Technical Presentation of M3 Candidate Missions

Frédéric Safa,
Future Missions Office (SRE-F)

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EChO

Exoplanet **Ch**aracterization **O**bservatory

ECh**O**: **E**xoplanet **Ch**aracterization **O**bservatory

Science

Physics and chemistry of the atmospheres of a representative sample of known exoplanet systems found around nearby stars

Payload

Telescope:

Elliptic aperture 1.13 m^2 , afocal, 3 mirrors off-axis, FoV 20" x 20”, diffraction limited @ 3 μm,

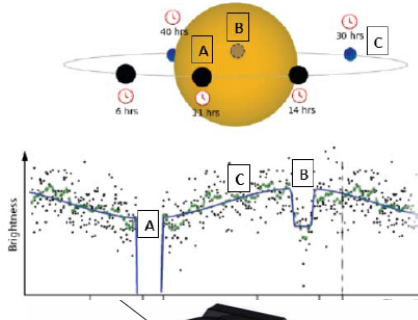
T ~ 50 K, passively cooled with V-grooves shields

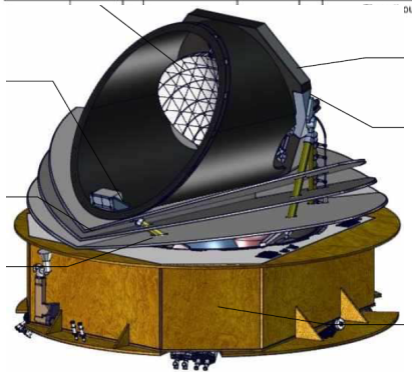
Focal plane instruments:

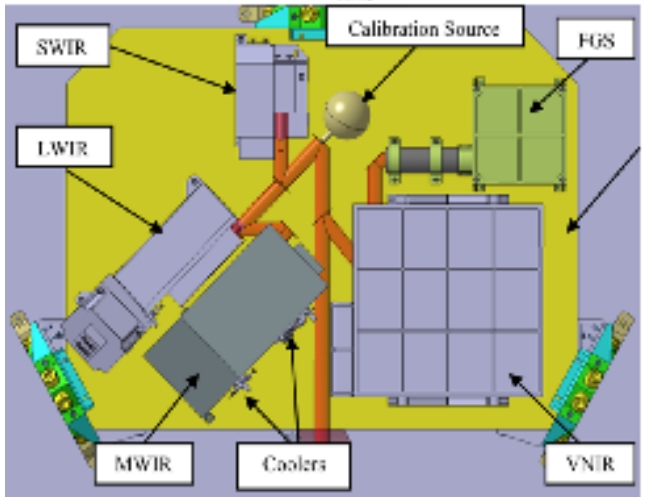
Multi-channel spectrometer,

λ = 0.55 to 11 μm, ~ 100 kg

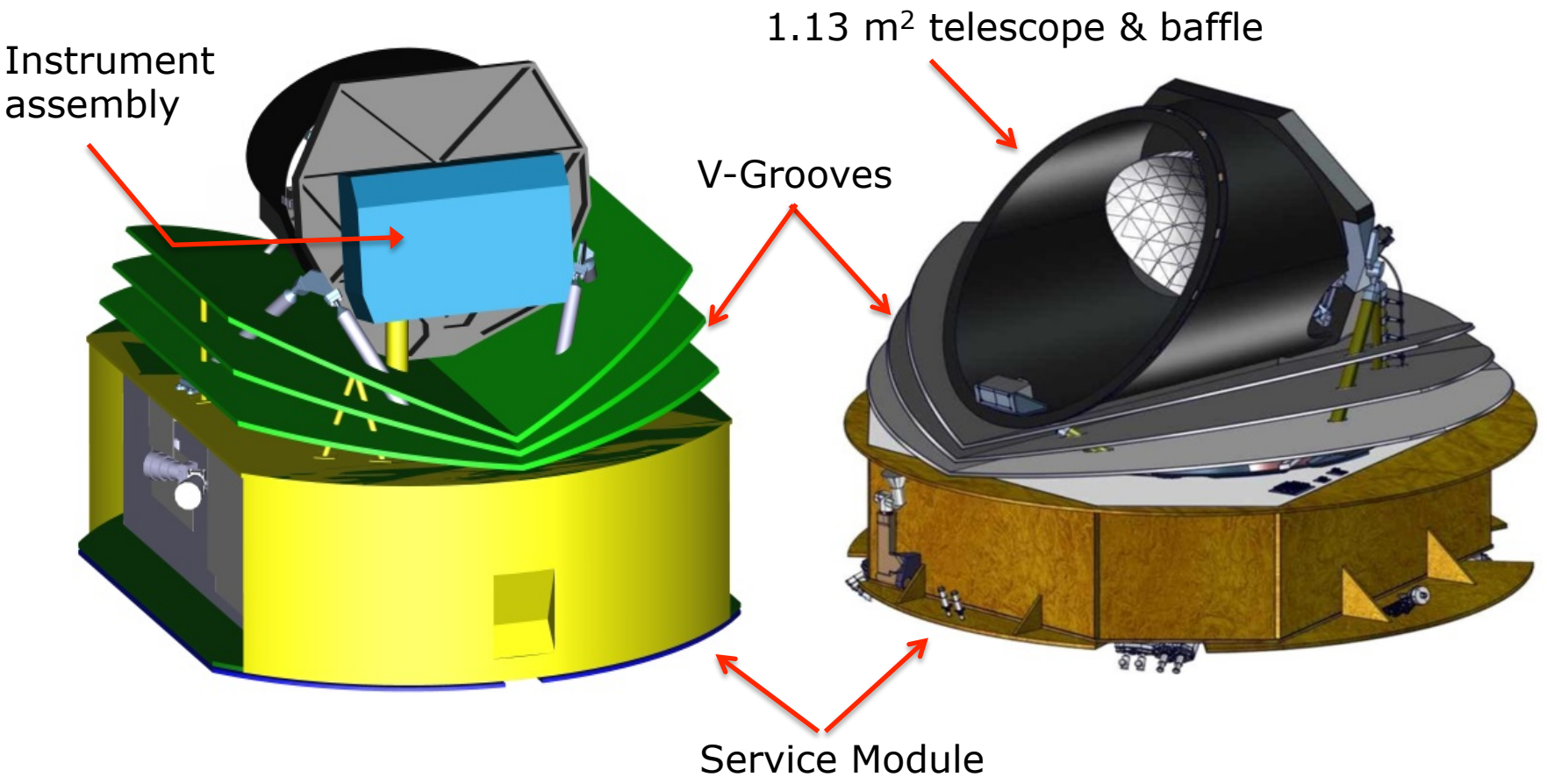
- VNIR and SWIR channels (λ < 5 μm) : λ/δλ > 300, Teledyne CMT detector, passive cooling 45 K
- MWIR channel (λ > 5 μm): λ/δλ > 30, Teledyne CMT detector, active cooling 28 K using Ne JT cooler







