FINDING EARTH-TWINS WITHIN 10pc

Hunting Earth-like planets: a long roadmap supported by ThalesAleniaSpace

A. Martelli - S. Mottini

19-20/Nov/2018

ThalesAlenia Space
a Thales / Leonardo company

Outline

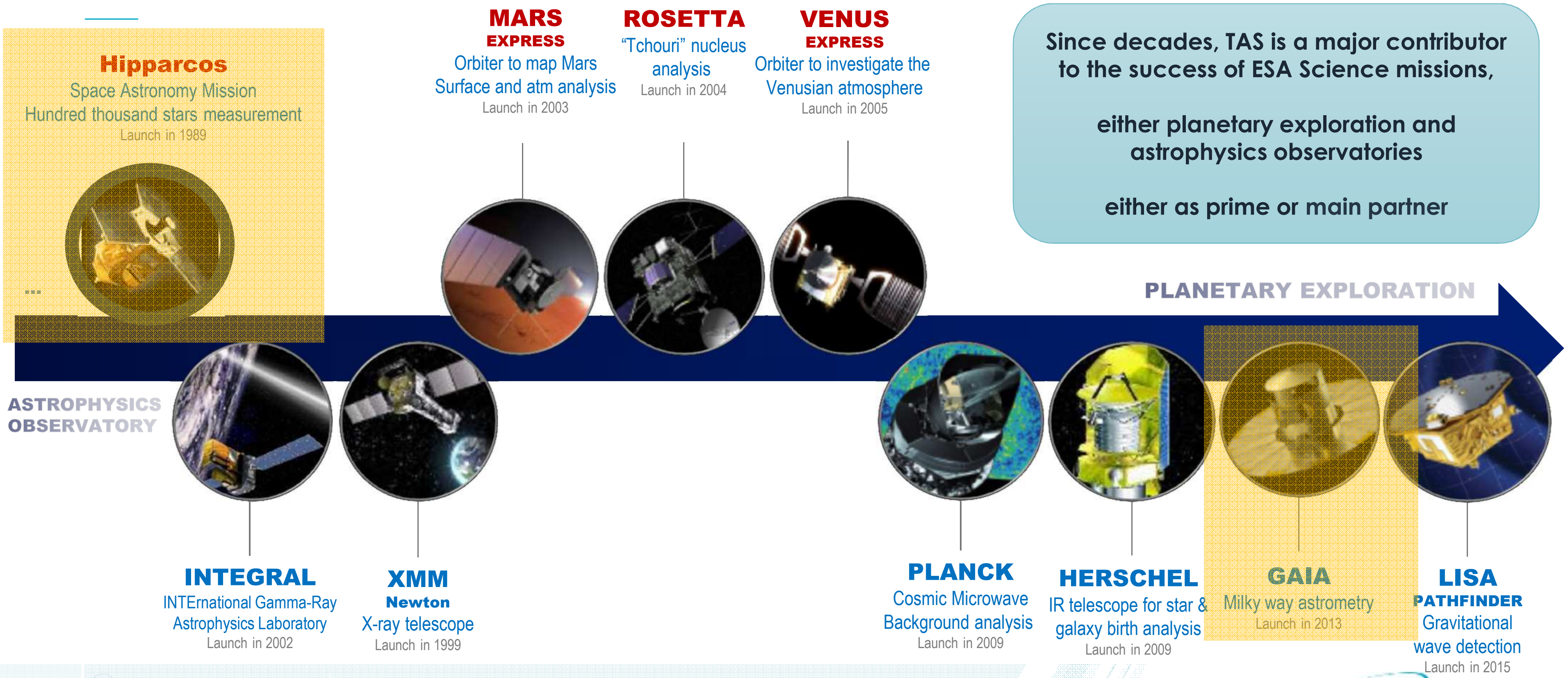
1. *TAS Heritage in Planetary Missions*
2. *The Contribution*
3. *TOLIMAN Needs*
4. *Available Key Technologies*
   a. *Attitude Control*
   b. *Thermo-Mechanical Stability*
   c. *Metrology*
   d. *AIT*
   e. *Ground Centre – ALTEC*
5. *Conclusions*

TAS CONTRIBUTION in SPACE SCIENCE - The PAST

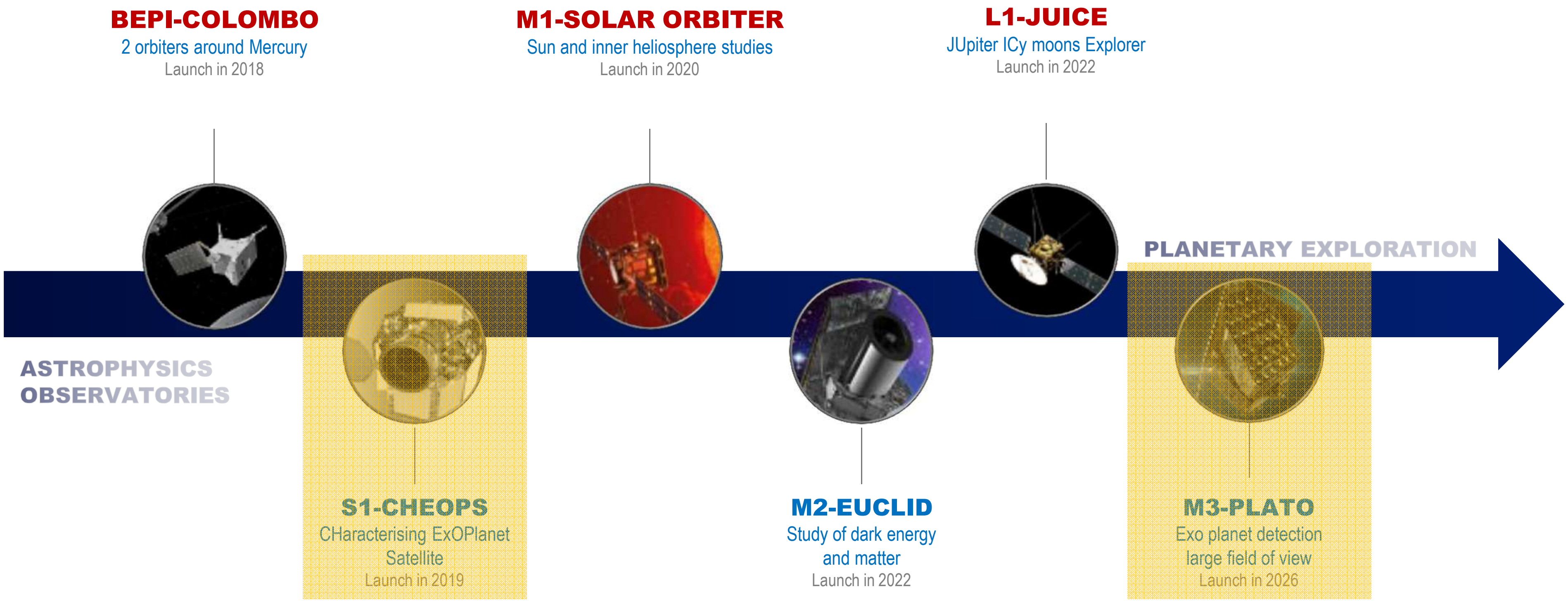
Since decades, TAS is a major contributor to the success of ESA Science missions,

