ESA Roadmap on Interplanetary CubeSats

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QARMAN (3U) studying atmospheric re-entry

GOMX-3 (3U) demonstrating new platform technologies

SIMBA (3U) monitoring climate variables

GOMX-4B (6U) demonstrating constellation technologies

PICASSO (3U) studying the atmospheric ozone

GOMX-5 (2 x 12U) next generation of constellation technology

PRETTY (3U) demonstrating GNSS reflectometry

RACE (2 x 6U) demonstrating rendezvous and docking

GOMX-4 (2 x 12U) next generation of constellation technology

RadCube (3U) measuring space radiation and magnetic field

M-ARGO (12U) demonstrating asteroid rendezvous and identifying in-situ resources

Lunar CubeSats for Exploration (2 x 12U) studying Moon's surface and its environment

HERA CUBESATS (2 x 6U) observing asteroid deflection assessment

RadCube (3U) measuring space radiation and magnetic field

XFM (2U) measuring solar X-Ray fluxes

PRETTY (3U) demonstrating GNSS reflectometry

SIMBA (3U) monitoring climate variables

ESAS TECHNOLOGY CUBESAT FLEET

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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)
- Star tracker (ISISpace NL)
- S-band Inter-Satellite Link (Gomspace)

- Orbit control manoeuvres (10 m/s @ 70 s)
- Precise attitude determination (30″ @3-sigma)
- 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?

Deep Space CubeSats

Piggyback on

Spacecraft

- Lunar Orbit
- Near Earth Object
- Sun-Earth L2 transfer
- Moon-bound
- Venus-bound
- Mars-bound
- Geo-Transfer

Launcher

Deployment at

- Low Lunar Orbit/L2
- Near Earth Object close prox.
- Sun-Earth Object rendezvous
- Near Earth Object L5 or <1 AU heliocentric
- Venus entry trajectory
- Mars Orbit

Manoeuvre to

- Low Lunar Orbit/L2
- Near Earth Object
- Sun-Earth L2 transfer
- Moon-bound
- Venus-bound
- Mars-bound
- Geo-Transfer

Using

- 12U chemical
- 3U/6U cold gas
- 12U electric
- 4x3U probes + micro-carrier
Mother-daughter architectures at single targets

Deployment of a swarm of CubeSats by a larger mothercraft

HERA mission to Didymos in 2023 (ESA)

Lunar Pathfinder mission in 2023 (ESA/SSTL/GES)

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 s/c

**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 of 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
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

Flight opportunity to lunar orbit for a 12U CubeSat (or two 6U)
Lunar Pathfinder mission in 2023
(ESA/SSTL/GES PPP proposed for Space19+)
Stand-alone Deep Space CubeSats

- Reflectarray High Gain Antenna
- X-band transponder
- Cold Gas RCS
- High power solar array
- Solar Array Drive Mechanism
- High specific impulse electric propulsion
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

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

High specific impulse electric propulsion system

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

Cold Gas RCS (Gomspace Sweden)

Reaction control & critical manoeuvres (10 mN)
Miniaturised Asteroid Remote Geophysical Observer (M-ARGO)

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

Status: Phase A started with Gomspace Lux & Politecnico di Milano Launch 2023-24 (TBC)

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
Fleet: Wide Survey of the NEO Population

Science: population diversity, small fast rotators

Exploration: identify asteroids with in-situ resources

Planetary defence: physical properties for deflection

83 targets (mp<2.5 kg)

10 s/c per launch to rendezvous with 10 different targets

Accessible NEO targets for M-ARGO s/c rendezvous

Multi-spectral imaging spectrometer

X-band radio science

Laser altimeter

Magnetometer on deployable boom

Servers radio science & navigation

NEO Magnetic field -> metallics

VIS/NIR/SWIR bands incl. navigation

VTT Fabry-Perot

Jenoptik

ICL
Fleet: Simultaneous Multi-Point Space Weather Measurements

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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