ESA small sat efforts

On behalf of Roger Walker, Ph.D [1]

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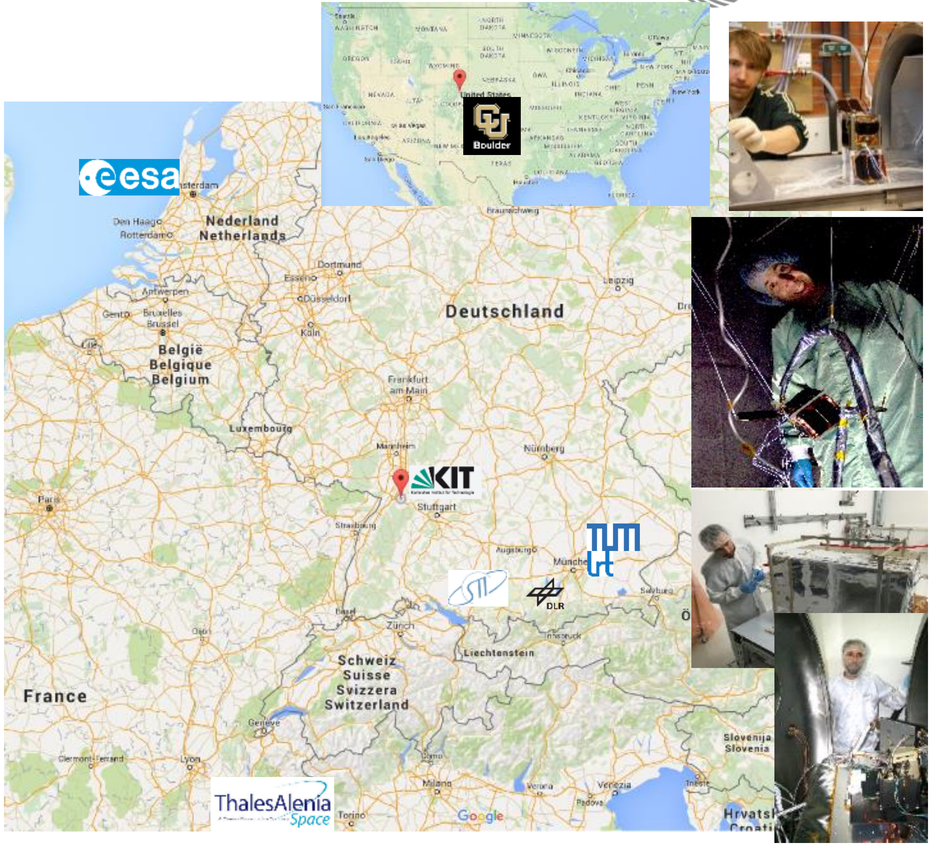
IPPW Small Sat Short Course,
Boulder, CO, USA, 9th of June 2018

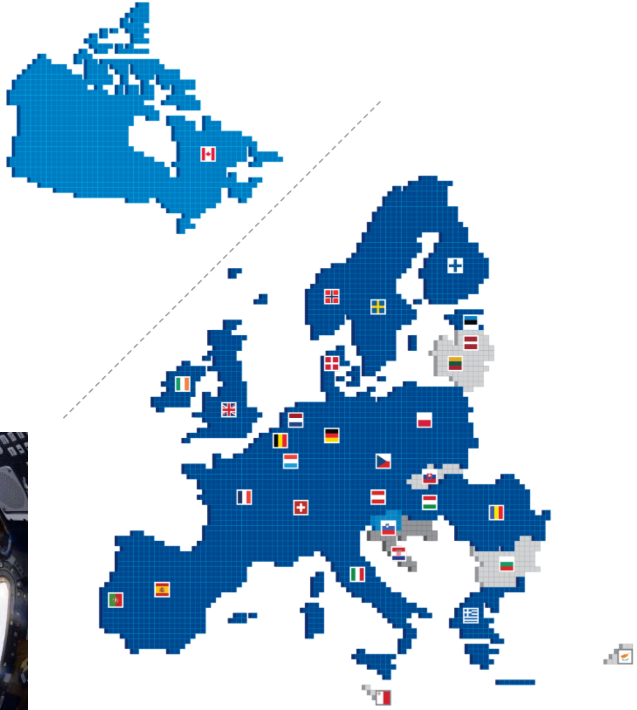
Personal Background

- **Universität Karlsruhe (GER)**
  - Pre-diploma (BSc) Mechanical Engineering
- **DLR Oberpfaffenhofen (GER)** – Teaching assistant
- **Thales Alenia Space, Torino (I)** - Internship
- **Technische Universität München (GER)**
  - Diploma (MSc) Aerospace Engineering
  - Research & Teaching Assistant
  - Ph.D. Aerospace Engineering
- **University of Colorado at Boulder (USA)**
  - Visiting Scholar, Bioastronautics Group
- **SpaceTech GmbH, Friedrichshafen (GER)**
  - System, Verification, AIT & Thermal Engineer:
  - LRI / GRACE-FO, Sentinel-5, MLI Test & Manufacturing
- **ESA ESTEC (NL)**
  - Thermal Engineer:
  - METOP-SG, PROSPECT & PILOT, CubeSats, CDF studies