either planetary exploration and astrophysics observatories

either as prime or main partner



TAS CONTRIBUTION in SPACE SCIENCE - The PRESENT



TAS CONTRIBUTION in SPACE SCIENCE - The FUTURE

2018 | 2019 | 2020 | 2022 | 2023 | 2024

S2 — M4 — L2 — L3 — F1 — M5 — M*

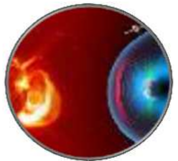
ASTROPHYSICS OBSERVATORIES

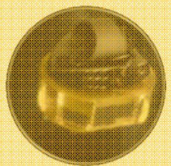
PLANETARY EXPLORATION

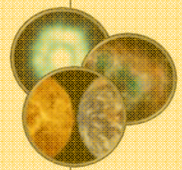
F1
Small planetary missions
with multipoint measurement
To be confirmed at CM19
For a dual launch with ARIEL

M5
3 candidate missions
selected in June 2018:
EnVision

M*
Mission to ice giants
To be confirmed at CM19
Cooperation with NASA
Favourable conjunction
launch slot 2028 - 2032







S2-SMILE
Interaction between Earth's
magnetosphere and supersonic
solar wind measurement
ESA /China instrument

M4-ARIEL
Super Earth
spectrometry

L2-ATHENA
X-Ray Observatory
Science follow-on
of XMM
New technologies

L3-LISA
Gravitational Wave
Observation

M5
3 candidate missions
selected in June 2018:
THESEUS, SPICA

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PAST MISSIONS

Hipparcos

- Pioneering European astrometry mission
- More than one hundred thousand stars with high precision; 1 milliarcsec level astrometry
- more than two million stars with lesser precision; Tycho 2 Catalogue includes 99% of all stars down to magnitude 11
- 20-30 milliarcsec astrometry and two-colour photometry (star magnitudes or brightnesses)
- Full extragalactic sky survey in GTO – slow spin
- 1000 Gbit of TOTAL Scientific data
- Optical all-reflective Schmidt telescope, 290 mm
- Beam combining'mirror, two fields of view, separated by about 58 degrees, and each of dimension 0.9 x 0.9 degrees
- Launch 1989

TAS

Major Contractor for SVM
Assembly Integration & Test
Launch Campaign Support

Gaia

- Survey celestial bodies down to the very faint magnitude 20 - 1 Billion of celestial bodies
- Two three-mirror anastigmat telescopes (collecting area = 0.7 m2) with LOS separated by 106.5° and beam combined on a common focal plane
- 3D map of stars location and their movements - measurement precision, reaching a few millionths of a second of arc
- 1 PetaByte
- Six European DPC for archiving, processing science data and calibrating instruments. ALTEC hosts the DPCT and operates it with Osservatorio Astrofisico di Torino

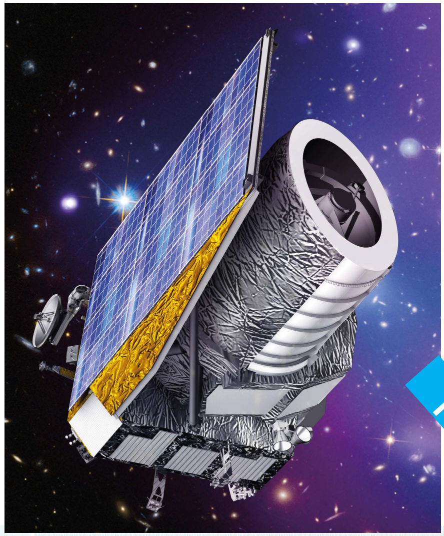
TAS

Study Definition Phase
Development of internal metrology
Scientific Mission Support – ALTEC DPC

CURRENT MISSIONS

EUCLID

Mapping Dark Energy and Dark Matter by measuring shapes and redshifts of galaxies and clusters out to z=2 (10 billion yr)

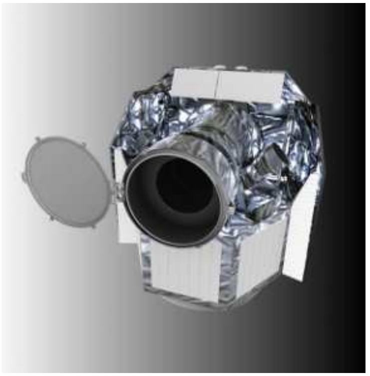


- **Full extragalactic sky survey at L2**
- **Wide-field all-SiC telescope with 1.2 m dia. primary**
  - Diffraction limited
  - 0.54 deg² FoV
  - 135°K operation
- **Visual Imager 0.55-0.9 µm**
- **Near-Infrared Grism Spectrometer 1.25-1.85 µm**
- **Photometric Imager Y, J, H bands**
- **Low noise AOCS**
  - RPE 75 mas 3σ in 700s
  - APE 7.5 as
  - GAIA-catalog based FGS
- **4Tb Mass Memory Unit**
- **K-band telemetry, 70 cm HGA, 74 Mbps, ~100 GB compressed data/day**
- **Launch 2022**

TAS

PRIME contractor
S/C design
AOCS – GNC Design

CHEOPS



Searching for exoplanetary transits by performing ultrahigh precision photometry on bright stars already known to host planets

- **First S-class mission in Cosmic Vision 2015-2025**
- **Sun-synchronous orbit, with an altitude of 700 km**
- **determine accurate radii for planets in the super-Earth to Neptune mass range**
- **a single medium-size telescope of ~0.3 m**
- **three-axis stabilised, with a pointing stability of better than 8 arcsec rms during a 48-hour science observation**
- **On-axis Ritchey-Chrétien telescope, passively cooled to < 233 K, with thermal stability < 10 mK**
- **Data budget for CHEOPS is estimated at 1.2 Gb/day . Link based on S-band system**
- **Launch 2019**