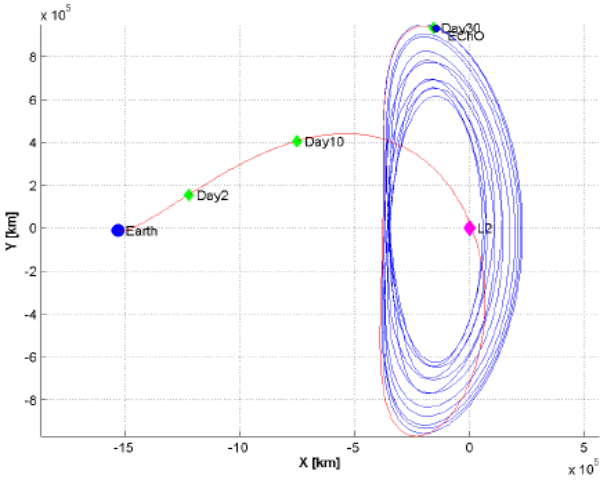
Spacecraft Configuration



Mission Profile and Concept of Operations

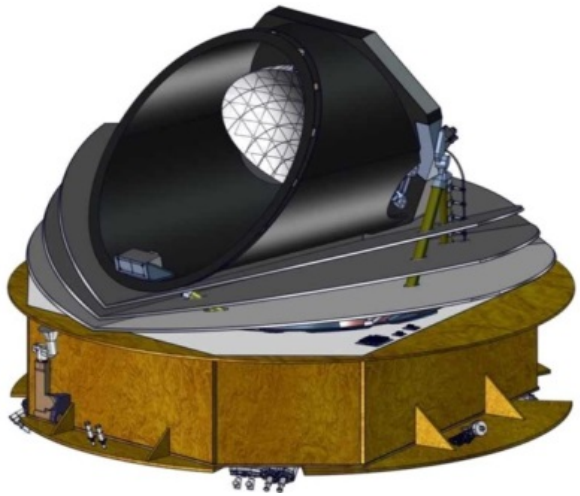
Mission Profile

- Soyuz Fregat launch from Kourou, direct transfer to large amplitude (1.5 Mkm) orbit around L2.
- ESTRACK ground stations
- 3.5 yrs science operations + 2 yrs extension



Concept of operations

- Observation of a transit for an average of 3.7 hrs (10 hrs max).
- Then slew to another target (15 min for 90° separation)
- Re-visit identical targets till required SNR is reached.
- 85% observation efficiency, on average 5 targets per day.



Spacecraft features

Payload

- High photometric stability (< 10^{-4})
- European IR detectors can be used if ready on time (VNIR/SWIR)

AOCS

- Reaction wheels for slews
- Cold gas thrusters for fine pointing, using payload FGS
  - Stability of 50 mas (1 σ) over 90 s
  - Drift of 20 mas (1 σ) over 10 hrs

Communications

- X-band, 2 x 2 h ground link per week (with 35 m ESTRACK stations)

Spacecraft characteristics	
Mass	1.5 t
Power	1 kW
Data volume	35 Gbit/week
Lifetime	4 yrs nominal 6 yrs goal
Dimensions	Ø 3.6 m x 2.6 m

LOFT

Large **O**bservatory **F**or x-ray **T**iming

LOFT: Large Observatory For x-ray Timing

Science

X-ray energy and timing mission – observing Neutron Stars and Black Holes - Cosmic Vision theme 'Matter under extreme conditions'

Payload

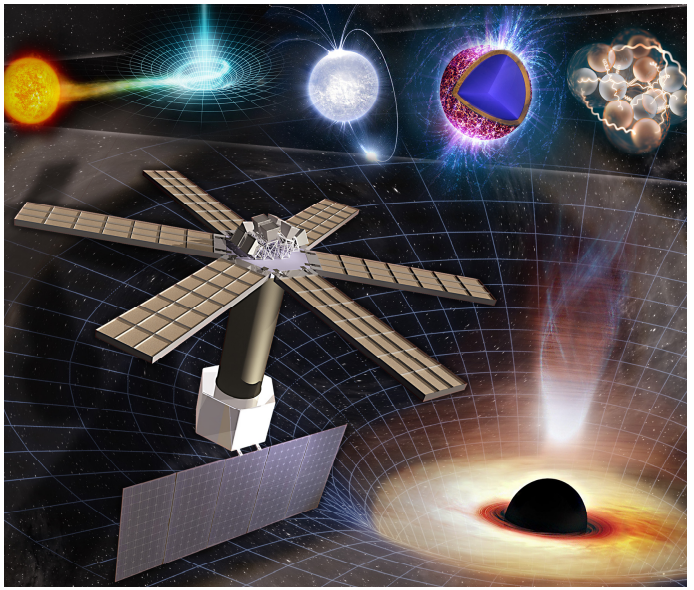
Large Area non-imaging Detector (LAD)

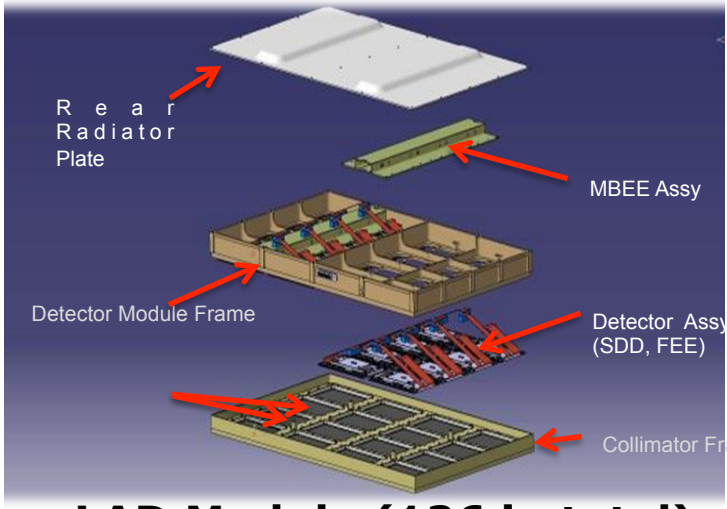
eff. area ~ 10 m^2 @ 6 keV, 1 deg FoV (collimators), time resolution 10 μs
Energy 2-30 keV, resolution 240 eV @ 6 keV

- Deployed in orbit, Constituted of 126 LAD modules, using each 16 Si Drift Detectors (SDDs)

Wide Field Monitor (WFM)

10 coded-mask cameras using Si Drift Detectors, energy 2-30 keV, FoV 10 000 deg^2, spatial localisation 1 arcmin



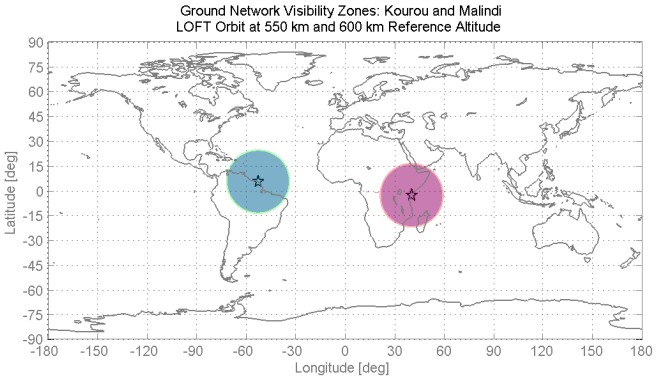


LAD Module (126 in total)

Mission Profile and Concept of Operations

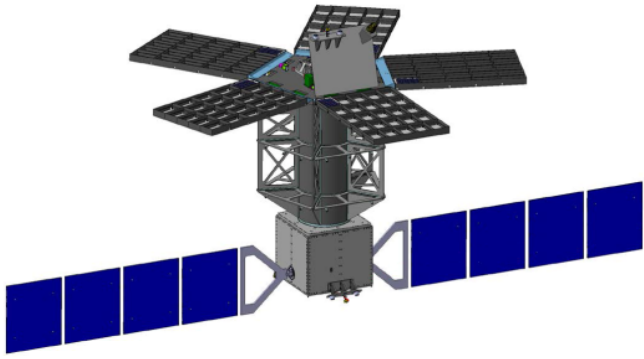
Mission Profile

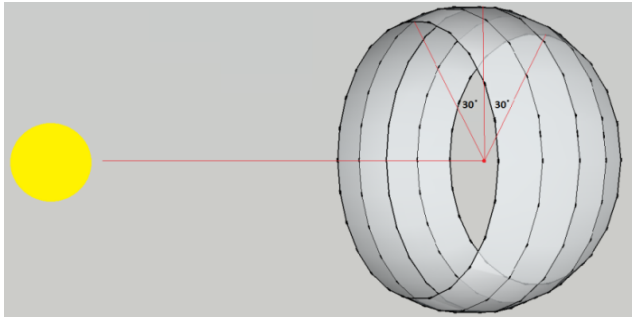
- Direct launch to 550x550 km equatorial orbit
- 3 yrs science operations + 2 yrs extension
- Ground stations: Kourou & Malindi