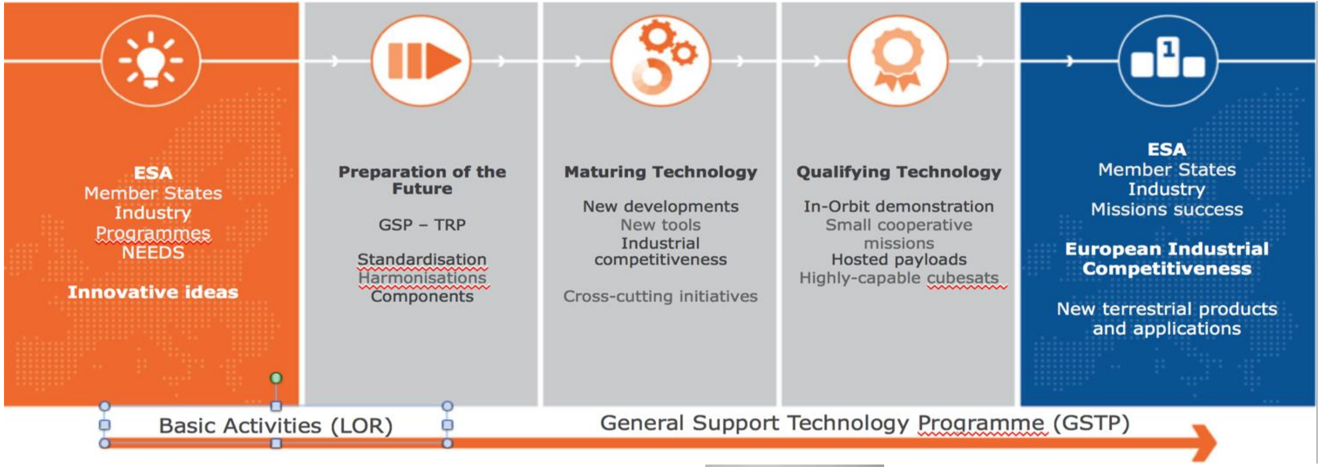


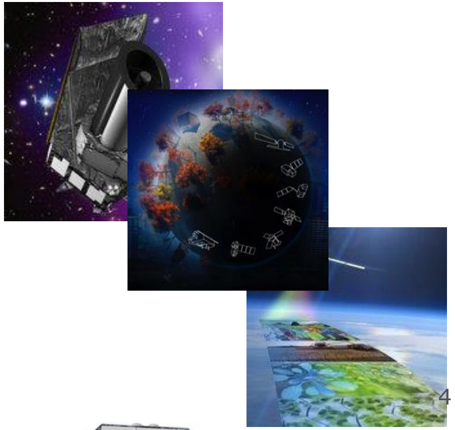
ESA facts and figures

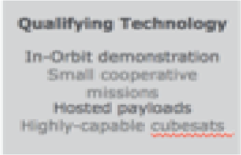
- Over 50 years of experience
- 22 Member States
- Eight sites/facilities in Europe, about 2300 staff
- 5.75 billion Euro budget (2017)
- Over 80 satellites designed, tested and operated in flight



Traditional technology chain at ESA – small missions



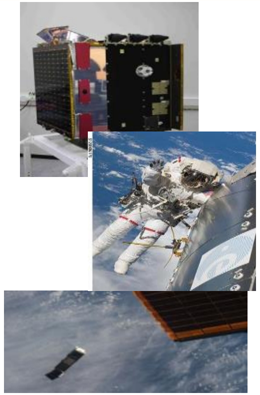




Micro/small Sats

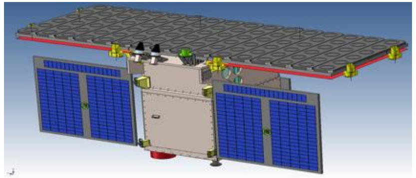
Hosted PL

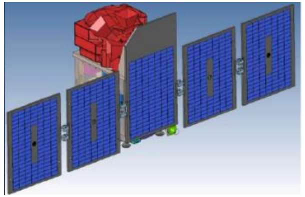
Cubesats



+ (recently) small missions from programs

SCI : CHEOPS





EOP : SAOCOM CS and Altius

General Support Technology Programme (GSTP)

Stimulating industrial competitiveness & growth

ELEMENT 1

Develop

Work plan driven envelope programme for **techno development**

ELEMENT 2

Make

Industry initiated, co-funded for **technology maturation** leading to products

ELEMENT 3

Fly (Small Missions)

Envelope which hosts sub elements such as Proba 3, cubesats, ISS payloads, **techno flight opportunities**

>10 M€ in ESA **GSTP FLY** Element (and since 2013 for 7 IOD CubeSat missions) in addition to the TFO (Technology Flight Opportunities) 2 M€, both frameworks are renewed once the funds are exhausted

Micro and Small missions - the right approach to In-orbit demonstration (IOD)

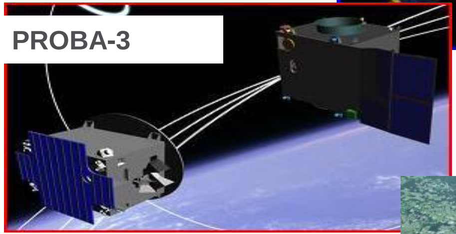
Why are micro/small missions important for ESA ?