TAS

Support to the Telescope
Thermo-Mechanical Analyses

CURRENT MISSIONS

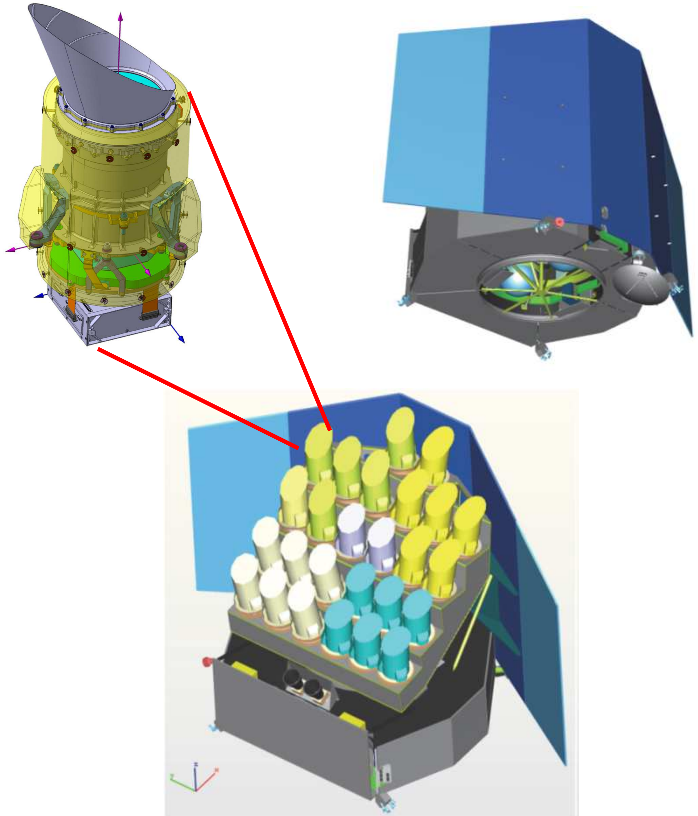
PLATO

Planetary Transits and Oscillations of stars

High precision, long-duration photometric monitoring in the visible band of very large samples of bright (mV ≤ 11–13) stars

- Detection and characterization of terrestrial exoplanets around bright solar-type stars
- seismic activity of host stars

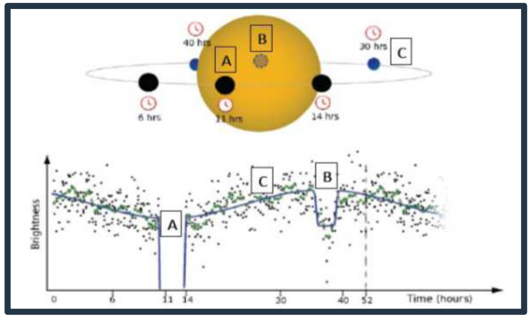
- **24 'normal' CCD cameras in 6 groups of 4**
  - 25s readout cadence
  - mV > 8
- **2 ‘fast' cameras**
  - 2.5s readout cadence
  - mV ~4–8
- **Total survey field of 2250 deg²**
- **Two single fields monitored for two years each**
  - 90° rotation around LOS every 3 months
- **6.5 (8) years at L2**
- **0.2 as·Hz$^{-1/2}$ over of 25 s to 14 hr time scales**
- **K-band telemetry, 72 Mbps, ~ 435 Gb per day**
- **2 Tb Mass Memory Unit**
- **Launch 2026**



TAS

Study Definition Phase
Telescope Structure Design

The Future

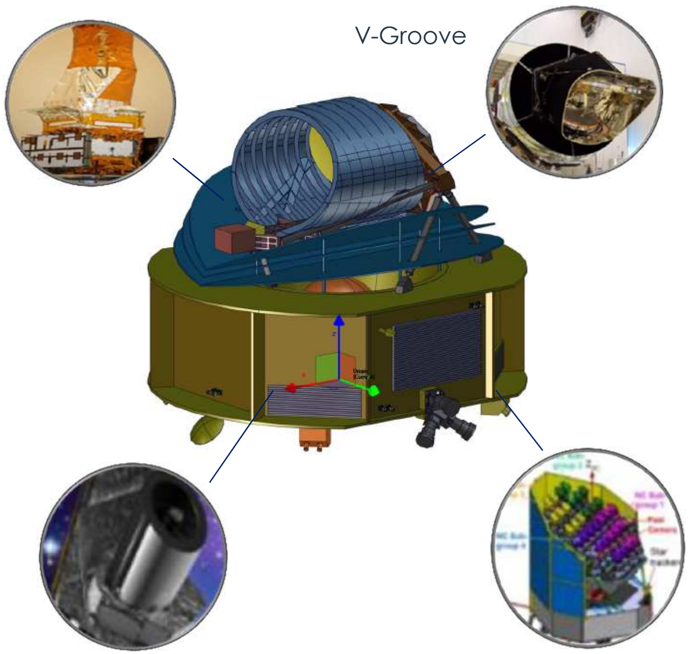


ARIEL

- ARIEL mission will have the primary objective of studying the physics and chemistry of the atmospheres of known Exoplanets, through the transit spectroscopy technique
- Visible to Near Infrared wavelengths of light (0.55 to 1.95µm and 1.95 to 7.8µm required), and will analyse the reflected, emitted and transmitted spectra of the targeted systems
- critical areas including Photometric Stability, Challenging Thermal Design and precision optical instrument development

TAS

Preliminary SVM Study Electrical Architecture

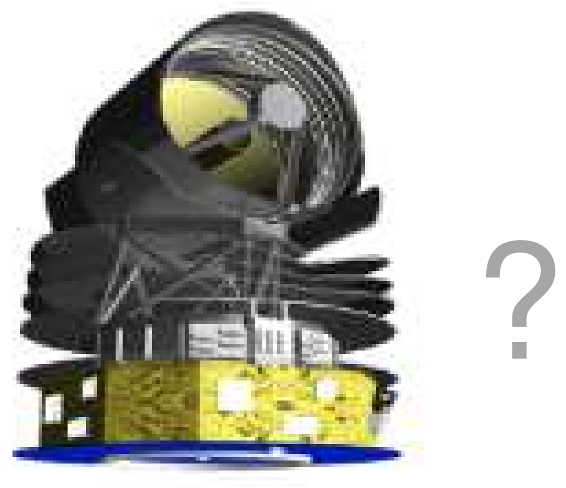


The Future

Among the three Selected M5 missions one is devoted to looking at the Planet forming systems
Phase A will start next year….