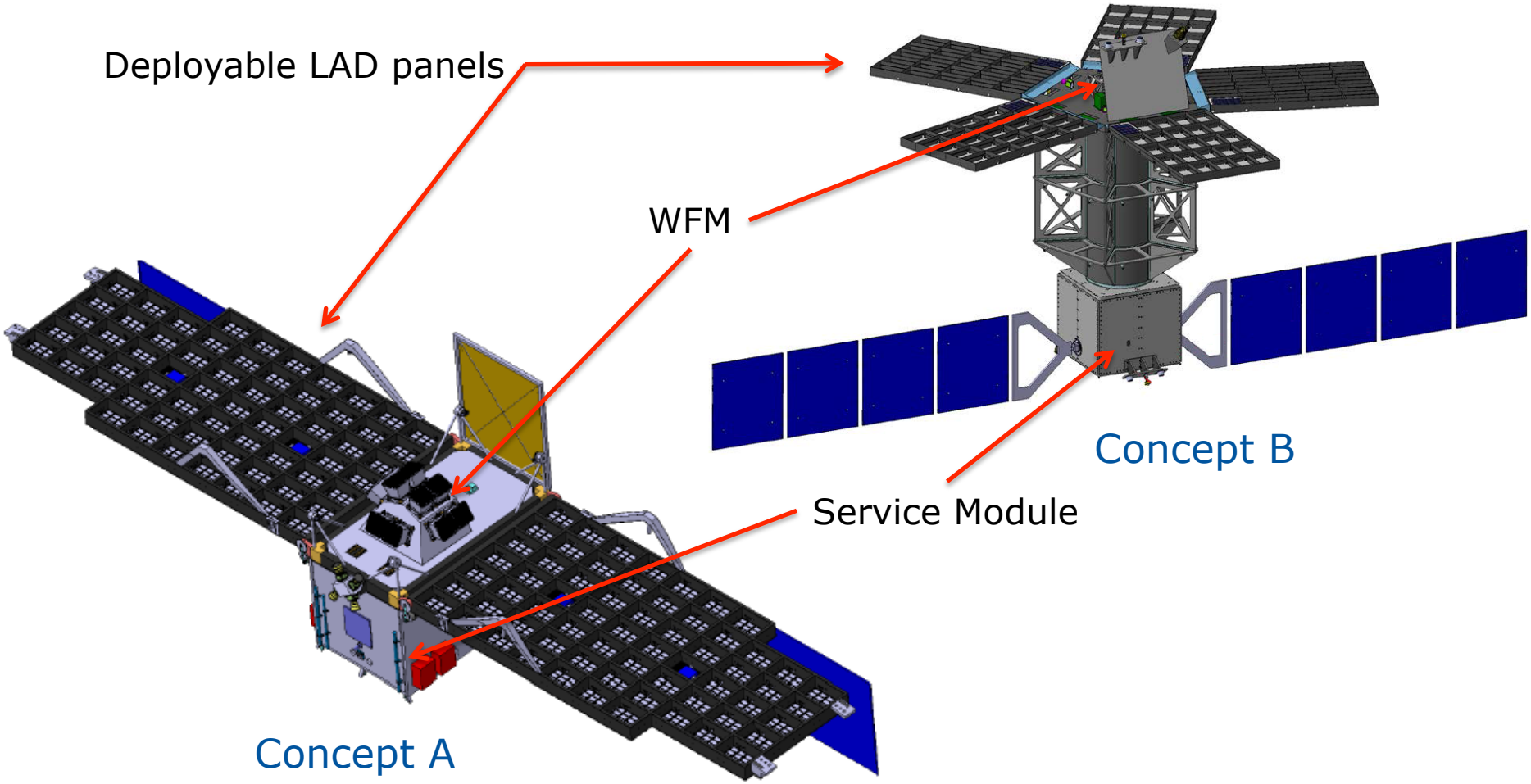
Concept of Operations

- LAD inertial pointing to X-ray targets (~2/day)
  - Main interruption: Earth occultation of target
- Sky coverage limited by LAD detector temperature (< -10 deg C)
  - Observation within a 'Field of Regard' (solid angle, 35% of the sky), minimising solar heating of LAD
  - The entire sky is covered in < 6 months
  - Out-of-field targets can be accessed for ~few hours due to thermal inertia of LAD array
- WFM
  - Sky monitoring and periodic burst-alert transmission to PI-provided VHF ground stations





Spacecraft Configuration



Spacecraft features

Payload

- Large serial production required

~ 2000 Si Drift Detectors, ~ 27000 ASICs

LAD mass ~ 1 tonne, WFM mass ~ 125 kg

AOCS

- Reaction Wheels for slew manoeuvres, off-loaded with Magnetorquers
  - Chemical Propulsion for orbit control, Safe and end-of-life disposal
  - Moderate pointing accuracy requirements

Data handling & communications

- X-band up/down, additional VHF-transmitter for burst-alert
  - Omni-directional coverage provided by LGAs in both cases

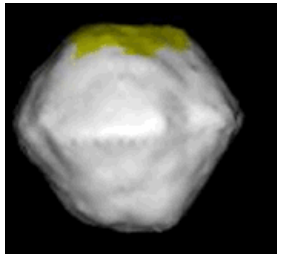
Mass	~ 4 tonnes
Power	~ 4 kW
Data volume	~ 7 Gbits/ orbit
Lifetime	5 yrs (3 + 2 yrs)
Dimensions	7 m x 16 m x 9 m

MarcoPolo-R

Sample return from a primitive near-Earth asteroid

MarcoPolo-R: Asteroid Sample Return

Science



Study of the solar system origin and evolution, through laboratory analyses on Earth of a ~ 100 g sample returned from a primitive asteroid,