- Micro and small missions allow to **test new space technologies and techniques**
- They serve targeted **scientific applications**
- They foster efforts of **national industries** in delivering a complete space system
- Micro/small missions are small in size but **real space missions** in all extent **requiring high tech industry**
- They provide **high visibility** to participating countries
- They provide opportunities for **creating links** between industries of ESA member states

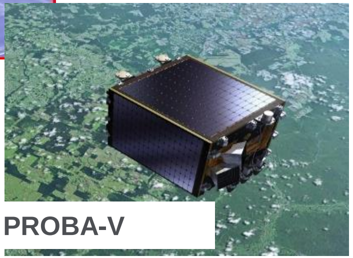
- Recently cubesats projects have also been initiated for IOD missions.

PROBA-1 Operating since 2001

PROBA-2 Operating since 2009

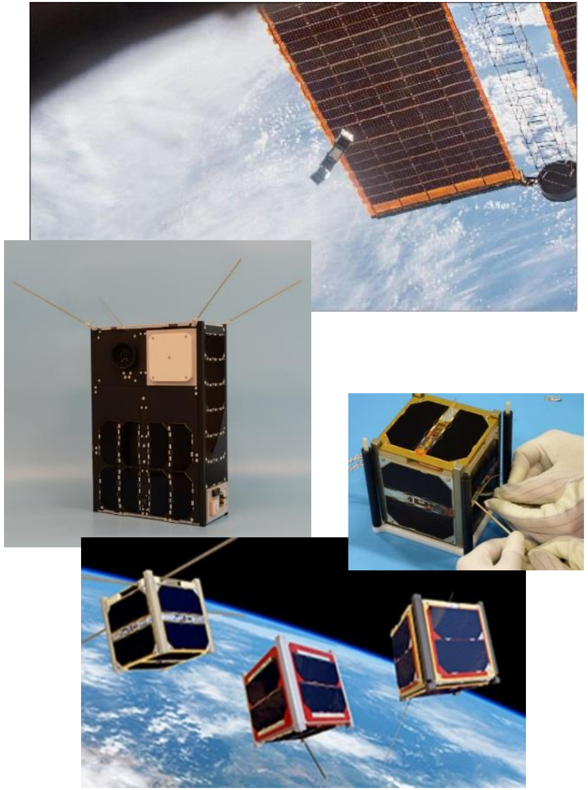


PROBA-3 Scheduled for 2020



PROBA-V Operating since 2013

CubeSats at ESA



Why is ESA interested in CubeSats?

- Proven worth as **educational tools** (students as well as new member states)
- Driver for **miniaturization of systems** (e.g. 'systems-on-chips', embedded propulsion)
- Affordable means of **demonstrating miniaturized technologies**,
- Affordable means of **demonstrating novel techniques** (e.g. formation flying, close inspection or rendezvous and docking)
- Opportunity to carry out **distributed multiple in-situ measurements**
- **Deploying small payloads** (constellation and swarms to overcome limitation in performance)
- **Augmenting solar system exploration** with:
    - Stand-alone fleet capable of rendezvous with multiple targets (e.g. near-Earth objects) or,
    - Swarm carried by a larger spacecraft and deployed at the destination (e.g. Moon, asteroid/comet, Mars).

MICRO AND SMALL SATS - OVERVIEW

PROBA 1 Demonstrator for autonomous operations and EO

Technology Demonstration / innovations (1998)

Platform:

- Autonomous on board flight dynamics (position, attitude and maneuver determination)
- Avionics technology (ERC32, DSP, 3D modules)
- Low cost autonomous star tracker for attitude
- Gyro-less maneuvering satellite
- Software methodology (auto coding and SVF)
- Battery Li-ion (ABSL)
- New instruments and sensor test (HRC, MRM, PASS, SIPs)

Ground Segment:

- Common ground infrastructure (EGSE and mission control centre)
- Ground segment automation

Payloads:

- Compact High Resolution Imaging Spectrometer (CHRIS)
- Radiation (SREM) monitor
- Debris (DEBIE) monitor

PROBA 2

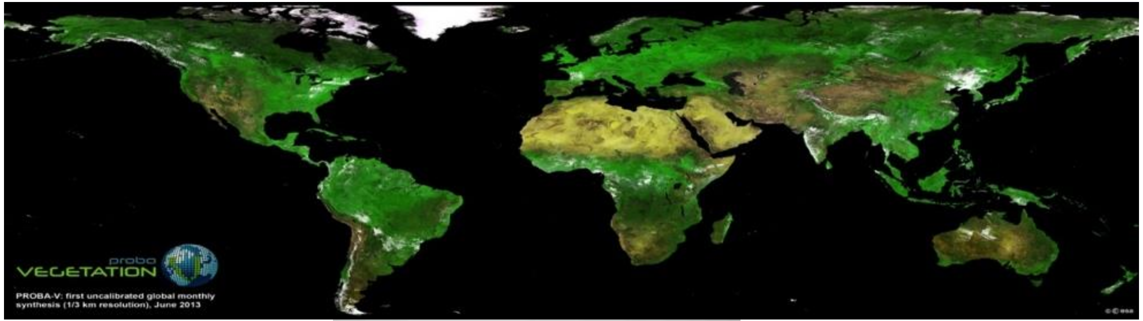
Technology Demonstration / innovations (2002)

Platform:

- Lithium-ion battery,
- Advanced data and power management system based on LEON
- Combined carbon-fibre and aluminium structural panels,
- New miniature reaction wheels (DYNACON)
- Miniaturised star tracker (uASC DTU)
- COTS based GPS receivers (PHENIX - DLR)
- Digital Sun-sensor (TNO)
- Dual-frequency GPS receiver (Alcatel)

