Overview of ESA CubeSat Activities

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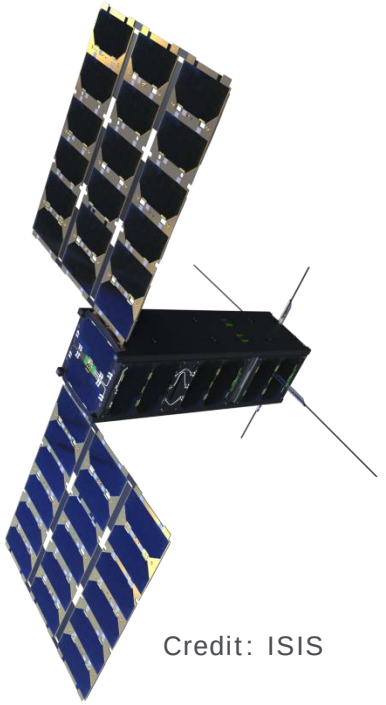
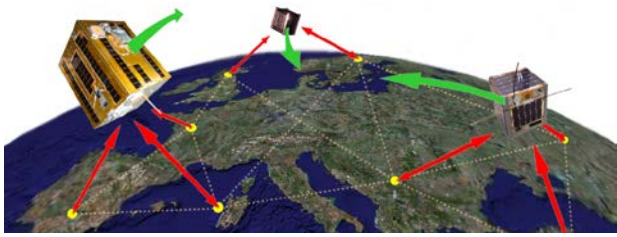
European Space Agency

CubeSat Nano-satellites and ESA

- CubeSats may serve several objectives in the context of ESA (beyond education):
  - A driver for drastic miniaturisation of systems, instrumentation, systems on chip, and totally new approach to packaging and integration, multi-functional structures, embedded propulsion, with benefits for larger systems
  - An opportunity to demonstrate such technologies and other innovative technologies in orbit at a low cost and fast pace,
  - An opportunity to carry out distributed multiple in-situ measurements, e.g. to obtain simultaneous multi-point observations of the space environment (atmosphere, ionosphere, magnetosphere, energetic particles)
  - Potential to deploy small payloads, e.g. very compact AIS receivers or optical instruments, where the potential deficit in performance may be largely compensated by the multitude of satellites in a constellation system



Credit: ISIS



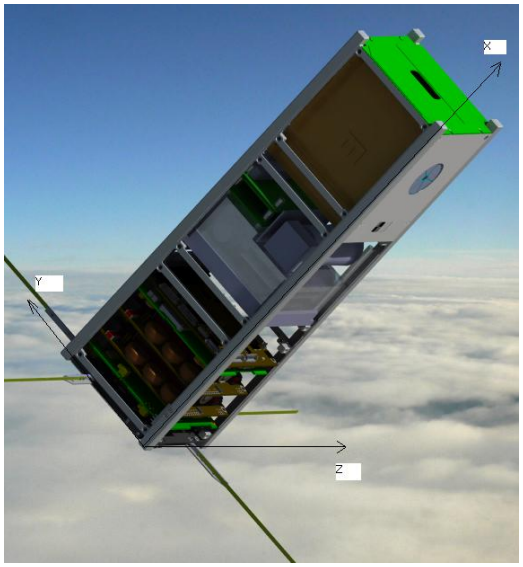
New ESA Activity on CubeSat IOD Missions & CubeSat Technology Development