2008 EV5, ~ 1 AU, diameter 350 m, rot. period ~ 3.7 h.

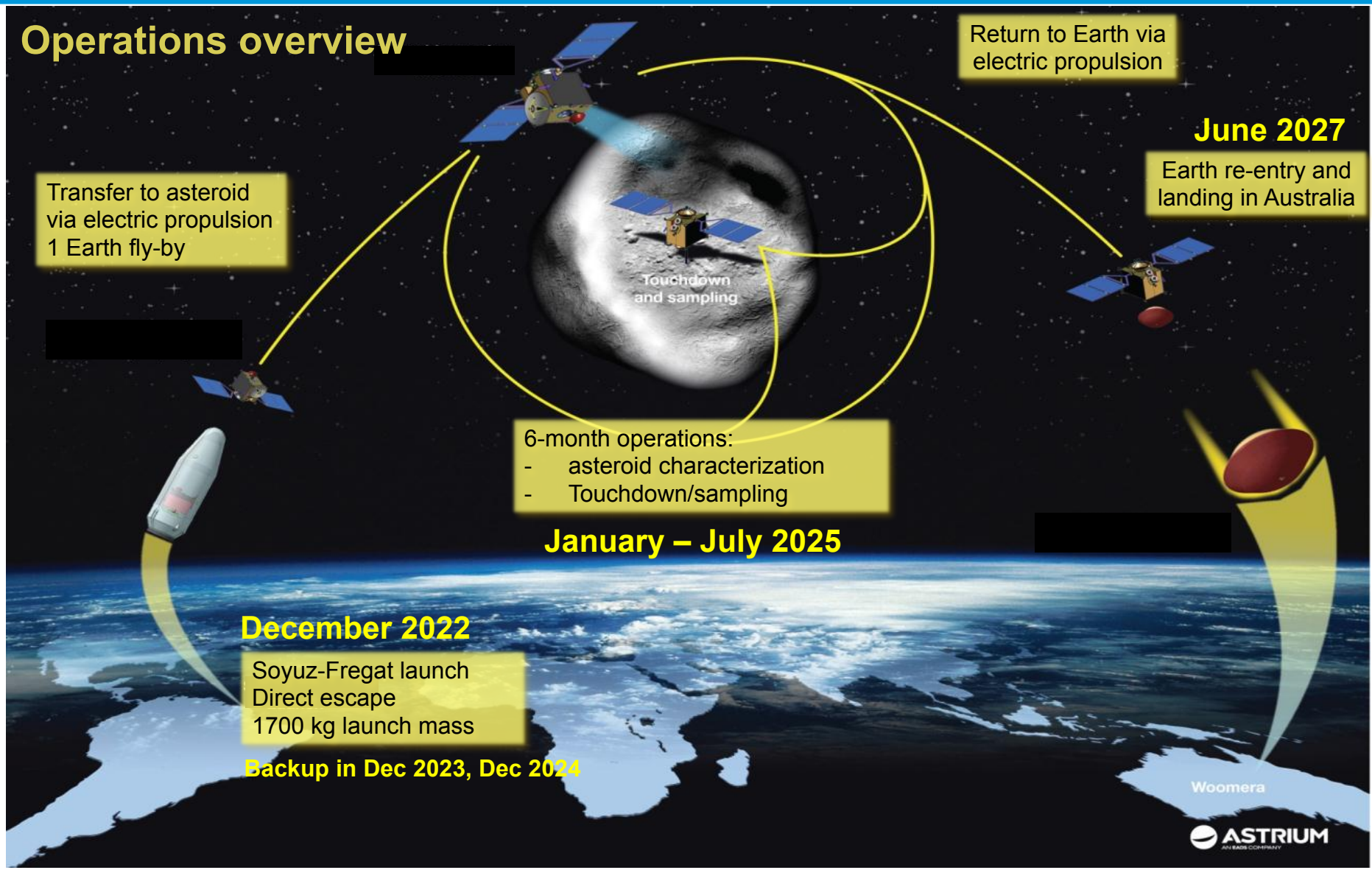
Payload and Sample acquisition

- Suite of 5 instruments (33 kg) + radio science experiment for fine characterisation of the Asteroid

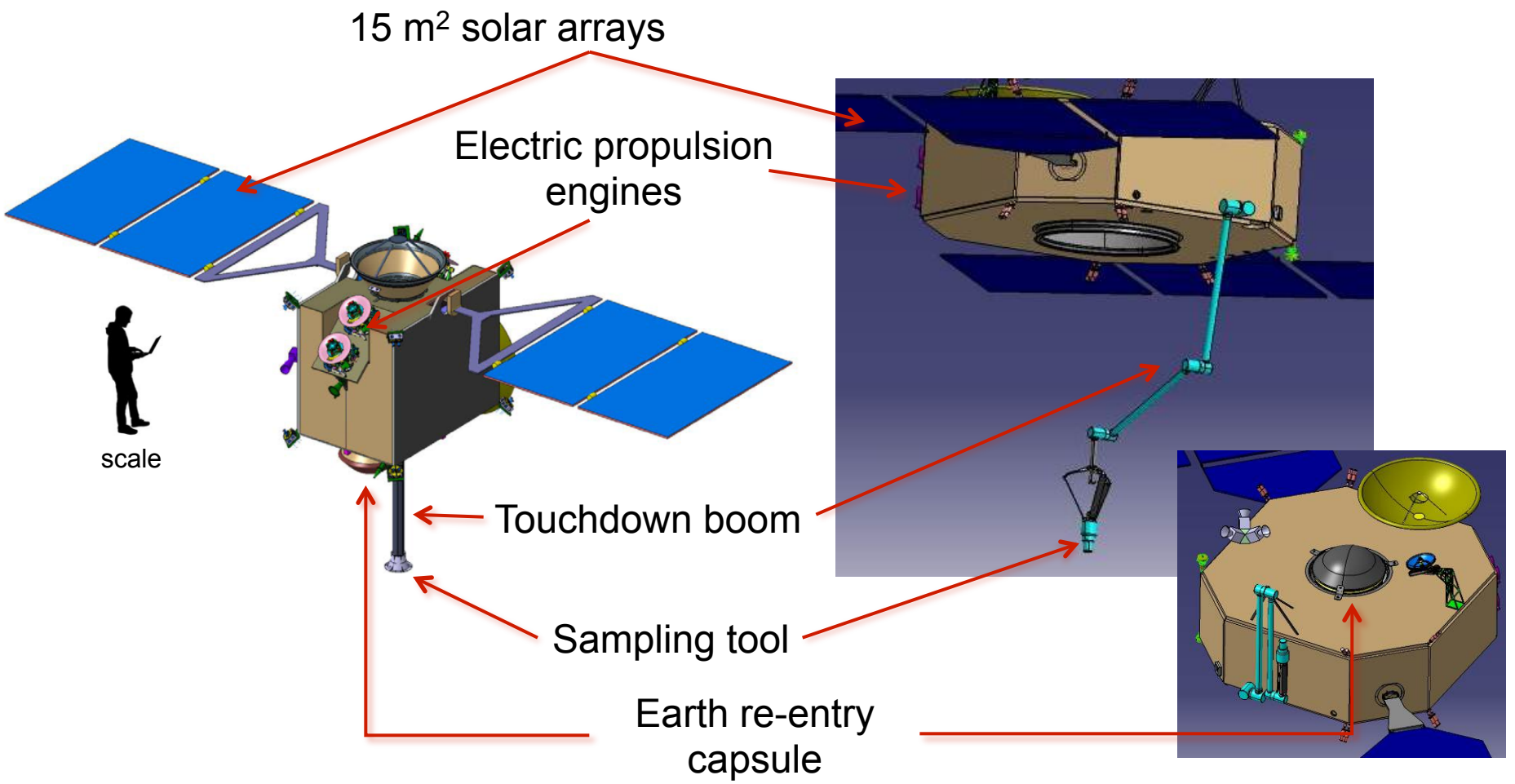
MaNAC - Narrow Angle Camera
CUC - Close-Up Camera
MaRIS - Visible and near-infrared imaging spectrometer
THERMAP - Mid-infrared spectro-imager
VISTA2 - Volatile In-Situ Thermogravimetry Analyzer
RSE - Radio Science Experiment (no HW, use of S/C TT&C)

- "Touch-and-go" sampling concept

Mission Profile and Concept of Operations



Spacecraft Configuration



Spacecraft features

Sampling technique

2 concepts: brush-wheel & grabbing scoop

Sampling tool used as sample container, sealing with Viton ring

Electric propulsion engine

Recurring from Smart1/Alphasat, 320 kg Xe

Navigation and Control

Ground-driven up to ~ 1 km altitude, then autonomous vision-based down to surface

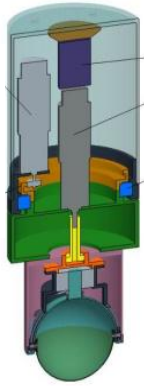
- Last 15 meters in free-fall, touchdown velocities 10 cm/s vertical, 5 cm/s horizontal. Use of camera + laser altimeter + standard AOCS (reaction wheels/star tracker/IMU)

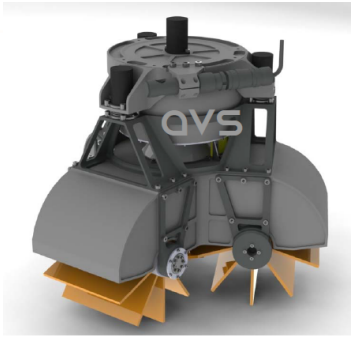
Re-entry capsule

12 km/s passive reentry, diam. 90 cm, 45 kg

Heat shield material now available in Europe. Crushable material to absorb landing energy

