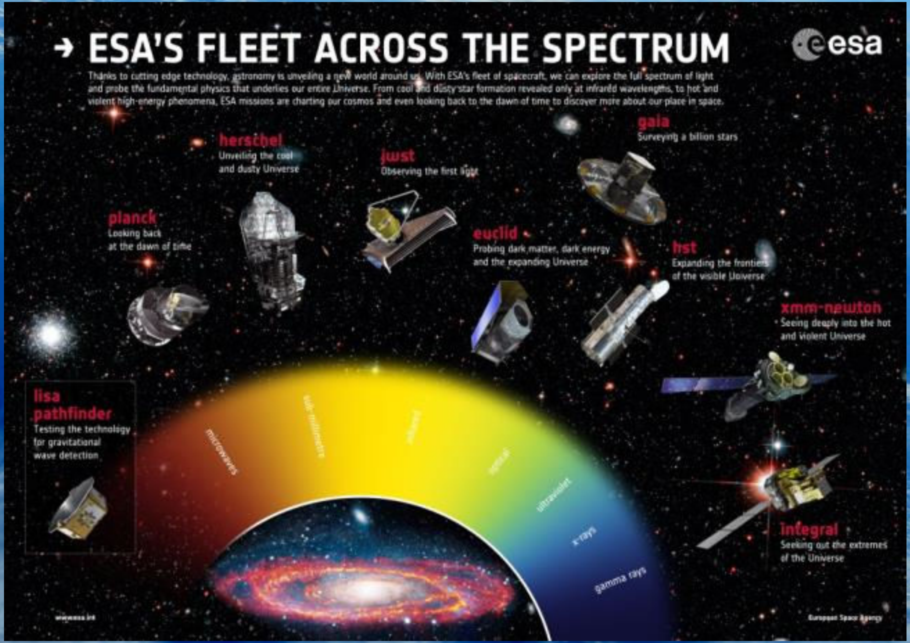
Overview of ESA Science Missions

Vulcano Workshop 2018

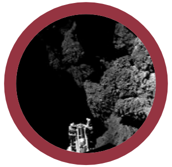


Carla Signorini
European Space Agency
ESTEC, Noordwijk (NL)

OUTLINE

- ESA introduction
- The Cosmic Vision and the Science Program
- Science missions under implementation
- Future scientific missions
- Planetary exploration mission: EXOMARS

ESA facts and figures



space science

human spaceflight

exploration

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

earth observation

navigation

telecommunications

operations

technology

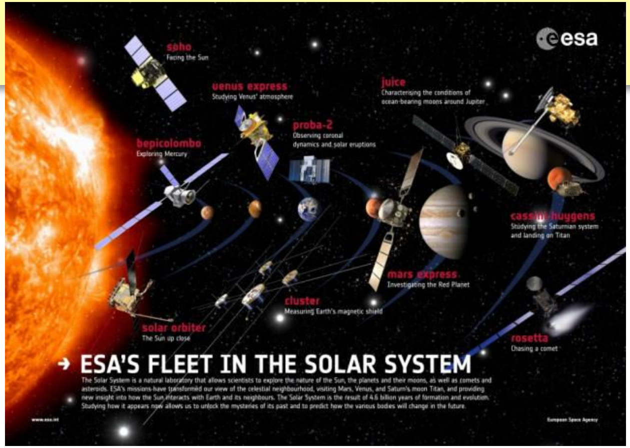
space transportation

COSMIC VISION

- Introduced in 2005
- Covers the ESA Science Programme till 2035
- 4 FUNDAMENTAL QUESTIONS

- What are the conditions for planetary formation and the emergence of life?
- How does the Solar System work?
- What are the physical fundamental laws of the Universe?
- How did the Universe originate and what is it made of?