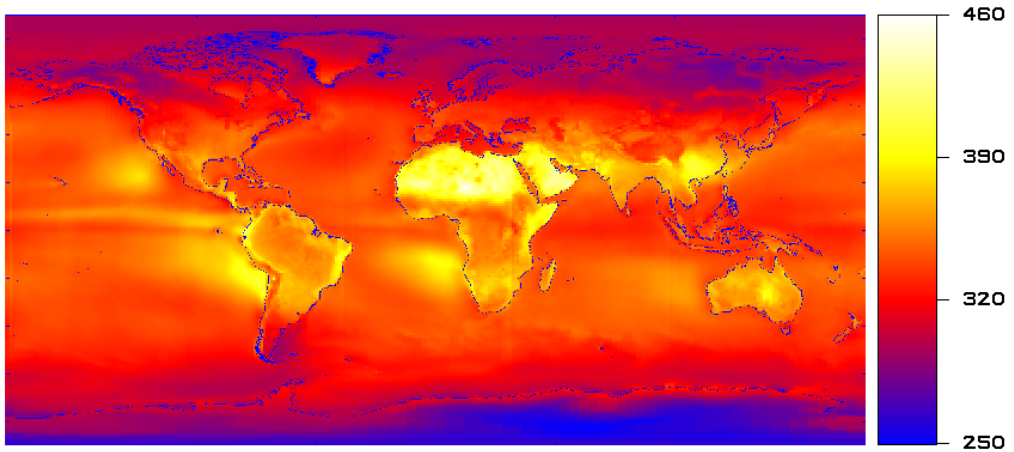
- Activity funded under ESA General Support Technology Programme since 2012
- Supported by various ESA Member States (Belgium, Switzerland, Netherlands, Denmark, Austria, Germany)
- Additional support from ESA Cooperating States (Hungary)
- Objectives:
  - in-orbit demonstration of innovative technologies for platform and instruments/payloads at a low cost and rapid schedule
  - development of CubeSat platform technologies, enabling CubeSats to be used by ESA in a future operational context
- Scope:
  - complete end-to-end development of several CubeSat nano-satellite systems, launch and mission operations (in-orbit validation of technology to TRL6)
  - ground validation of future CubeSat products to TRL 5 using small laboratories & test facilities
- Programmatics:
  - 7 MEuro total budget, 8 different projects
  - 5 missions, 3 technology development activities

IOD MISSIONS IN DEVELOPMENT

SIMBA IOD Mission

- Contractor: Royal Meteorological Institute and KU Leuven (Belgium)
- Sun-Earth radiometric science demonstrator:
  - Measure the Essential Climate Variables of Total Solar Irradiance, Earth Radiation Budget and Sun-Earth radiation imbalance
  - Payload: absolute cavity radiometer (RMI), 3-axis ADCS with star tracker (KUL)
  - Platform: 3U CubeSat (ISIS)
  - Heritage: Sova-P instrument on CNES Picard mission; Diarad on SOHO
  - Launch on QB50 flight in 2016 to 380x700 km altitude, 98° inclination