Mass	1100 kg dry 1550 kg wet
Power	3 kW
Data volume	120 GBits
Lifetime	4.5 y (6.5 in 2024)
Dimensions	2.2 x 1.9 x 1.4 m^3





Grabbing scoop (left) & brush-wheel (right)

PLATO

PLAnetary **T**ransits and **O**scillations of stars

PLATO: PLAnetary Transits and Oscillations of stars

Science

Exoplanet detection using transit technique and characterization of parent star using asteroseismology

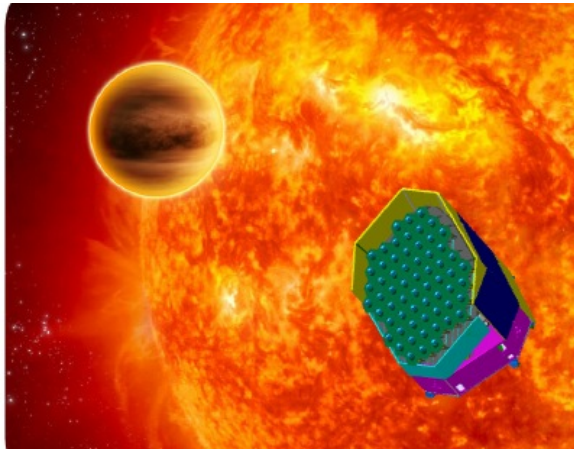
Payload

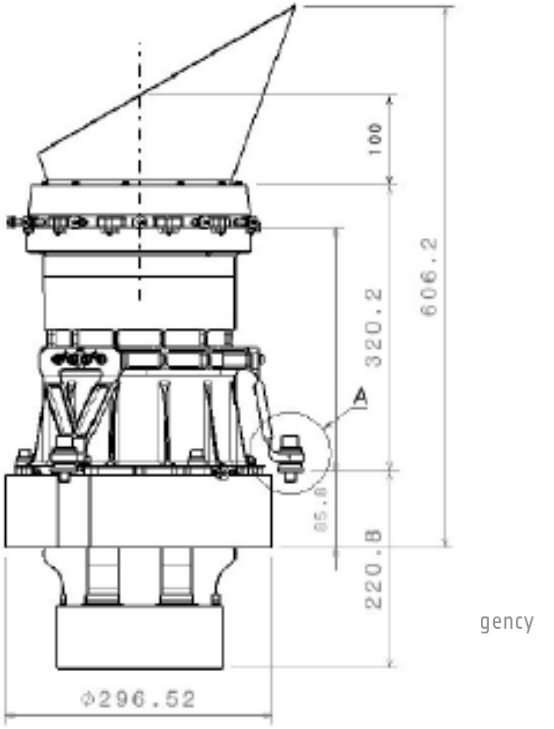
32 "Normal" + 2 "Fast" cameras, including each:

- Refractive optics (6 lenses),
- 4 large CCDs 4510 x 4510 pixels, 18 μm pitch
- Front End Electronics

Camera FoV 1100 deg^2. Total FoV ~ 2250 deg^2, achieved with the 32 telescopes distributed in 4 groups with overlapping field of views

Overall payload mass 600 kg





Mission Profile and Concept of Operations

Launch and orbit

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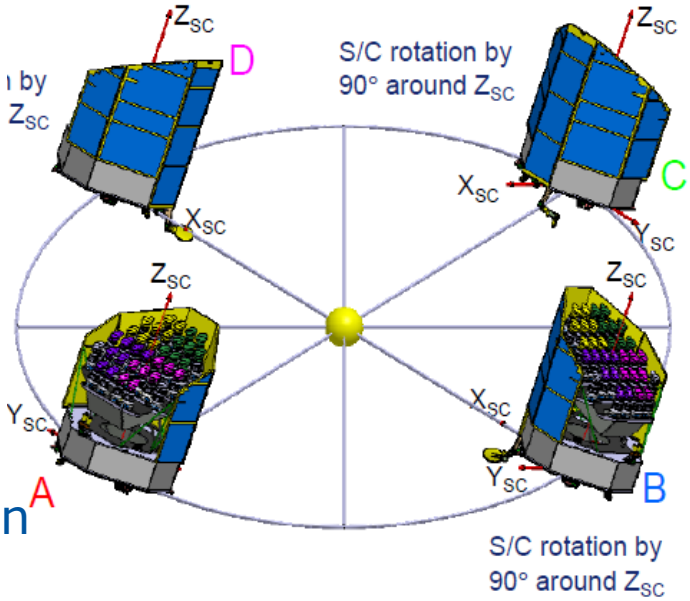
- ESTRACK ground stations
- 6.5 yrs operations + 2 yrs extension



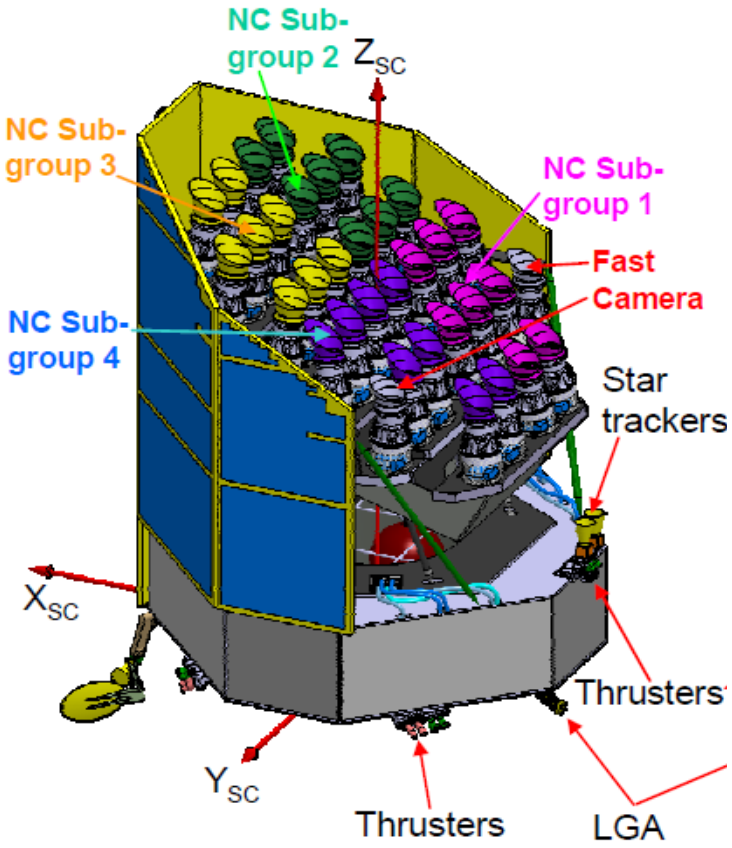
Concept of operations

All observations in staring mode. Long-Duration Observation Phases (2 fields) then Step-and-Stare Phase to observe several sky fields (2 to 5 months each)