M5

- **Unveil dusty matter in the universe**
- **Reveal the inner workings of galaxies, star forming regions, and planet forming systems**
- **Mid/Far-IR observing**
- **2.5 meter telescope, < 8K**
- **Looking for the thermal and chemical history of the building blocks of planets**
- **Three istruments**
  - *SAFARI/SPEC -high sensitivity* grating spectrometer
  - *SAFARI/POL -imager polarimeter*
  - *TheMid-infrared Spectroscopy Instrument SMI*
- **Launch 2032**



TAS

TAS heritage L2 missions (H-P, Euclid, Plato, ARIEL….)

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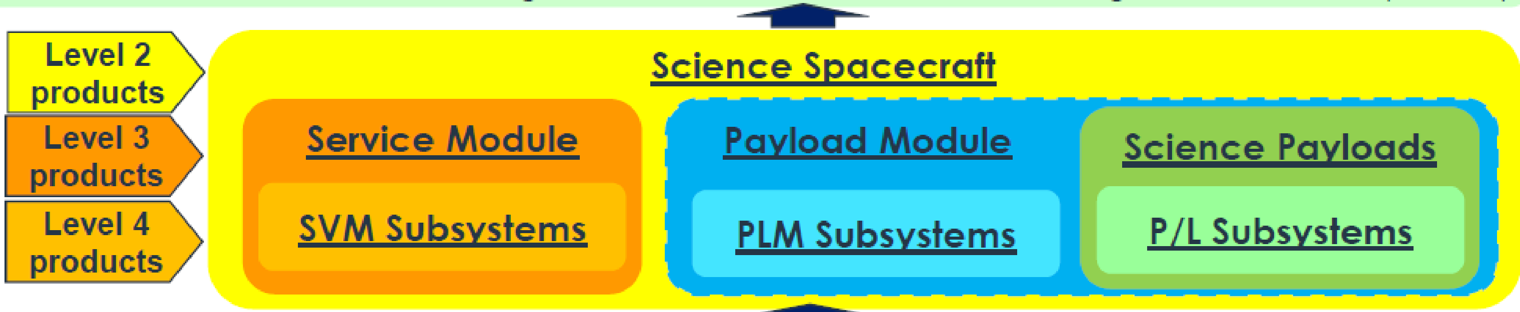
TOLIMAN NEEDS

Basic architecture of the TOLIMAN mission		***Design approach and solutions***
• Thermally stabilized space telescope with 0.3m diameter aperture	→	Thermal modeling and analyses. Passive thermal control
• 2-mirror high stability optical design with a single focal plane	→	Low CTE material, TM design to minimize distortion
• Minimum complexity optical and mechanical systems	→	Optical design, AIT and verification methods
• Fast, agile, low-cost mission	→	Reuse of Available P/F - Components . Maximize expertise
• Full Science Mission duration - 3 years	→	High Availability – Functional Design
• Can be designed for various orbits (GEO is baseline)	→	Compatibility with different environmental conditions / Launchers
• Pointing 1 arcsecond with drift/jitter better than 1arcsec/sec	→	AOCS-GNC-FGS - FSM
• Raw Data Rate: 10GB/Hour	→	DH and Mass Memory
• Estimated downlink requirement < 1GB/day (after on-board processing)	→	Visibility analysis, link budget, data volume
• On-board instrument flight metrology: thermal and optical monitoring	→	Compact instrument, accurate measure, (close loop with GNC?)

Enabling Techno

Current Missions/Programs

- Missions of ESA's Space Science Program (BepiColombo, CHEOPS, Solar Orbiter, Euclid, PLATO, M4, JUICE, ATHENA, LISA) and some of their payloads (CHEOPS-TEL, Metis, PLATO-TOU, MAJIS)
- Missions for Earth science falling under of ESA's Earth Observation Program Directorate (NGGM)



Technologies

- High-stability, lightweight structures
- Optical metrology (inter-satellite, intra-satellite)
- High-performance spacecraft dynamics control (orbit, attitude, drag-free, formation, pointing)
- High-performance thermal control (for utmost stability, large thermal fluxes, low temperatures)
- Contamination monitoring and prevention (particulate, molecular, electro-magnetic, radiation)
- End-to-end mission performance simulators (including high fidelity models of the payloads)

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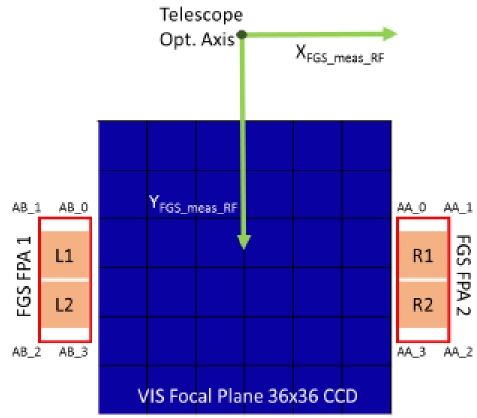
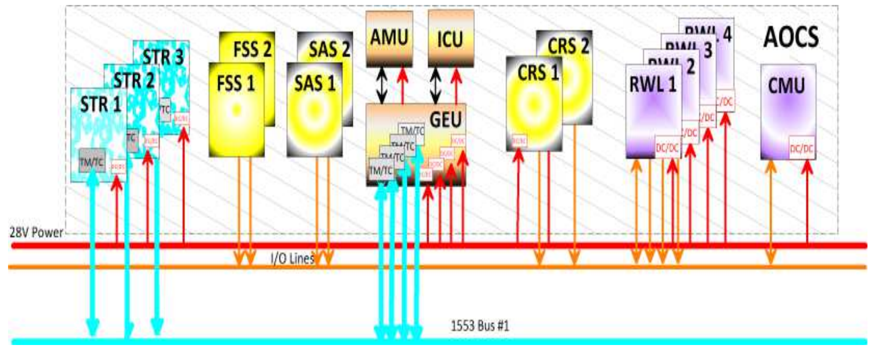
5. Conclusions