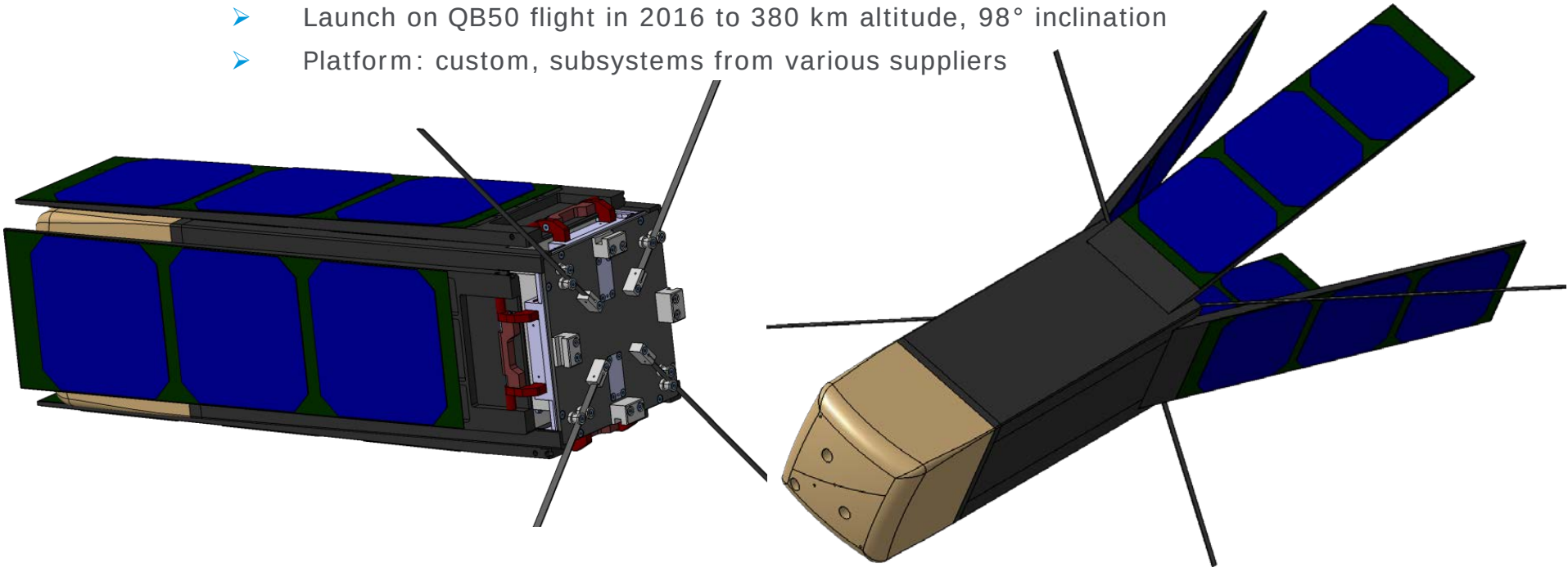


Credit: RMIB

Status: PDR ongoing

QARMAN IOD Mission

- Contractor: Von Karman Institute (Belgium)
- Atmospheric re-entry demonstrator
  - New heat shield materials -> ablation, plasma field measurements
  - Aerodynamic drag augmentation and passive attitude stabilisation system
  - Telemetry data relay system during re-entry via the Iridium constellation
  - Launch on QB50 flight in 2016 to 380 km altitude, 98° inclination
  - Platform: custom, subsystems from various suppliers