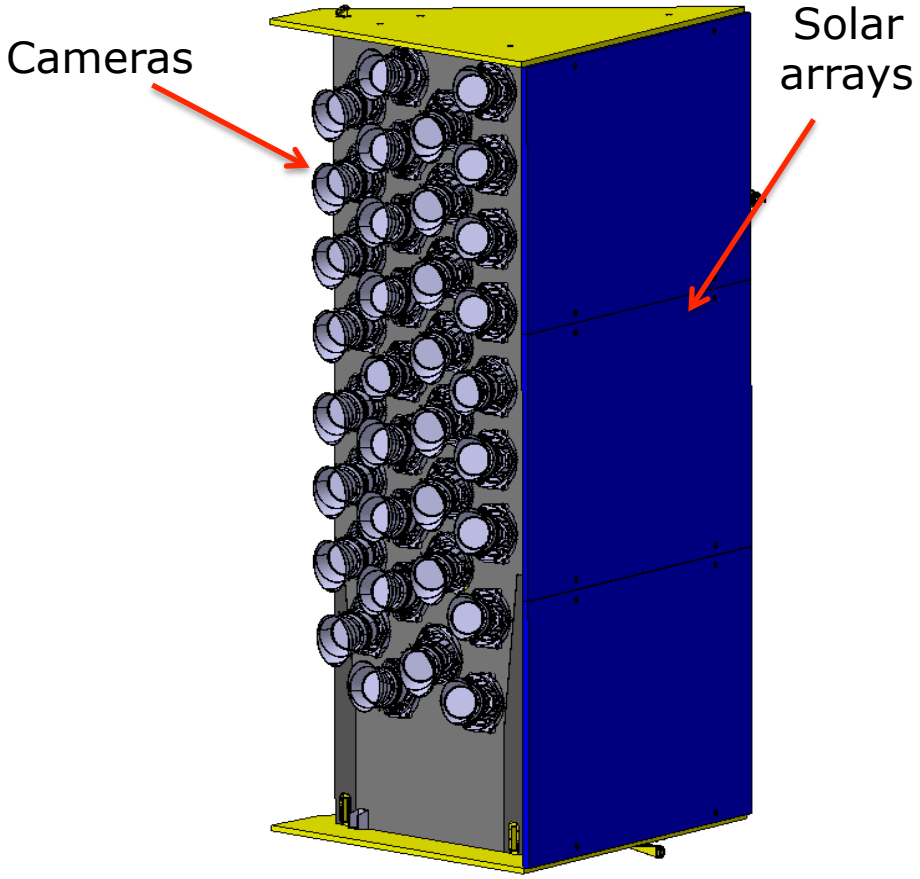
During long observations phase, the spacecraft is rotated every 3 months around the payload axis

Nominal science operations 6 years		
Long duration, field #1, 2-3 yrs	Long duration, field #2, ~ 2 yrs	Step & stare obs, 2-5 months each

Spacecraft Configuration



Concept A



Concept B

Spacecraft features

Payload

- High photometric stability (27 ppm in 1 h @ mv = 10.8)
- Passive cooling of CCD detectors -65 deg C
- On-board processing and data compression
- Serial production of 136 large format CCDs, 34 telescope units, and 18 data processing units.

Attitude and Orbit Control

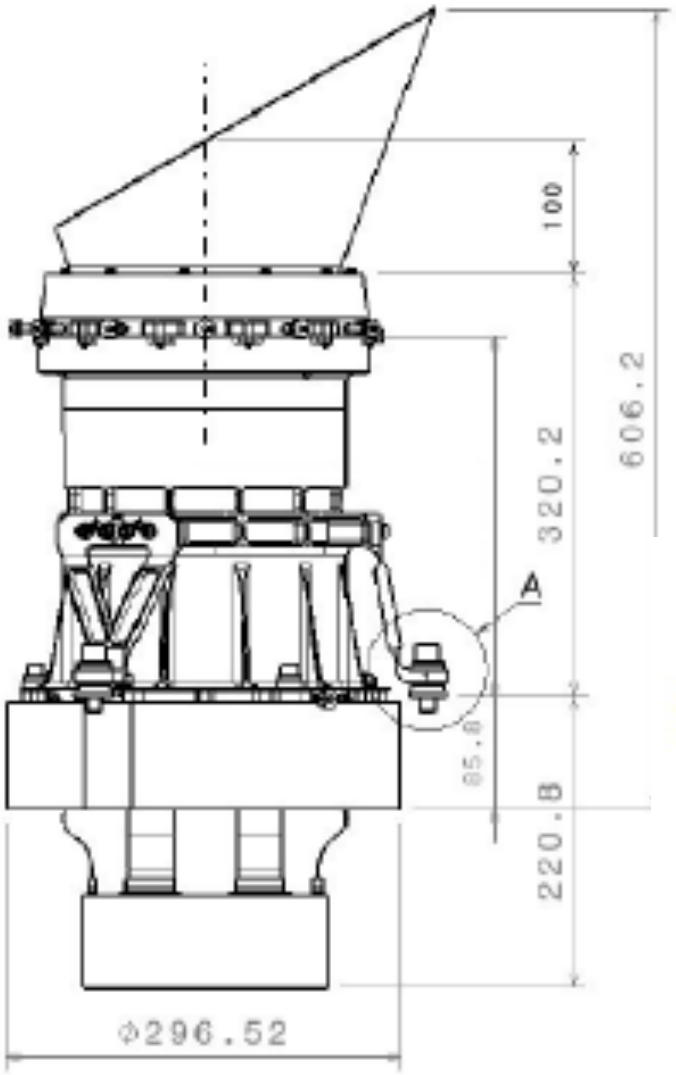
- Science mode attitude control using payload fast cameras, gyros, and star tracker.
- Reaction wheels actuators

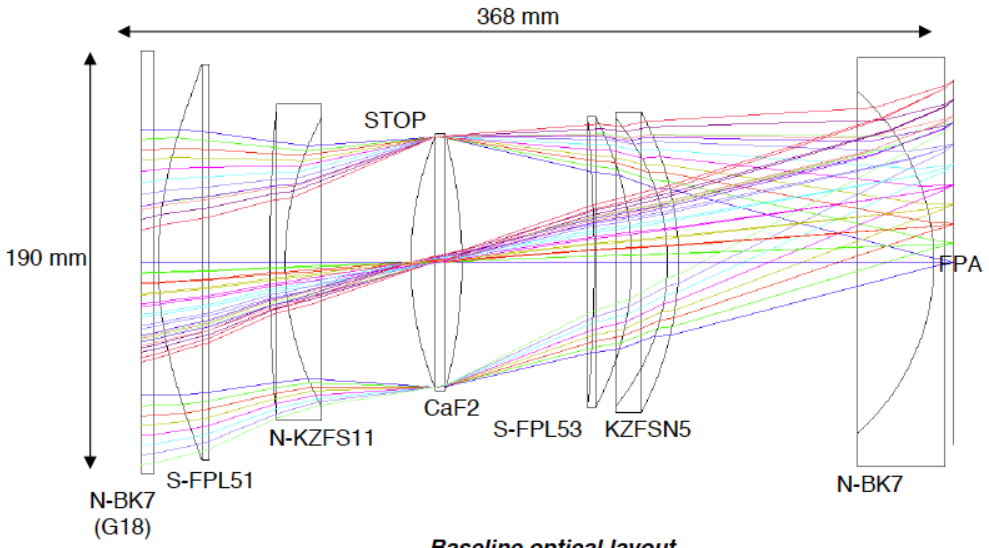
Data handling & communications

- X-band for up/down link,
- Deployable steerable HGA with two DoF

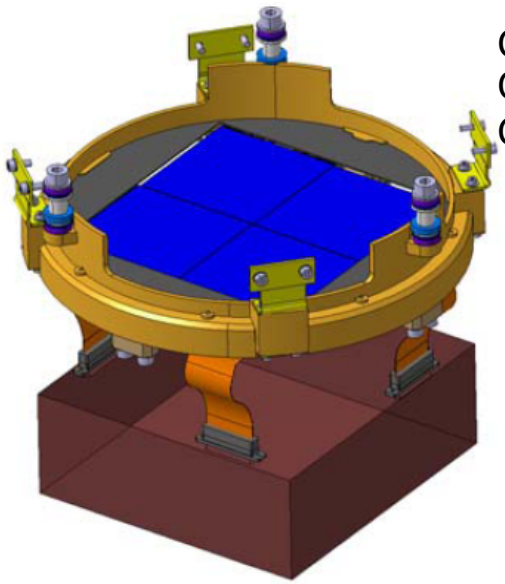
Mass	2100 kg
Power	1.6 kW
Data rate	109 Gbit/ day
Lifetime	6 years
Dimensions	5m x 3m x 3m

