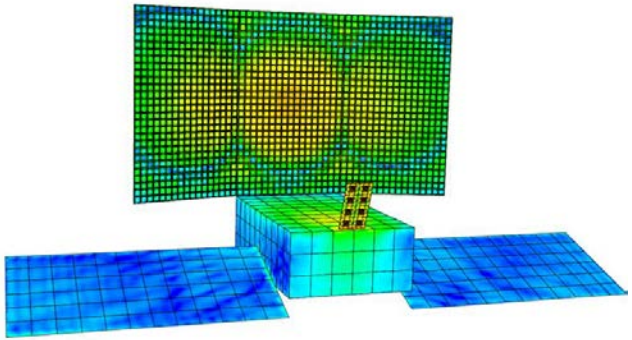


New Technologies Enabling Missions Beyond LEO

Ongoing Developments

Solar Array Drive Assembly
(IMT Italy)

High power generation
(120 W)



Reflectarray Flat Antenna
(TICRA/Gomspace Denmark)

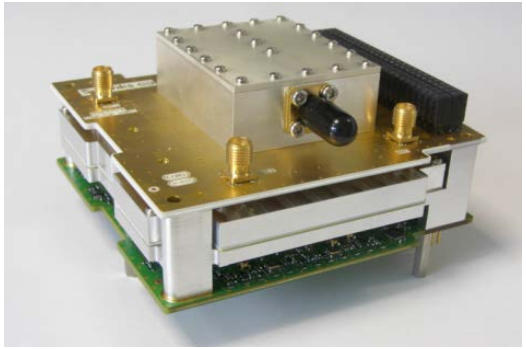
High RF gain
(29 dBi)

Highly integrated rad hard
avionics module

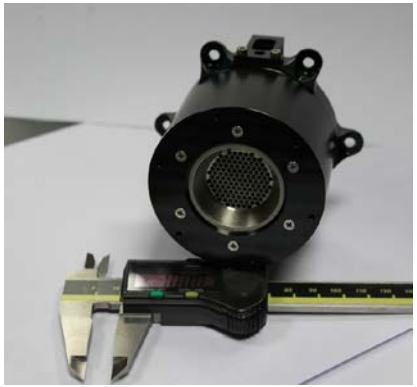
High autonomy
(DHS, GNC, FDIR) &
payload data processing