- Fibre-sensor system for temperatures and pressures
- APS based star-tracker (BepiColombo)
- New 3 axis magnetometers
- Very high precision flux-gate magnetometer
- Solar panel with a solar flux concentrator
- Solid-state nitrogen gas generator
- Exploration micro-camera (X-CAM)
- New GNC algorithms

PROBA V - Gap Filler for Vegetation Mission

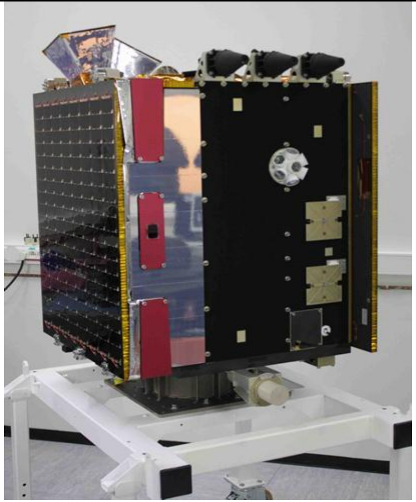


Objectives:

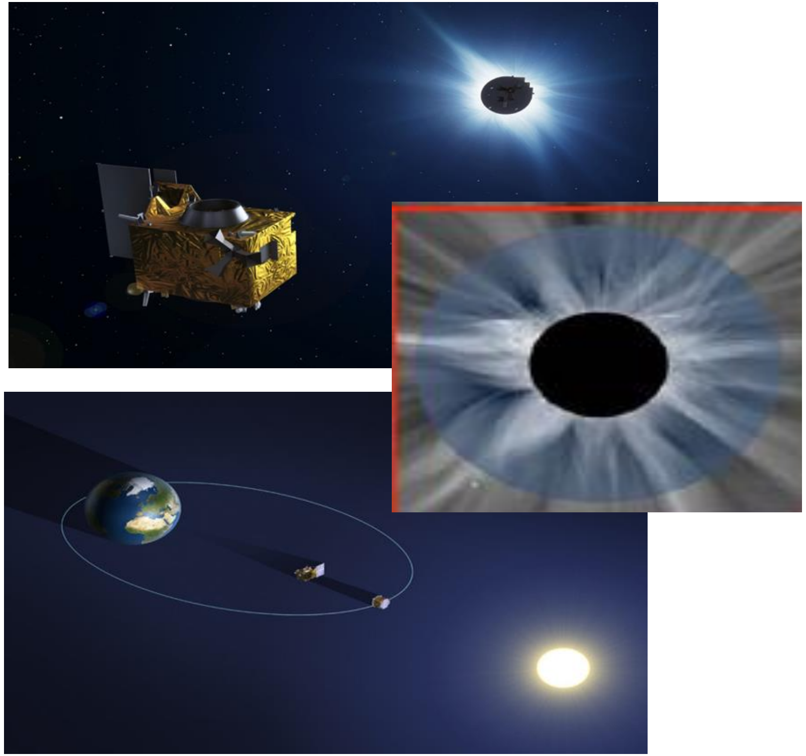
- Small sat (<150kg)
- Gap filler SPOT-5 Sentinel-3
- Operational Mission
- Daily global vegetation monitoring
- Improve GSD to 300m
- Fly guest payload (IOD)

Platform:

- Platform highly recurrent from Proba-2
- First X-Band for Proba
- Improved AOCS



PROBA 3



Proba-3

- The power of 2 satellites to synthetize missions unaffordable to even the largest systems,
- New architecture / system concepts, distributed instruments,
- New technique: satellite precise formation flying, to overcome the limitations of monolithic or deployable structures