AOCS - FGS

Euclid as an example of very high stability AOCS

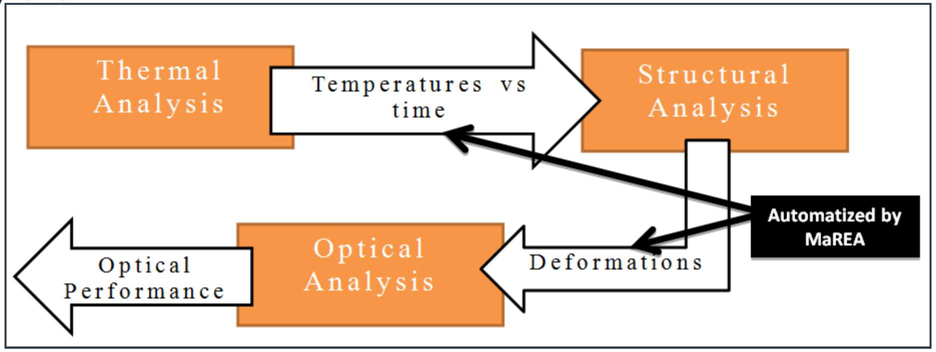
- Pointing performance (APE, RPE) derived from apportionment of image quality (FWHM, ellipticity) requirements
  - APE 7.5 arcsec (3σ) / RPE 75·10^{-3} arcsec(3σ) over 700s
- Fine Guidance Sensor (FGS) for accurate attitude measurement
  - Consists of 4 extra CCD sensors at the edges of the VIS focal plane
  - absolute attitude measurement with accuracy < 0.6 arcsec cross-axis and <5 arcsec around optical axis
  - relative attitude measurement with accuracy < 30 mas cross-axis and < 2.1 arcsec around optical axis, over 4500s
  - Autonomous slew guidance by custom-built star catalogue regularly uploaded from ground
- Micropropulsion (MPS) actuators for low noise & fine command resolution
  - <1 µN thrust resolution, <0.5 µN thrust bias, thrust noise <1 µN/√Hz from 0.01 Hz to 1 Hz
- Mission efficiency by minimum-time slews and dithers
  - High torque actuation by Reaction Wheels in start-and-stop mode
  - Extended attitude control bandwidth by Gyro package
- Detector suite for acquisition / transition / safe modes
  - Two Sun Acquisition Sensors (SAS) with two channels each
  - Two miniaturized Fine Sun Sensors (FSS)
  - Two Coarse Rate Sensors (CRS)
  - Three Star Trackers (STR)

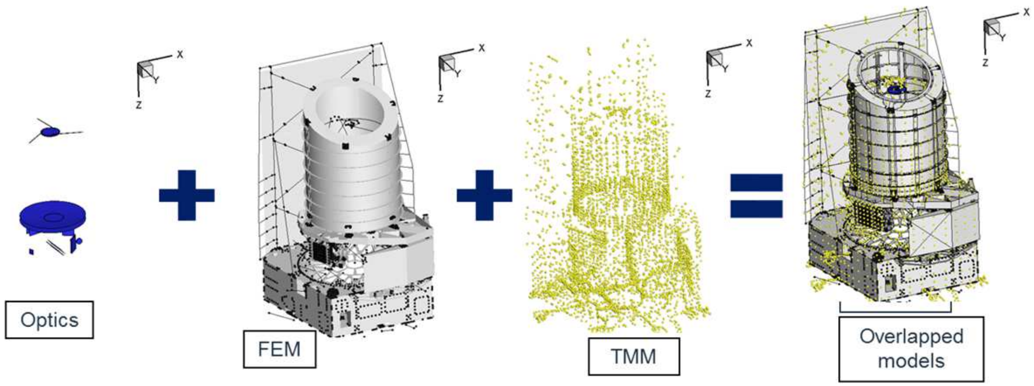




Thermo Mechanics – STOP Analysis

- **TAS develops tools and methods for fully integrated STOP analysis**
  - STOP analysis is an integrated, multidiscipline system analysis which predicts performance of an optical system
  - An integrated team, involving expertise from thermal, structural and optical engineering, is active
  - Mathematical models are built considering specific objectives:
    - Mapping temperatures
    - Monitoring optical displacements
    - Representing the system optical Figure of Merit
  - Various projects have been benefitting of the STOP analysis methodology
    - METIS
    - EUCLID
    - LISA



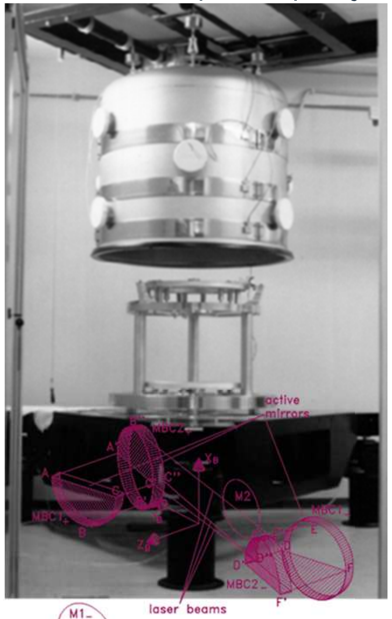


Optics and Optical Metrology (1/4)

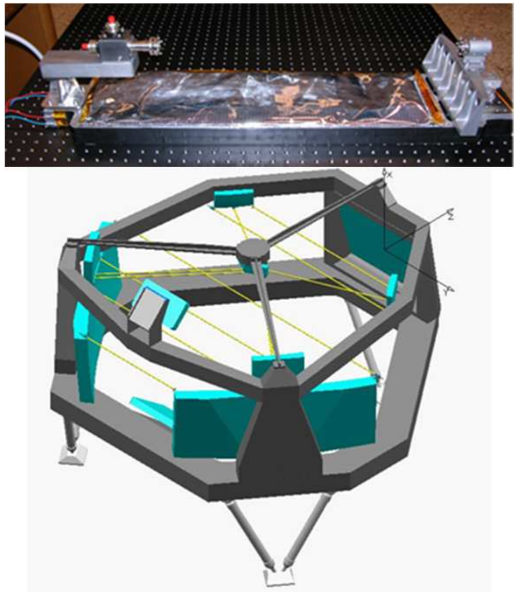
- Optics competences in Exploration & Science Department (DESI)
  - Design, architecture and requirement specification
  - Analyses (design, optimisation, tolerance, STOP, straylight)
  - Assembly and test of breadboards
  - Support to integration/alignment and test of flight optical instruments
- Specific software tools: CODE-V, Zemax, TracePro, LabView, MaREA (internally developed tool for STOP analyses)
- Facilities and equipment
  - Large optical laboratory in ISO 8 clean room with anti-seismic floor endowed with optical benches and two vacuum chambers.
  - Smaller optical laboratory endowed with optical benches.
  - Availability of different laser sources (including two frequency stabilised Nd:YAG lasers), detectors, cameras, precision translation stages, sighting telescopes, optical elements, test equipment, data acquisition systems (including real time acquisition), workstations.

Optics and Optical Metrology (2/4)

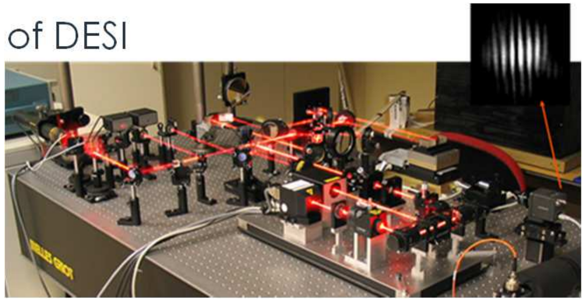
Past optics projects performed by the Optics Unit of DESI



1997-98: first breadboard of the laser metrology device for monitoring the basic angle of GAIA.