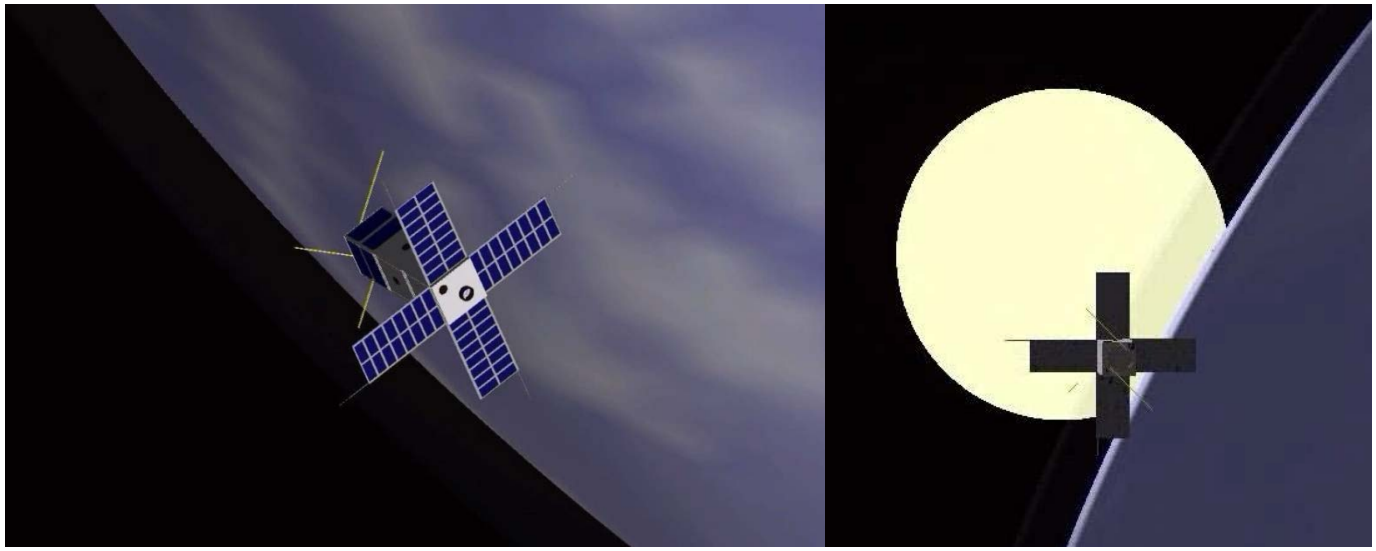


Credit: VKI

Status: PDR ongoing

PICASSO IOD Mission

- Contractor: Belgian Institute of Space Aeronomy (BISA), VTT Finland, Clyde Space UK
- Atmospheric chemistry science demonstrator
  - Stratospheric Ozone distribution -> limb sounding of solar disk with multi-spectral imager
  - Mesospheric Temperature profile -> multi-spectral imager (VTT)
  - Electron density in the ionosphere -> multi-Needle Langmuir Probe (BISA)
  - Platform: 3U CubeSat (Clyde Space)
  - Launch on QB50 flight in 2016 to 380x700 km altitude, 98° inclination

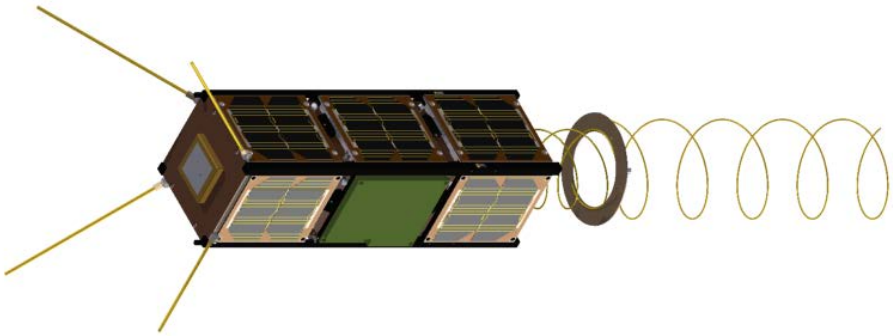


Credit: BISA

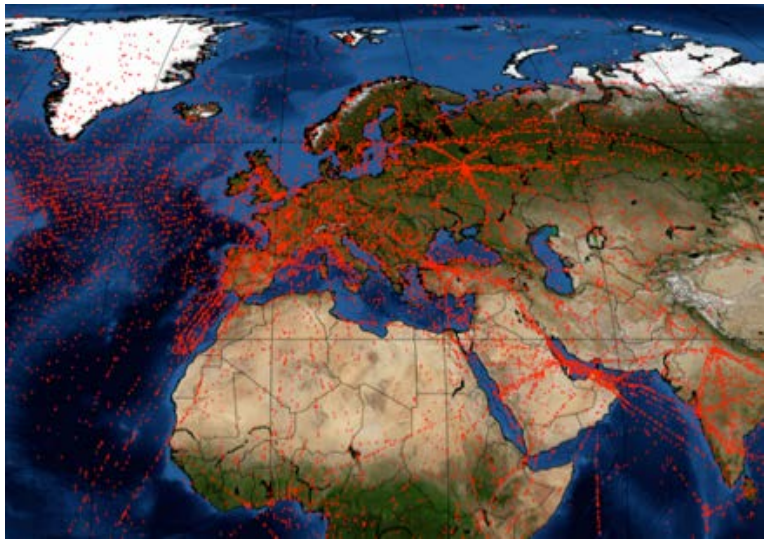
Status: PDR in December 2014

GOMX-3 IOD Mission

- Contractor: GomSpace (Denmark)
- 3U CubeSat telecommunications payload demonstrator
  - Improved Detection/de-coding of ADS-B signals broadcast by aircraft
  - Characterisation of Spot beams broadcast by GEO telecom satellites
  - Primary Payload: L-band Reconfigurable Software Defined Radio receiver
  - Additional payload: 3-axis ADCS for improved nadir pointing accuracy (day/night)
  - Launch to ISS via GomSapce/NanoRacks in July/August 2015
  - Deployment during Short Duration Mission of ESA astronaut Andreas Mogensen