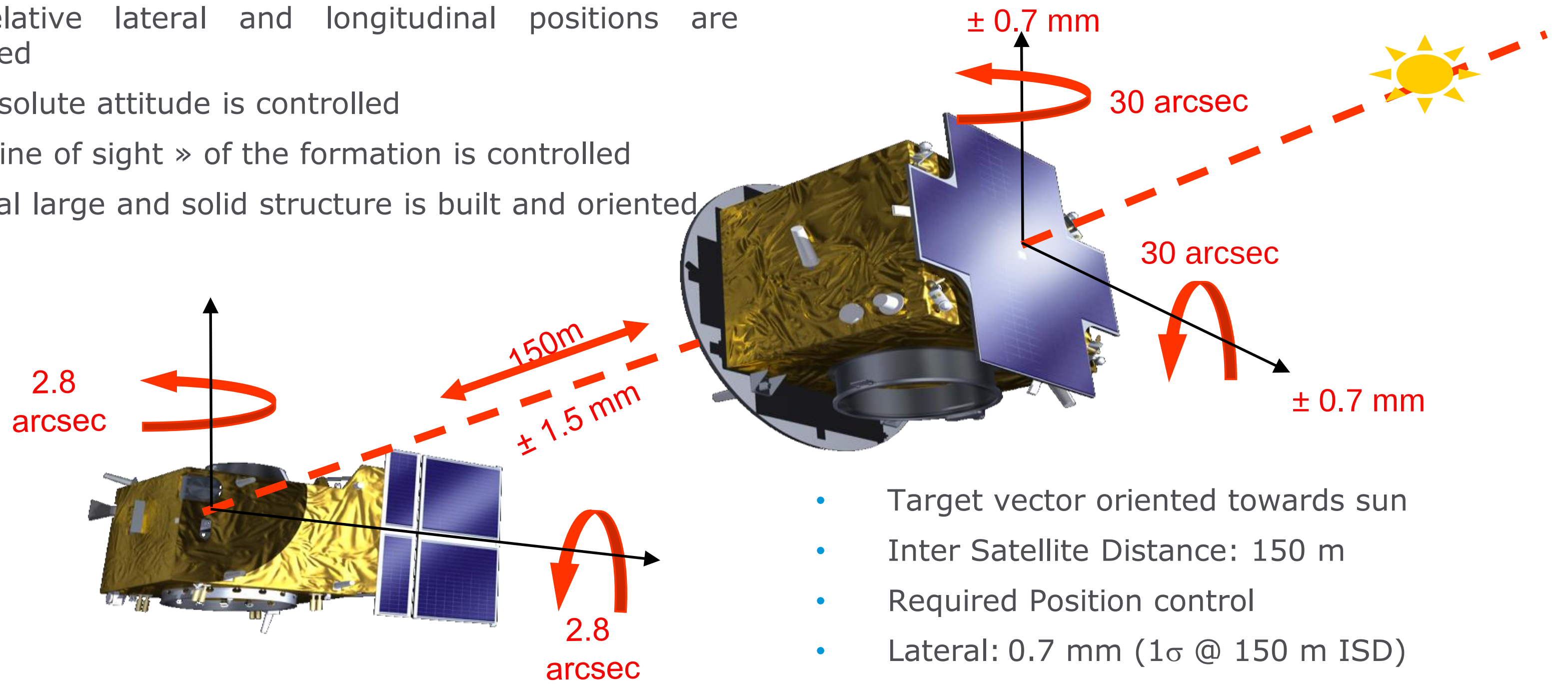
- Two small satellites flying in formation 150 m apart with mm and arcsec precision to synthetize a distributed instrument, a giant sun coronagraph to produce the perfect eclipse, observing the sun limb to the lowest tangent point improving significantly the performance of previous missions (e.g. LASCO on SOHO)

Status: In development (November 2017 CDR Kick-off)

PROBA 3 Mission overview

PRECISE FORMATION FLYING

- The relative lateral and longitudinal positions are controlled
- The absolute attitude is controlled
- The « line of sight » of the formation is controlled
- A virtual large and solid structure is built and oriented



- Target vector oriented towards sun
- Inter Satellite Distance: 150 m
- Required Position control
- Lateral: 0.7 mm (1σ @ 150 m ISD)
- Longitudinal: 1.5 mm (1σ @ 150 m ISD)

ESA CUBESATS - OVERVIEW

ESA CubeSats - Overview

ESA CubeSats

Technology development

In-orbit demonstration (IOD)

- GomX3
- GomX4B
- SIMBA
- PICASSO
- QARMAN
- RADCube
- PRETTY
- AMS-SAT
- OPS-SAT
- HERA
- RACE
- PROBA-V CubeSat

Telecommunication

- PocketQube
- Astrocast

Educational

Fly your Satellite (FYS)

FYS 1st edition

- OUFTI-1
- e-st@r-II
- AAUSat-4

FYS 2nd edition

- LEDSAT
- EIRSAT-1
- CELESTA
- 3CAT4
- UoS3
- ISTsat-1

New (ESA) Member states

- TRISAT

(Inter-planetary) CubeSat Studies

- M-ARGO
- SysNova Luce
- COUPLED
- AIM COPINS ->Hera
- Small Planetary Probe (SPP)

Disclaimer: No 'official' ESA slide – this is the presenters perception and not-conclusive attempt to cluster different ESA CubeSat involvements.

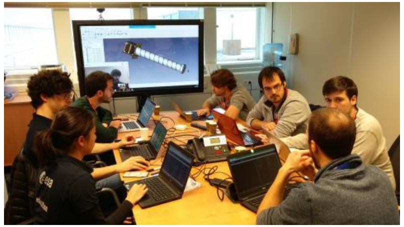
Fly Your Satellite!

Objectives for university student teams :

- **Transfer of experience and know-how**
- **Preparation of students for career in aerospace industry**

CubeSat teams participating in the programme:

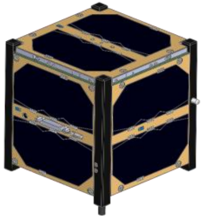
- Direct support from **ESA specialists**
- Introduction to **verification** and **documentation**
- Participation in **workshops and training courses**
- **Access to environmental test facilities**
- Get acquainted with **ESA standards and best practices**



ESA will offer the **launch opportunity** to teams that demonstrate the flight readiness of their CubeSat

Current participants – FYS 2nd edition

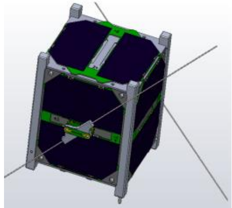
3CAT-4
Technical University of Catalonia, Spain



Mission Objectives

Perform Earth Observation combining a **GNSS-Reflectometer, a radiometer, and an AIS receiver**

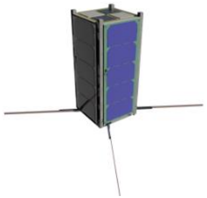
CELESTA
University of Montpellier, France



Mission Objectives

Monitor the LEO environment and perform in-orbit testing of the 1U CubeSat platform.