Payload cameras: configuration





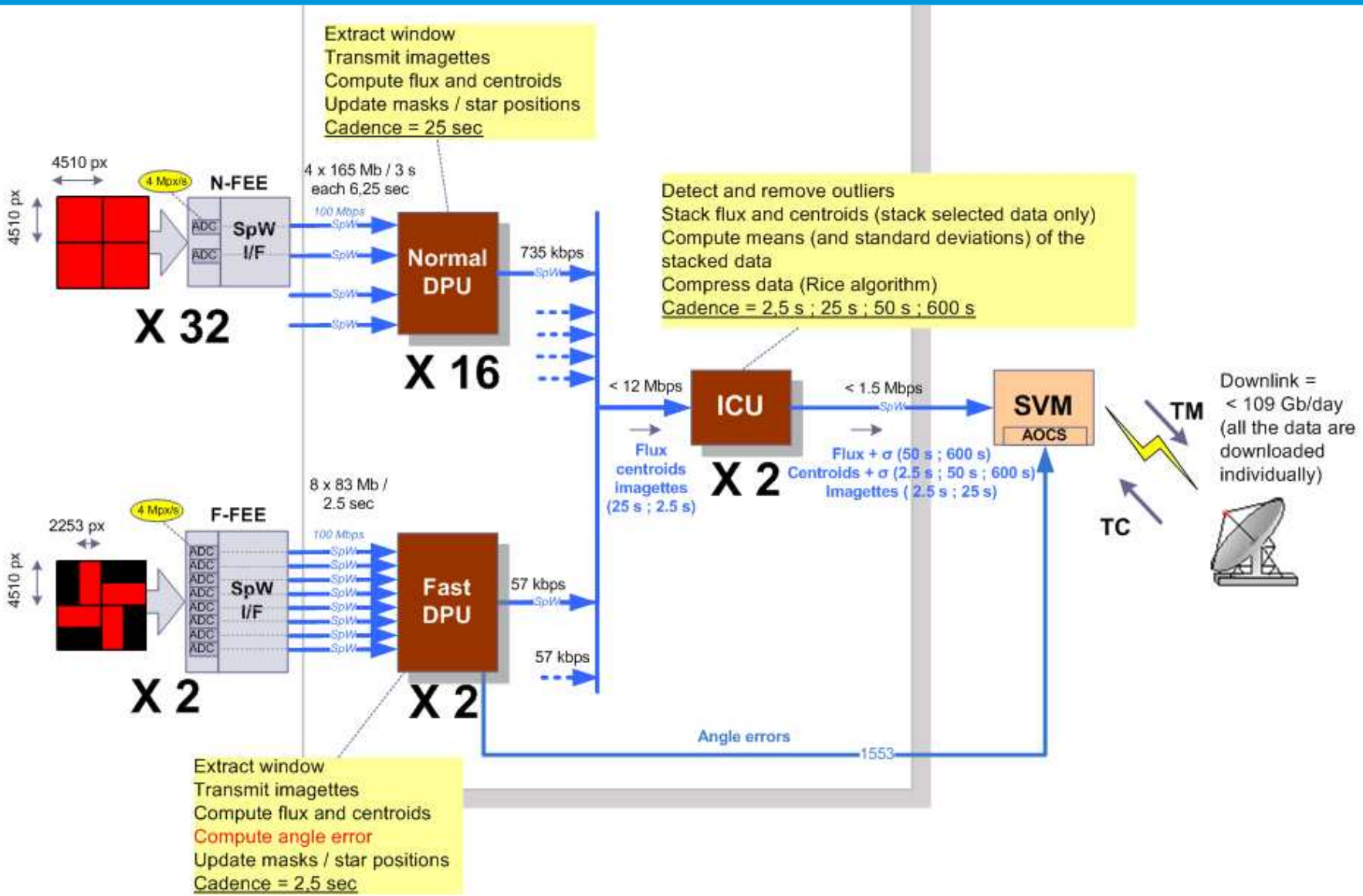
Baseline optical layout



Camera mass (w/o FEE): 11.7 kg
Optics operation temperature: -80 C
CCD operation temperature: <-65 C

FPA (CCDs in blue):
- Normal cameras: four 4.5x4.5 Mpixels CCDs in full frame mode.
- Fast cameras: four 4.5x2.25 Mpixels CCDs in frame transfer mode.

On-board data handling and processing



STE-QUEST

Space-**T**ime **E**xplorer and

QUantum **E**quivalence principle **S**pace **T**est

European Space Agency

STE-QUEST: Space-Time Explorer and QUantum Equivalence principle Space Test

Science

General relativity tests: gravitational redshift in the Sun and the Earth frames and test of the weak equivalence principle

Payload

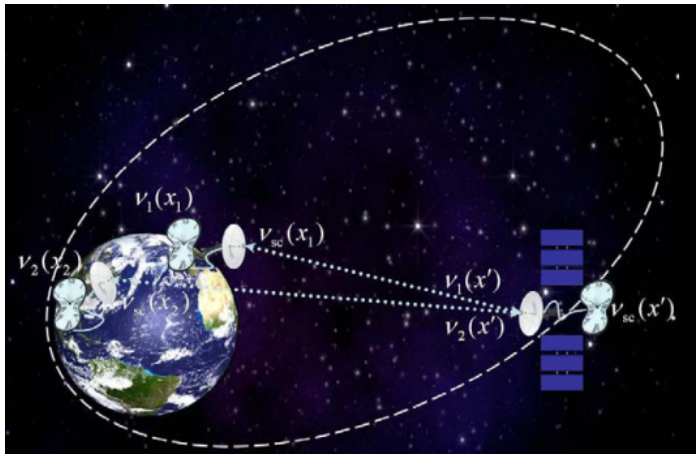
Atom Interferometer (ATI, 250 kg): Mach-Zehnder matter wave interferometer, with ultra-cold atoms (Rb87, Rb85) obtained through multi-stage laser trapping

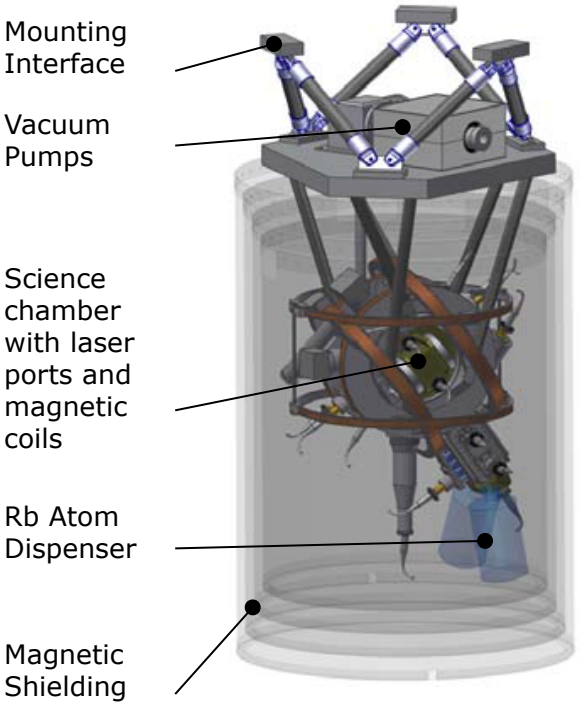
- Single-Shot accuracy: 3E-11 m/s^2 ,
- per Orbit: ~ 5E-14 m/s^2

Microwave links for On-Board/Ground clock comparison, 33 kg

- Ground Terminals with > 1 m antenna and direct link to high-performance clock (member states)