Credit: GomSpace



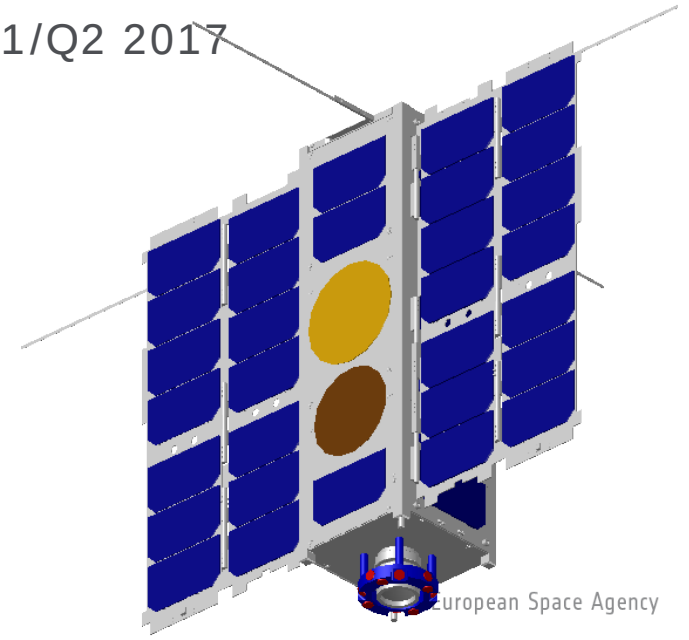
Status: CDR completed

OPS-SAT IOD Mission

- A representative (but low cost, cubesat based) platform for in-orbit demonstration of innovative operations concepts for future ESA missions
- Accept risks, expect failures, **ensure** recovery
- 100+ experiments submitted
- ESA will capitalize on past investment, demonstrate what works and what doesn't. Industry will get freedom, a platform, a reference story and contacts.
- Phase AB1 successfully completed in Jan 14
- Phase B2CDE will kick off Dec 14 with launch in Q1/Q2 2017

Spacecraft highlights:

- Powerful processing core (Dual core 800 MHz processors + integrated reconfigurable FPGA)
- Camera (<80m ground resolution, video)
- Fine ADCS with star tracker (<<1°)
- X band down (50 Mbps)
- S band up/down (CCSDS compatible)
- Optical uplink



Engineering and PA/QA Approach

- The challenge:
  - Improving in-orbit reliability within the very tight project cost/schedule constraints
  - Accepting higher risk due to limited/no redundancy, extensive COTS components
  - Eliminating/preventing known CubeSat failure root causes
- Project/risk management:
  - Project reviews (PDR, CDR, TRR, FAR) by ESA expert team on minimum document set
  - For example: system-level technical, component lists, PA plan, safety, VCM, test plans
  - Protoflight model philosophy with early EMs for new developments
- Applicable requirements:
  - Highly tailored version of the ECSS-E engineering standards
  - Emphasis on engineering best practices, functional verification, environmental testing
  - Light PA/QA requirements adapted from those proven for small ESA payloads
  - Emphasis on configuration control, traceability, inspection/handling/storage, cleanliness, verification control, non-conformance handling, workmanship, EEE component selection
  - Space debris mitigation requirements
- Specific risk mitigation (planned):
  - radiation (SEE) testing of COTS components/boards without flight heritage/test data