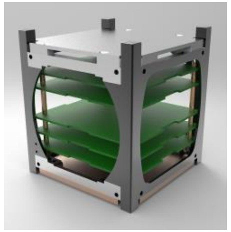
EIRSAT-1
University College Dublin, Ireland



Mission Objectives

In-flight demonstration of a **gamma-ray detector, thermal control coatings** and an **attitude control algorithm**.

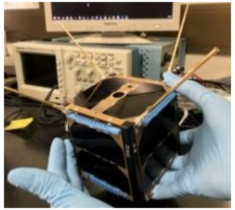
ISTsat-1
Instituto Superior Técnico, Portugal



Mission Objectives

Characterize the **ADS-B aircraft detection technology in orbit**

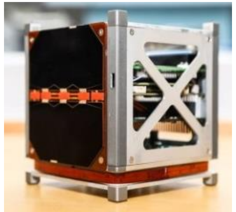
LEDSAT
Sapienza University of Rome, Italy



Mission Objectives

Test a LED-based payload on-board a 1U CubeSat for improving **LEO optical satellite tracking**

UoS3
University of Southampton, UK



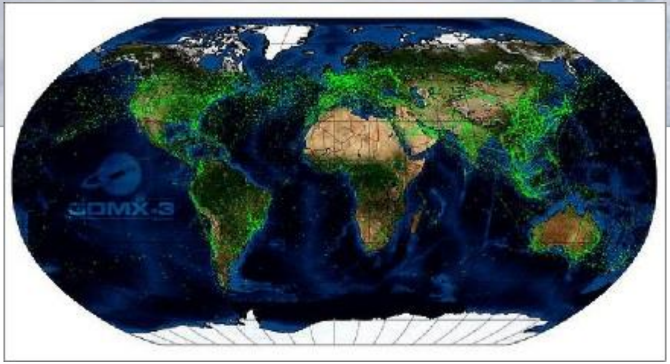
Mission Objectives

Support atmospheric re-entry prediction tools and obtain images of Europe for outreach purposes

IOD CubeSats – First ESA Technology CubeSat

GOMX-3 (Denmark) – (3U)

- Implementation: 1 year KO to flight readiness
- **Deployed from ISS on 5th October 2015**
- Re-entered after 1 year of successful operations



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

Constellation Technology Demonstration

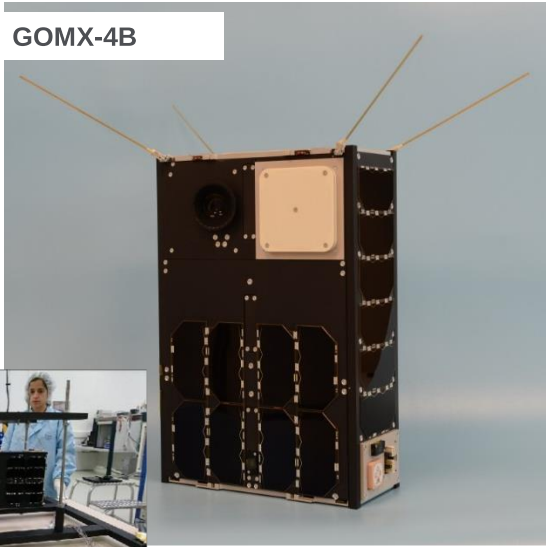
GOMX-4B (Denmark) – (6U)

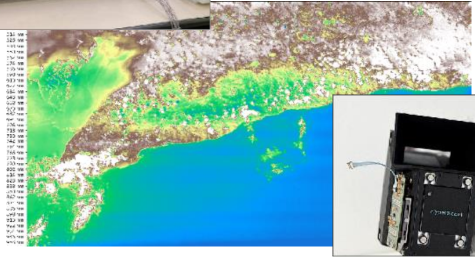
- Primary Mission:
  - Along-track station acquisition/keeping using on-board cold gas propulsion (Nanospace)
  - Inter-satellite link with S-band software defined radio (GomSpace) at distances up to 4500 km

- Additional payloads:
  - HyperScout hyperspectral imager (Cosine)
  - Star tracker (ISISpace)
  - Radiation Hardness Assurance (ESA)

Status: Launched on **2nd of February 2018 to SSO 500 km on LM-2D**

- Operations: Tandem mission with GOMX-4A (DK MoD)



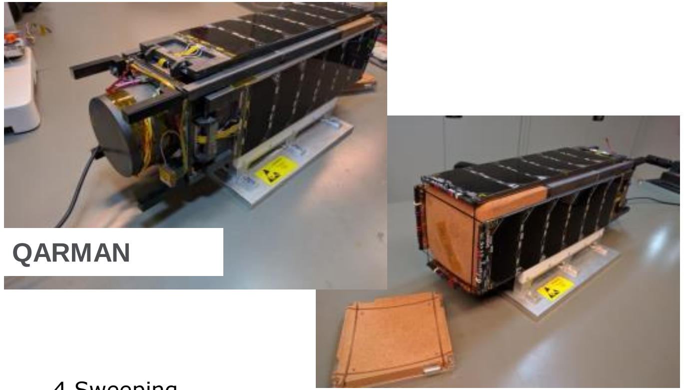


Re-entry R & T Demonstration / Atmospheric Science Demonstration

QARMAN (Belgium) – (3U)