GNSS receiver (GPS/Galileo) for precise orbit determination





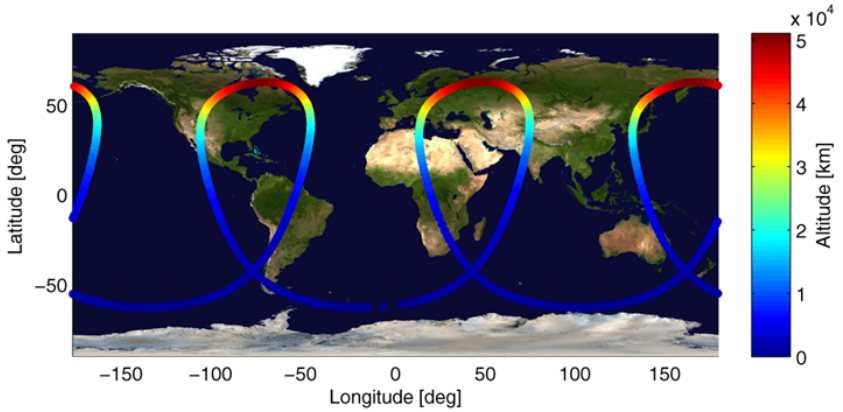
Mission Profile and Concept of Operations

Mission profile

Soyuz Fregat direct insertion

HEO (apogee 51 000 km, perigee 700 km), 63 deg inclination, 16h period (2 day cycle)

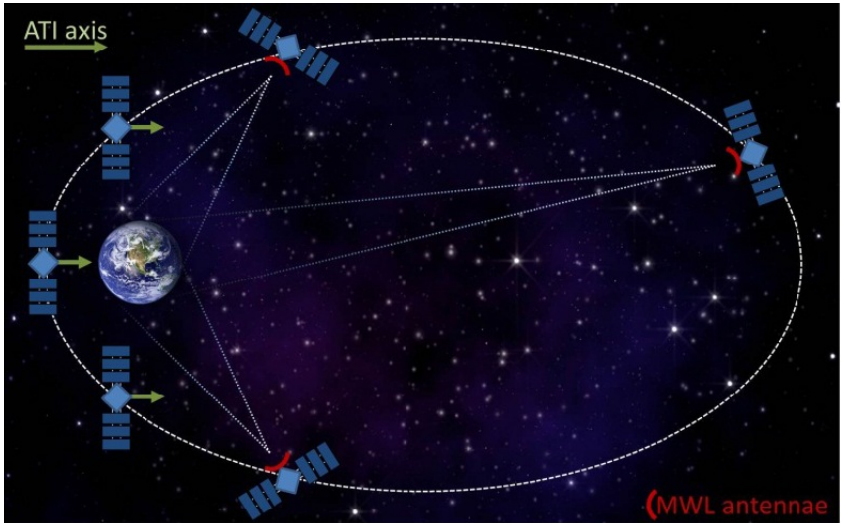
Use of ESTRACK 35 m ground stations, and of 3 dedicated ground clock terminals (Boulder, Turin, Tokyo)



Concept of operations

- Perigee passage: ~ 2000 s, inertial pointing, interferometer measurements, 20 s per shot
- Apogee: Ground Clock comparisons, nadir pointing (satellite as clock relay)

  Transition between inertial and nadir pointing: ~ 3000-7000 km



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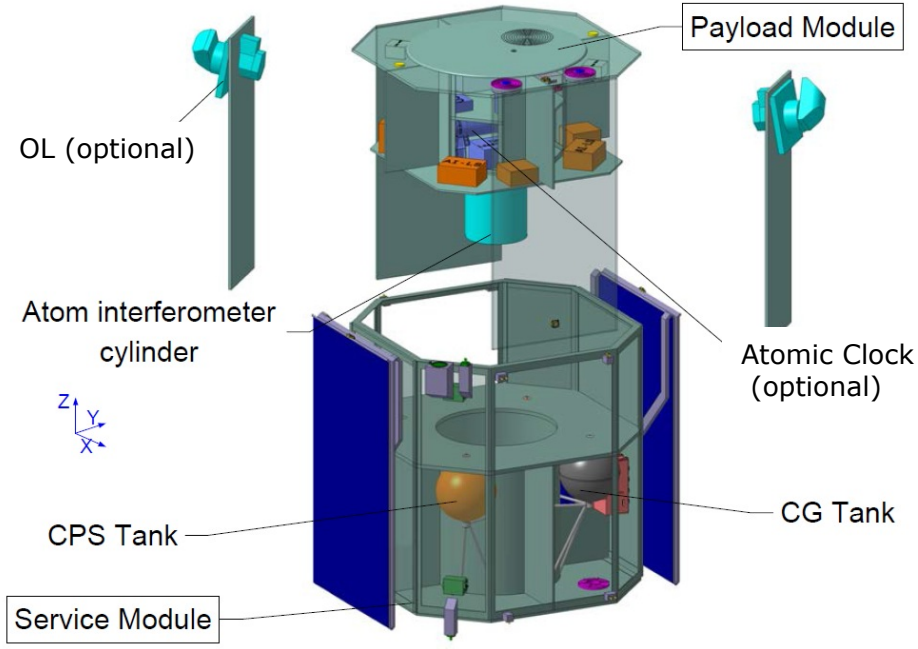
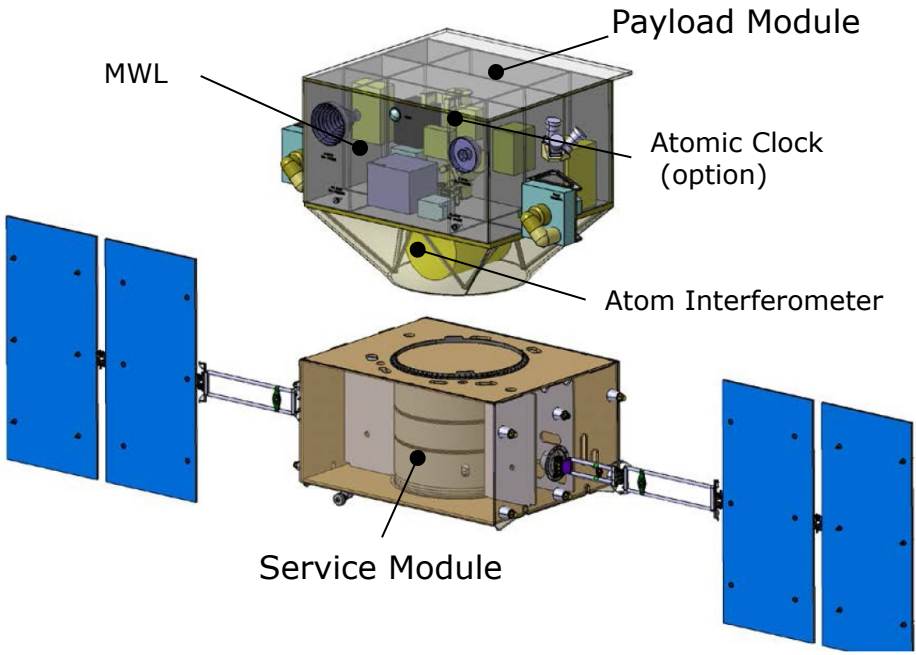


Concept A



Concept B

Spacecraft features

Payload

Atom Interferometer: Low maturity of some elements (TRL 3)

Microwave links: upgrade from ACES (ISS)

Requirements on S/C rotation rates (1 μrad/s) and residual non-gravitational accelerations (static 4 E-7 m/ s^2 + noise spectrum)

Spacecraft environment

High radiation levels

- comparable to GEO for electrons, 330 krad with 3 mm shielding, <50krad inside spacecraft
- Comparable to GNSS for protons (~1E10 cm^{-2}): need for shielding optical components

AOCS

Cold gas μ-propulsion or low vibration reaction wheels

Mass	< 2000 kg
Power	< 1300 W
Data volume	15 Gbit/ 48h cycle
Lifetime	5 yrs
Dimensions	W 2.5 m H 2.7 m

The End