2004-5: second breadboard of the laser metrology device for monitoring the basic angle of GAIA.



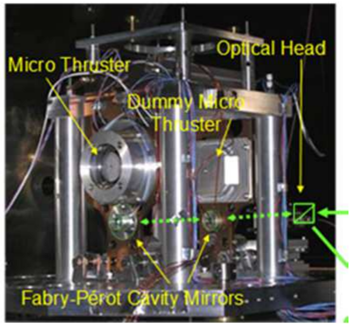
2003-5: breadboard of laser metrology system for the co-phasing of an optical interferometer in visible light.

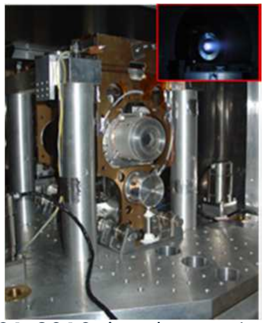
2018: Bifocal metrology

- Accurate projective metrology able to determine the relative position of two objects in 6 degrees of freedom
- Compact optical head
- No internal mechanism
- Provides 6 d.o.f. with better accuracy than standard projective metrology
- Suitable to real time applications
- Patented by TAS-I DESI (3 patents)

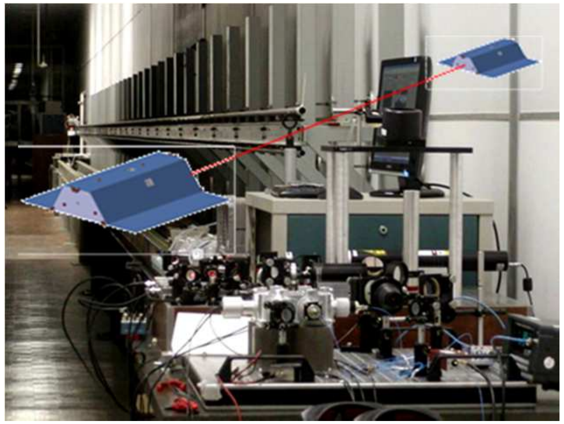
Optics and Optical Metrology (3/4)

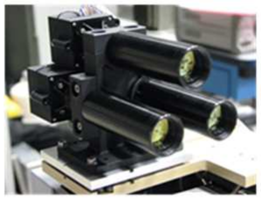
Past optics projects performed by the Optics Unit of DESI

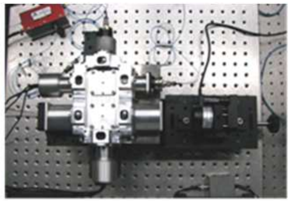




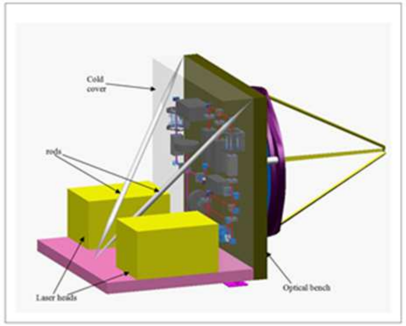
2001-2010: implementation & operation of the Nanobalance for micro-propulsion test (0.1 μN res).



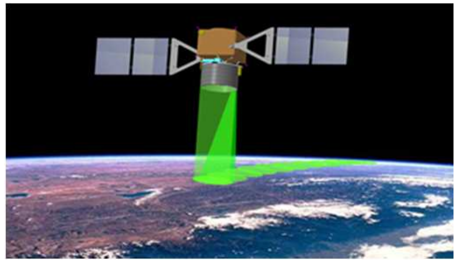




2007-2009: breadboard of the laser interferometer & auxiliary metrology for the Next generation Gravity Mission



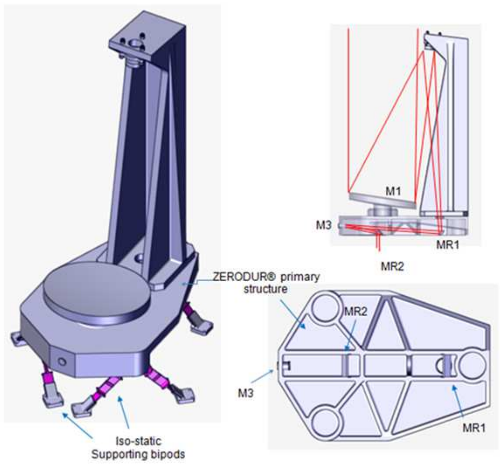
2003-4 Study of monostatic and bistatic Lidads for EarthCARE.



2011-2012 Study of different laser ranging techniques for altimetry.

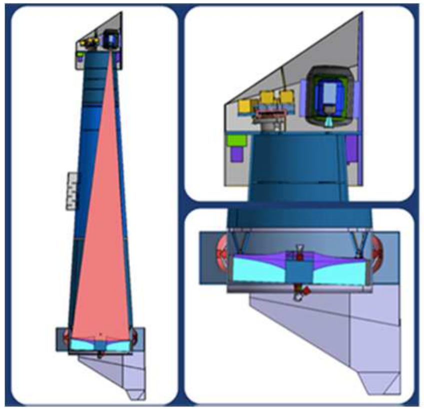
Optics and Optical Metrology (4/4)

Metrology Telescope Design for LISA



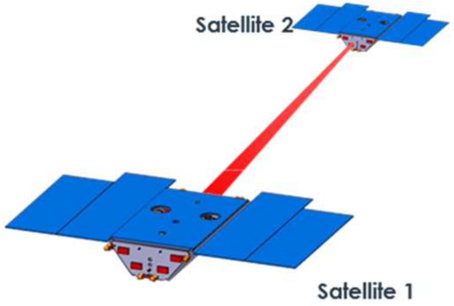
2017-18 Metrology Telescope Design for LISA
development of a preliminary design of the telescope for the LISA mission:

- Development of a mathematical model of the wavefront
- Pointing and tracking architecture
- Preliminary opto-mechanical design
- Preliminary straylight analysis
- Development plans



2016-18 On board Metrology for Atehna
Measure the lateral and longitudinal position of the X-ray detectors (telescope focal length = 12 m)
Requirements:

15 μm in lateral position
20 μm longitudinal position

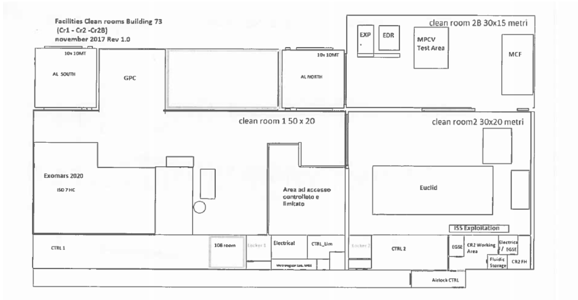


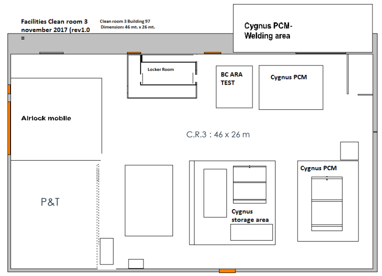
Acquisition and Pointing Metrology System for NGGM

Detect and measure the direction of a remote satellite (100 km distant) for driving the pointing of an interferometer laser beam.
Requirements:

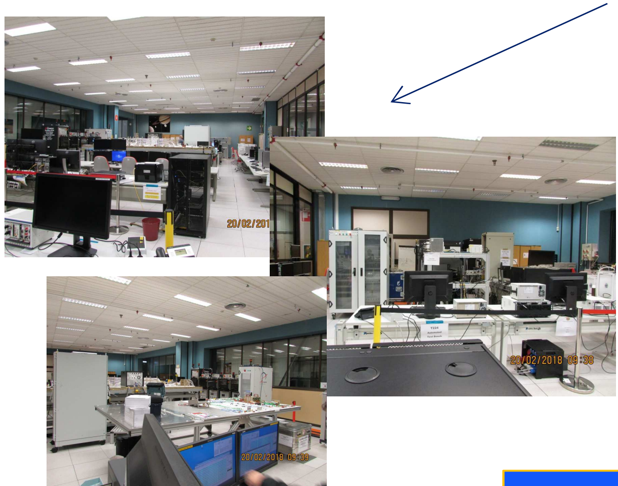
- Measurement accuracy <100 μrad (goal <10 μrad).
- Measurement error spectral density <1 μrad/√Hz from 1 to 100 mHz.

AIT – Facilities Turin Site

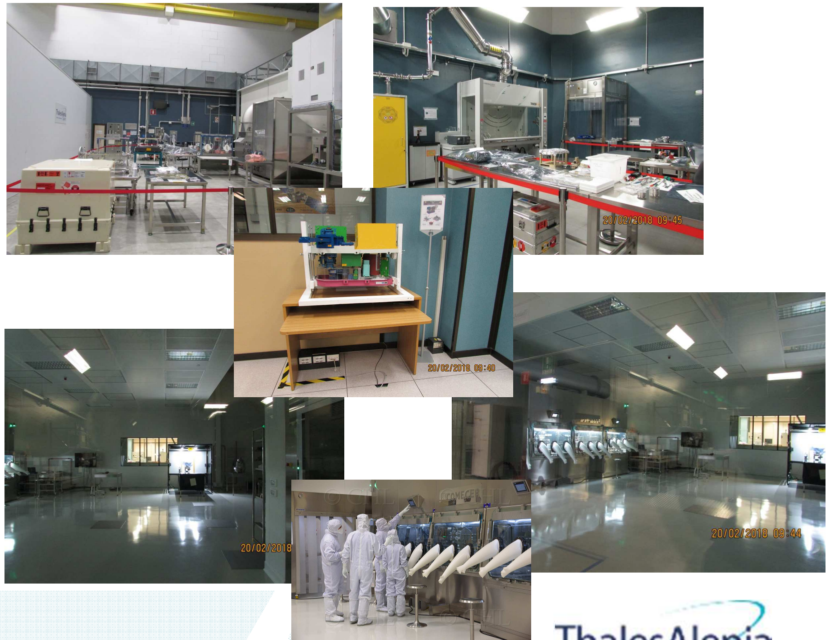




Control Rooms



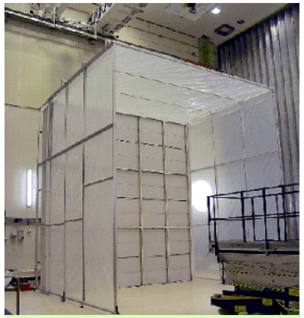
Special Integration Facilities



Turin Site- ‘facilities’ for test activities

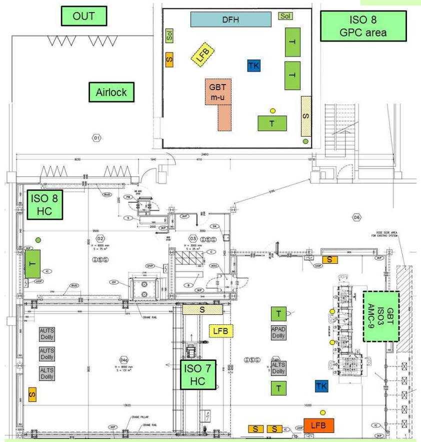

ISO 7HC


Sterile, Molecular Contamination controlled ISO 3

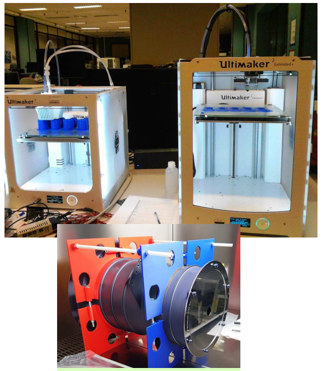

ISO 5 portable tent

ISO 7 HC Portable Tent

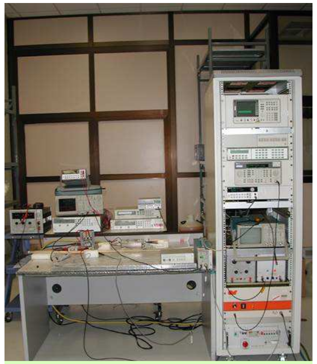

Magnetic coil facilities



’ExoMars’ Facility



3D printers

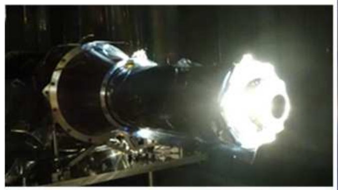

EMC test equipment

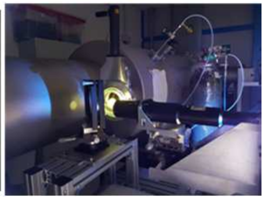

Thermal chamber

Recent delivered Programs

METIS

2017 - Flight model of the Metis coronagraph, delivered for integration on Solar Orbiter