New Technologies Enabling Missions Beyond LEO

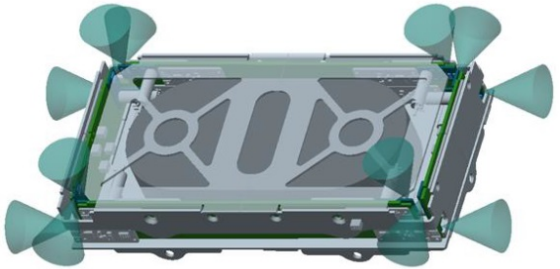
Planned Near-term Developments



Nanosat X-band TT&C transponder EM



High specific impulse electric propulsion system



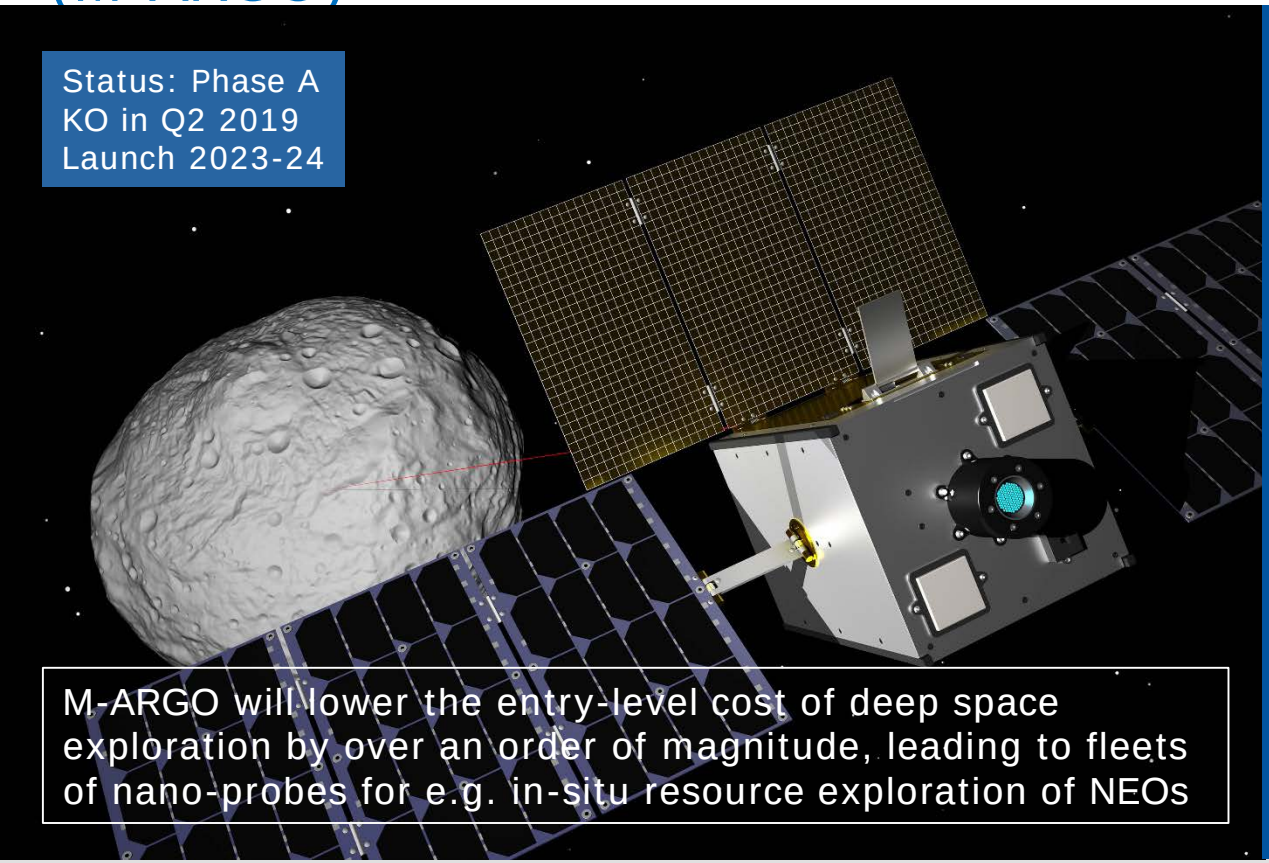
Cold Gas RCS (Gomspace Sweden)

Deep space communication & ranging (10 kbps @ 1AU)

Interplanetary transfer manoeuvres (3750 m/s @ Isp 3000s)

Reaction control & critical manoeuvres (10 mN)

Miniaturised Asteroid Remote Geophysical Observer (M-ARGO)



Status: Phase A
KO in Q2 2019
Launch 2023-24

M-ARGO will lower the entry-level cost of deep space exploration by over an order of magnitude, leading to fleets of nano-probes for e.g. in-situ resource exploration of NEOs

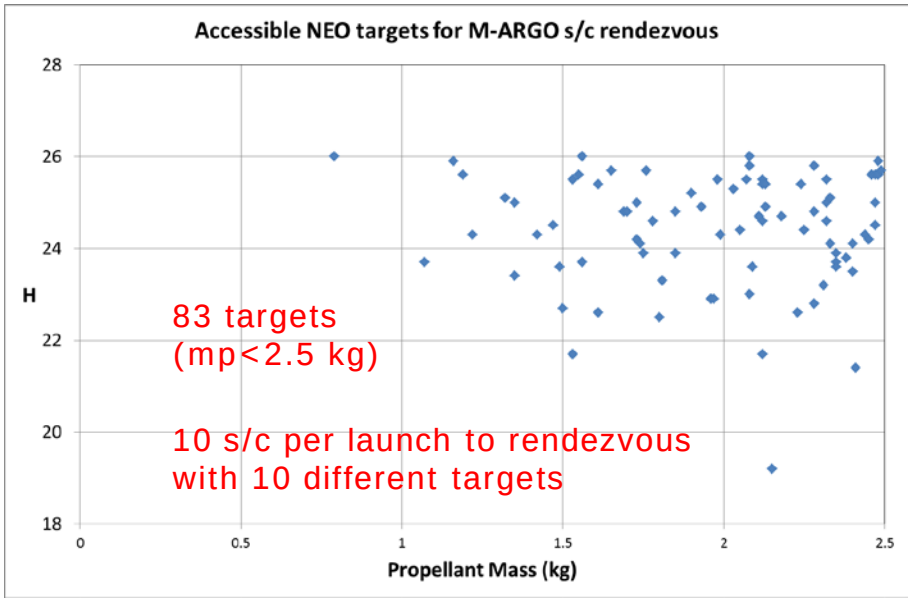
Objectives:

- Demonstrate critical technologies & operations for stand-alone deep space CubeSats in the relevant environment
- Rendezvous with a Near Earth Object (NEO)
- Physical characterisation of NEO with a small payload suite for in-situ resource exploration purposes

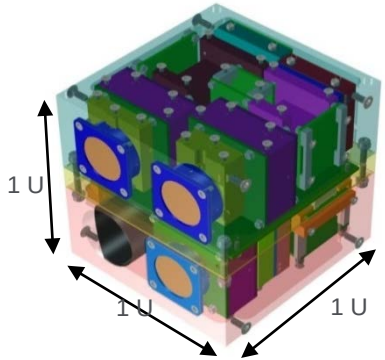
Mission concept:

- 12U CubeSat
- piggyback launch to Sun-Earth L2 transfer or lunar swing-by
- parking in L2 halo orbit
- 1-2 year low-thrust interplanetary transfer
- 6-month close proximity ops at NEO target
- 83 different NEO targets accessible

Fleet: Wide Survey of the NEO Population



Multi-spectral imaging spectrometer



VIS/NIR/ SWIR bands incl. navigation

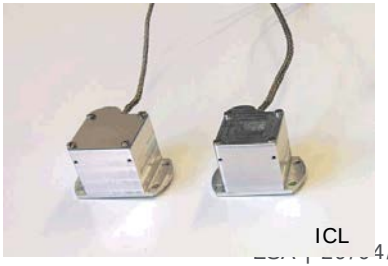
VTT Fabry-Perot

X-band radio science

Laser altimeter

Supports radio science & navigation

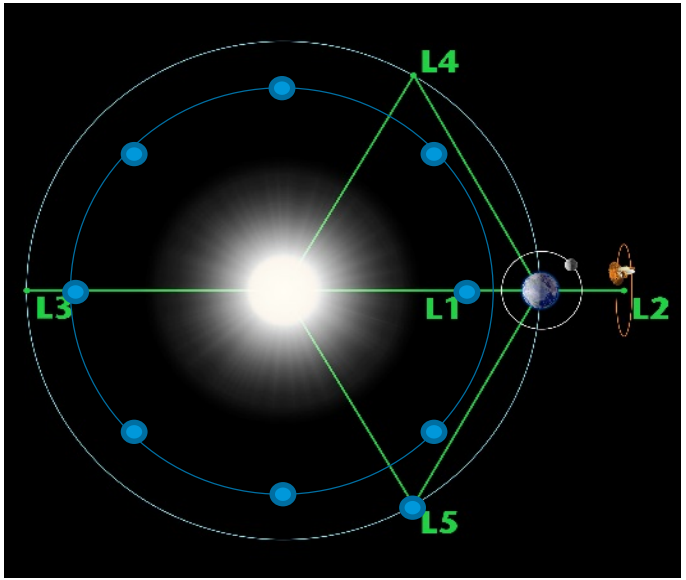
Magnetometer on deployable boom

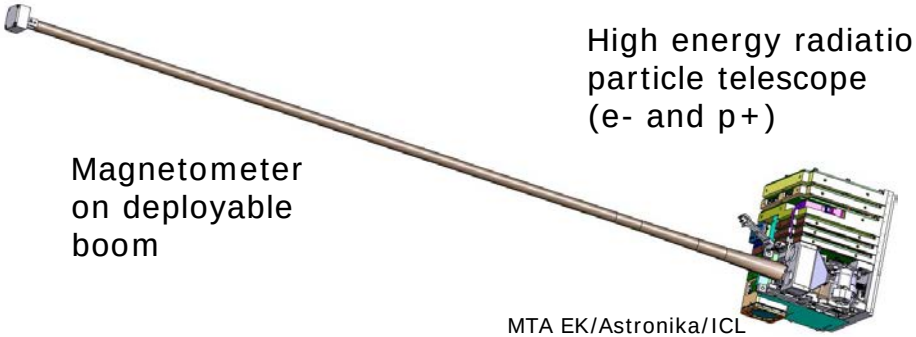


NEO Magnetic field -> metallics

Science: population diversity, small fast rotators
Exploration: identify asteroids with in-situ resources
Planetary defence: physical properties for deflection