- Spectrometer for in-situ re-entry plasma analysis; Temperature, pressure, strain sensors
- Ablative front heat shield materials (Cork P50); Passive aerodynamic drag attitude stabilisation (SiC); In-flight telemetry data relay via the Iridium constellation

Status: satellite PFM integration in May 2018 following successful aerothermodynamic test, launch: **Cargo flight to ISS in Q1 2019**

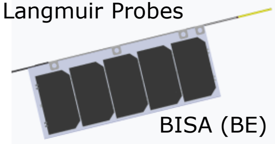


PICASSO (Belgian, Finland & UK) – (3U)

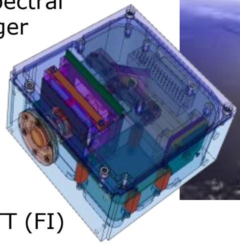
- Stratospheric Ozone & Mesospheric Temperature profiles via solar occultation measurements; Ionospheric Electron density in-situ measurements
- VISION multi-spectral imager with Fabry-Perot Interferometer (VTT); Sweeping Langmuir Probe (BISA)

Status: Flight model produced, system AIV starting, launch: **Q1 2019 to SSO 500 km - Vega Vega Small Satellite Mission Service (SSMS)** proof of concept flight

4 Sweeping
Langmuir Probes



Multi-spectral
imager



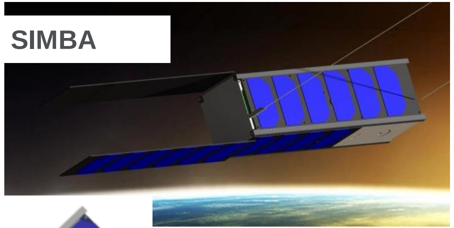
VTT (FI)

Sun-Earth Radiometry and Space Weather Demo

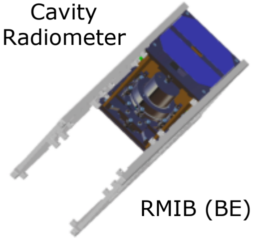
SIMBA (Belgium & The Netherlands) – (3U)

- Total solar irradiance, Earth radiation budget; Precision 3-axis pointing demo
- Absolute cavity radiometer (RMIB); 3-axis ADCS with star tracker & reaction wheels (KUL)

Status: Platform FM ready, payload FM in production, launch **Q1 2019 to SSO 500 km - Vega Vega Small Satellite Mission Service (SSMS)** proof of concept flight



Cavity Radiometer



RMIB (BE)

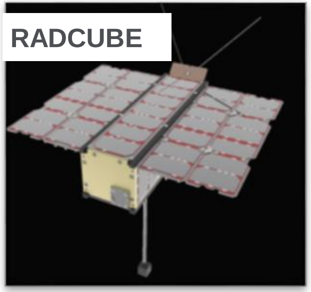
Integrated 3-axis ADCS

KU Leuven (BE)

RadCube (Hungary, UK, & Poland) – (3U)

- In-situ radiation environment & magnetic field monitoring for future space weather services; Characterisation of radiation effects on EEE components
- RadMag including electron/proton/cosmic ray particle detector (MTA EK), magnetometer (Imperial) on boom (Astronika), Radiation Hardness Assurance board (ESA)

Status: PDR completed, launch **Q4 2019 to SSO <600 km**

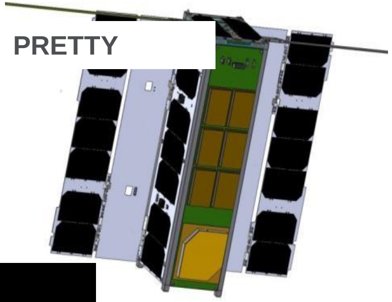


Further IOD satellites

PRETTY (Austria) – (3U)

- High precision (relative) altimetry for sea state and ice detection
- Characterization of radiation dose environment
- Software-defined GNSS-Reflectometry receiver & antenna (RUAG) & Radiation dosimeter (Seibersdorf)

Status: PDR in October 2018, launch 2020 to SSO <600 km (TBC)



Credit: TU Graz

OPSSAT (Austria) – (3U)

- Demonstration of operation techniques in orbit
- Provide easy and free access to in-orbit processors

Status: CDR in January 2016; Flight model produced

RACE - Study – (3U)

- Rendezvous & docking; Target fly-around; GNC testbed
- 6 DoF propulsion, Relative navigation sensors (vis, Lidar), Autonomous GNC, Docking mechanism

Status: A/B KO in Q2 2018; launch Q4 2021 LEO 500 km

Further ESA CubeSat activities

PocketQube (Unicorn-2 – Scotland) - (3p):

- S-band radio; ADCS actively-controlled 3-axis -> becoming the first satellite of a 3p size to achieve this capability.
- Solar panel wingspan of greater than 400 mm.

ASTROCAST (Switzerland) – 3U:

- Constellation of nanosatellites dedicated to the Internet of Things (IoT) and Machine to Machine communication (M2M).