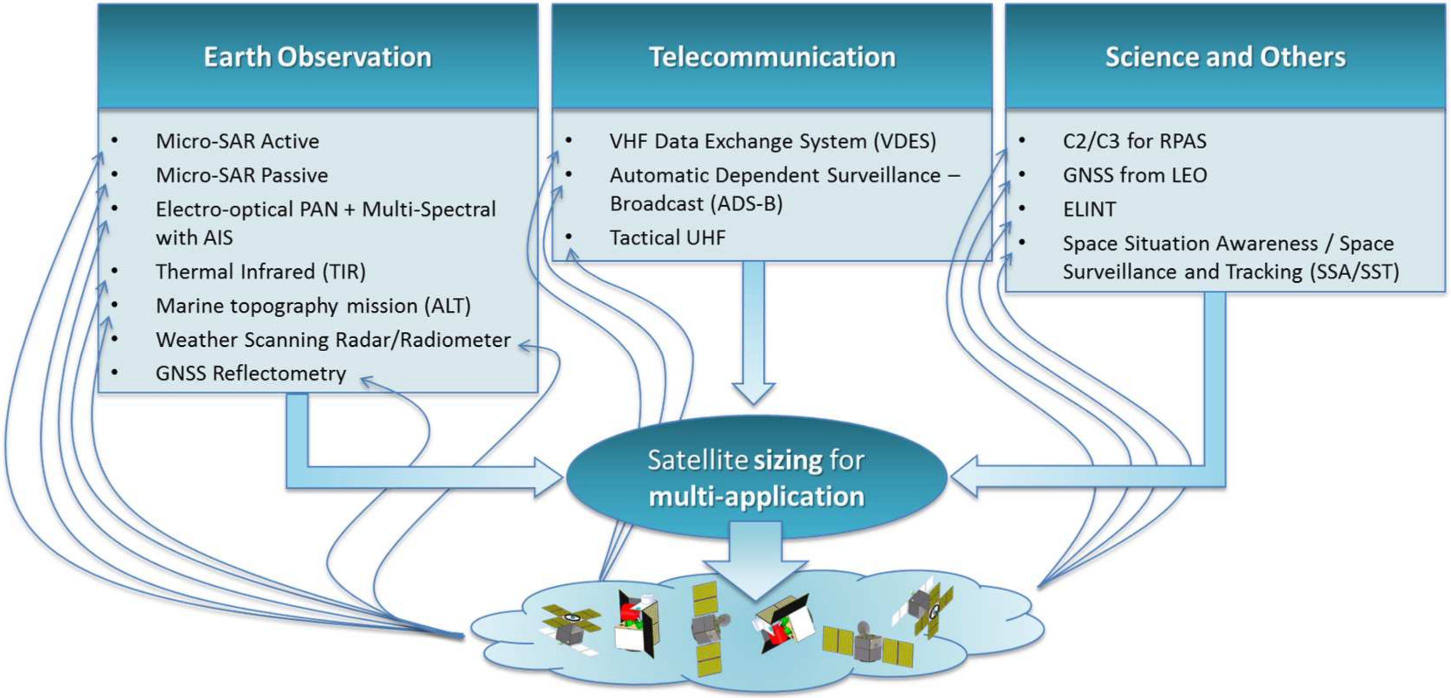


BepiColombo

2018 - completion of B-C AIT in TASI
- TASI responsible for the Design Electrical, Communications and Heat Shield S/S

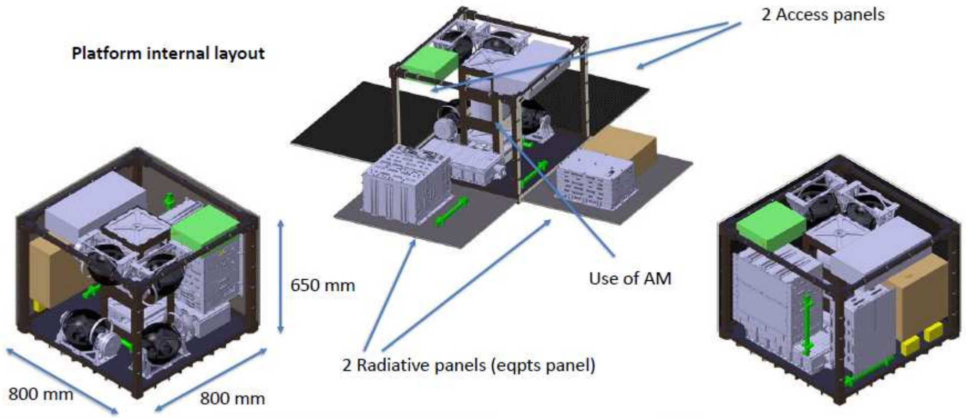
PLATiNO MULTI-MISSION SIZING SCENARIO

Platform design *based on a* ***worst case set of requirements*** *to ensure* ***multi-mission compatibility***



Architecture and building blocks: Physical Configuration

- Fully modular approach
- Dedicated Payload Supporting Structure
- Modular solar array layout
- Platform mass 80-120 kg
- Payload mass up to 80 kg
- S/C launch mass < 200 kg
- About 50 % of available volume for Payload



P/L max mass	Up to 80 kg
P/L power cons.	Up to 100 W OOA, 750 W Peak
P/L allowable volume	Up to 800x800x550 mm³
S/C launch mass (kg)	<200 kg
S/C envelope LxWxH	800 x 800 x 1200 mm³
S/C power gen.(W)	Up to 1.2 kW Peak
Battery capacity	Li-Ion, 1.2 kWh
Pointing accuracy	<0.01°, 3-axis stabilization

Pointing knowledge	0.006°
Slew rate	Up to 5 °/sec
Delta-V	Up to 1 km/s
TT&C	S-band, up to 5 Mbps
PDHT data rate	X-band, up to 500 Mbps
PDHT data storage	Up to 1 Tb
S/C redundancies	Full-cold / partially hot P/F red.
Lifetime	3 to 5 years

Outline

1. *TAS Heritage in Planetary Missions*
2. *The Contribution*
3. *TOLIMAN Needs*
4. *Available Key Technologies*
   a. *Attitude Control*
   b. *Thermo Machanical Stability*
   c. *Metrology*
   d. *AIT*
   e. *Ground Centre – ALTEC*
5. *Conclusions*

CONCLUSIONS

- Heritage and competence developed in TAS: a long history
- Key technologies for complex science missions available and successfully implemented
- TAS Dedicated Facilities and Tools well suitable for analyses, integration and testing
- Solutions identified in terms of platforms and dedicated components such as metrology, GNC, Thermal control, pointing mechanism….