Fleet: Simultaneous Multi-Point Space Weather Measurements



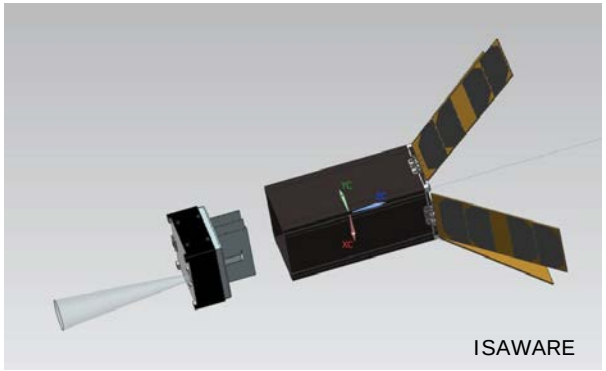


High energy radiation particle telescope (e- and p+)

Magnetometer on deployable boom

MTA EK/Astronika/ICL

Solar X-ray Flux Monitor



ISAWARE

In-situ measurements of solar activity over full solar longitude
10 CubeSats (M-ARGO s/c design) in heliocentric orbit <1 AU
Additional CubeSats at Sun-Earth L1 & L5

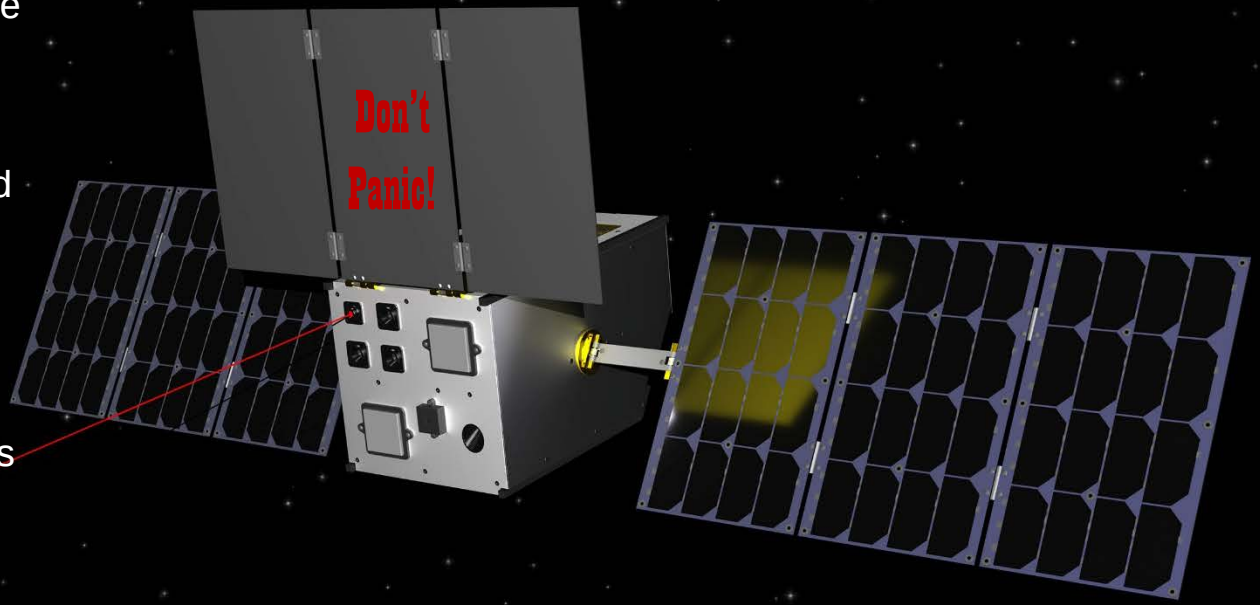
Conclusions

Exploit Piggyback opportunities to near Earth escape/lunar orbit/deep space

Factor 10 reduction in entry-level cost of deep space missions, enabling distributed systems

New missions identified for fleets e.g. wide survey of the NEO population & distributed space weather measurements

After MarCO, a new era in truly low-cost space exploration begins!!



THANK YOU

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