TRISAT (Slovenia) – 3U:

- Multispectral SWIR imager
- CCDS compatible full-duplex communication module (COMM) with a SoC design approach providing UHF downlink and VHF uplink.
- CCSDS compatible S-band half-duplex communication module
- In-house EPS & OBC

Credit: AlbaOrbital

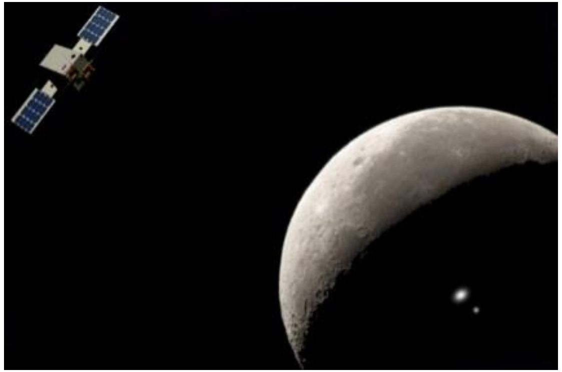
ASTROCAST

Credit: Astrocast

TRISAT

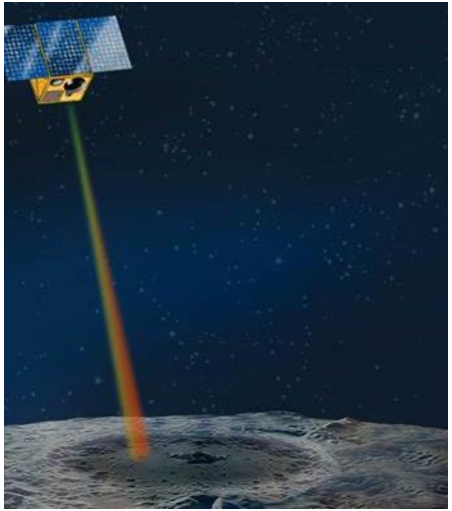
Credit: University of Maribor

LUnar Cubesats for Exploration (LUCE)



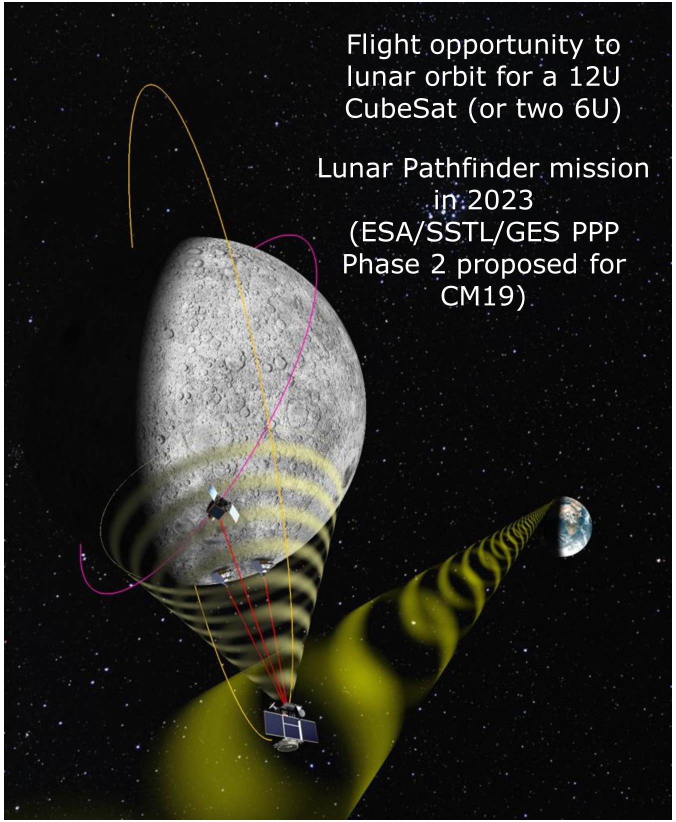
LUMIO (Lunar Meteoroid Impacts Observer)

- Capturing flashes of meteoroids impacting the far side with a sophisticated camera



VMMO (Volatile and Mineralogy Mapping Orbiter)

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



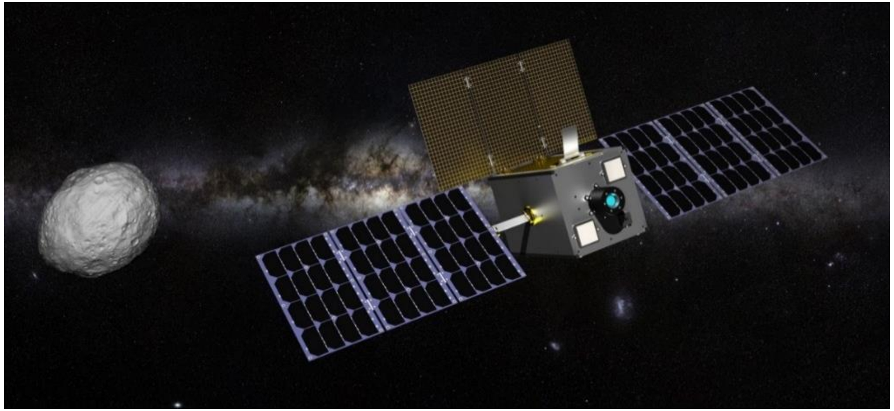
M-ARGO

Objectives:

- Demonstrate critical technologies & operations for stand-alone deep space CubeSats in the relevant environment
- Rendezvous with a suitable NEO target
- Perform physical characterisation of NEO target with a small payload suite

Mission concept:

- 12U CubeSat
- Piggyback launch to Sun-Earth L2 transfer
- Parking in L2 halo orbit
- Low-thrust interplanetary transfer
- Close proximity operations at NEO target
- Target selection based on launch date & transfer time



THANK YOU

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- Credit to the artists impression; photographs provided by the team for all of the missions