RADIATION PAYLOADS

Ali Zadeh

ESA CubSAT based RHA verification and EEE component technology test bed activity

- The purpose of this activity is to develop a set of in-flight Radiation Hardness Assurance verification and EEE component technology test bed payloads for flight on CubeSATs. All payloads are flown in conjunction with radiation monitors.
- The payloads will be compatible with 1U and up to 3U CubeSATs.
- The preferred orbit for such missions is highly elliptical with a duration of minimum 1-year.
- The feasibility and compatibility of the following experiments for CubeSAT missions will be assessed:
  - Total Ionising Dose experiments
    - Enhanced Low Dose Rate sensitivity experiments on bipolar based devices
  - Displacement Damage experiments
    - Opto Electronics, bipolar based ICs, imaging devices, detectors. In support of DD test guidelines development
  - Single Event Effect experiments
    - FPGAs (e.g. Virtex-7 family), Memory devices, power MOSFETs, etc.

Memory Test Experiment

- The first payload selected concerns a Single Event Effect experiment based on memory devices.
- The current plan includes flight of:
  - NAND FLASH, MRAM, FRAM and SRAM
- Devices will be selected based on their radiation sensitivity to obtain data with good statistics.
- The experiment aims at investigating Single Event Latchup (SEL) and non-destructive SEEs.
- In flight results are compared to extensive ground based test data to assess current RHA processes.
- A Next Generation Optically stimulated luminescence (OSL-NG) dosimeter plus RadFETs will be flown in conjunction with the payload.
- The SEE experiment is developed and manufactured by the University of Montpellier 2's Centre Spatial Universitaire and is planned flown on their ROBUSTA platform CubeSAT.
- The development and manufacturing activity duration is 2-years (planned launch end-2016) with a nominal in-flight lifetime of 2-years.

Status: CDR planned for December 2014

MISSION STUDIES

Active Debris Removal IOD Mission

- Contractor: Swiss Space Center, EPFL
- Objective:
  - IOD and operational validation of critical ADR technologies at sub-scale for future use on full-scale missions to remove large debris objects
- Mission concept #1:
  - Rendezvous sensors (Flash Lidar, VIS/IR cameras, radar)
  - Inspection/Motion reconstruction of uncooperative target
- Mission concept #2:
  - Net capture system dynamics & target interaction
  - Coupled two-body tether dynamics and control
- System concept:
  - 8U Chaser satellite + 4U Target satellite
  - Coupled together and launched in 12U deployment system
  - Low velocity mutual separation after LEOP
  - Close proximity ops with 6 DoF chaser around “passive” target with settable attitude rates

Credit: Swiss Space Center

Status: study completed Sept 2014

CubeSat Mission Applications

- ARTES 1 study “Nano-satellites for Commercial Telecommunication Services”
  - Open competitive Invitation To Tender (now closed)
  - Any revenue generating service from telecom (e.g. M2M, signal detection, frequency monitoring etc)
  - Assessment of technical feasibility and commercial viability of selected concepts
  - Single nano-satellites or nano-satellite constellations
  - CubeSats or other form factors up to 12U/16 kg

- GSP SysNova Study “Remote Sensing with Multiple Cooperative Nanosats”
  - Open competitive Invitation To Tender (now closed)
  - Award of up to 6 parallel studies
  - Evaluation of studies and selection of a winner
  - Prize: ESA Assessment study in the ESTEC Concurrent Design Facility
  - Challenges: Land (optical), Atmospheric Chemistry (optical), Weather (RF)
  - High spatial or temporal resolution enabled by constellations or swarms
  - CubeSats or other form factors up to 20 kg, system ROM cost <60 MEuro

Conclusions

- ESA has made its first steps in the CubeSat domain beyond education
- A small fleet of CubeSats are now under development by European research institutes and CubeSat industrial companies for launch in 2015-2017 timeframe
- Missions are focussed on In-orbit Demonstration of miniaturised payloads and flight qualification of CubeSat platforms for scientific research and applications
- Mission applications of nano-satellites (including CubeSats) operating in constellations or swarms have been identified and related studies have been initiated
- Studies for innovative and challenging future IOD CubeSat missions are underway and in the future work plan
- Open to ideas from the community!

→ THANK YOU

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