Sun	Solar System	Astrophysics	Fundamental Physics
Implementation			
[2020] Solar Orbiter	[2022] JUICE [2018] BepiColombo	[2026] PLATO [2020] Euclid [2020] JWST [2018] CHEOPS	
Operations / Post-Operations			
[2009] PROBA2 [1995] SOHO	[2016] ExoMars TGO & Schiaparelli [2005] Venus Express [2004] Rosetta [2003] Mars Express [2003] Double Star [2000] Cluster [1997] Cassini-Huygens	[2013] Gaia [2009] Planck [2009] Herschel [2002] INTEGRAL [1999] XMM-Newton [1990] Hubble	[2015] LISA Pathfinder



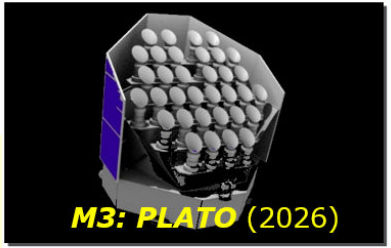
Science Programme

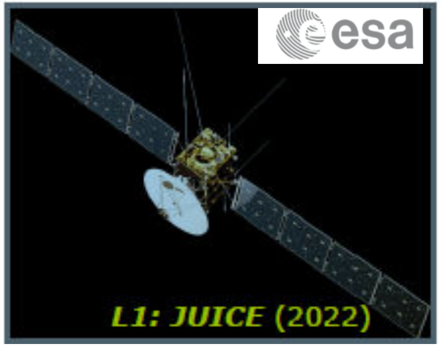
Yearly budget (YB) = ~510 M€

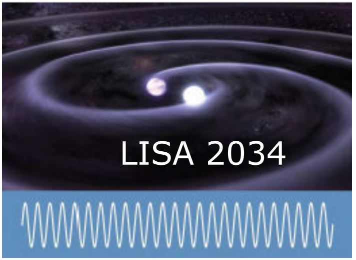
- **L-missions**: large European led flagship missions; ESA cost of ~2 YB.
  L1: JUICE (2022), **L2**: ATHENA (2031) and **L3**: LISA (2034)
- **M-missions**: provide the programme with flexibility; ESA led or implemented through international collaboration. Cost to ESA of ~ 1 YB; launch one every 3-4 years
  M1:Solar Orbiter, **M2**:Euclid, **M3**:PLATO, **M4**:ARIEL, **M5:** Theseus, Spica and EnVision (Phase 0 in 2018)
- **S-missions**: small missions allowing national agencies to play a leading role in missions, ~ 0.1 YB
  S1: CHEOPS
- **O-missions**: missions of opportunity; led by other agencies (XARM, LiteBird, EP, WFIRST,..) or joint missions: ESA-CAS mission SMILE
- **F-Missions**: cost cap to ESA ~150 M€ (~0.3 YB); possible call Q3/Q4 2018
  (300-500kg S/C, ~ 6 years from selection to launch)

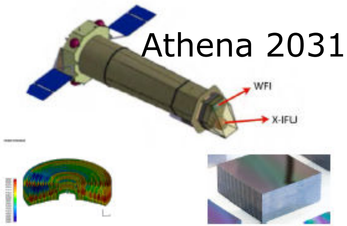
Mission Calls

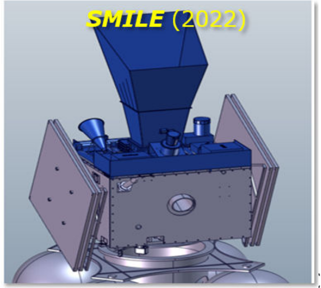
- M1/M2/L1 (2007) → Solar Orbiter (M1), Euclid (M2), Juice (L1)
- M3 (2010) → PLATO
- S1 (2012) → Cheops
- L2/L3 WP (2013) → The hot and energetic Universe & The gravitational Universe
- L2 (2014) → ATHENA
- M4 (2015) → ARIEL, THOR & XIPE (ongoing MSR)
- S2 (2015) → SMILE (ESA, CAS)
- M5 (2016) → Theseus, Spica and EnVision→ Phase 0 in 2018
- L3 (2017) → LISA
- Future calls F1 (2018, TBC), ~~M6~~, M7 (?)



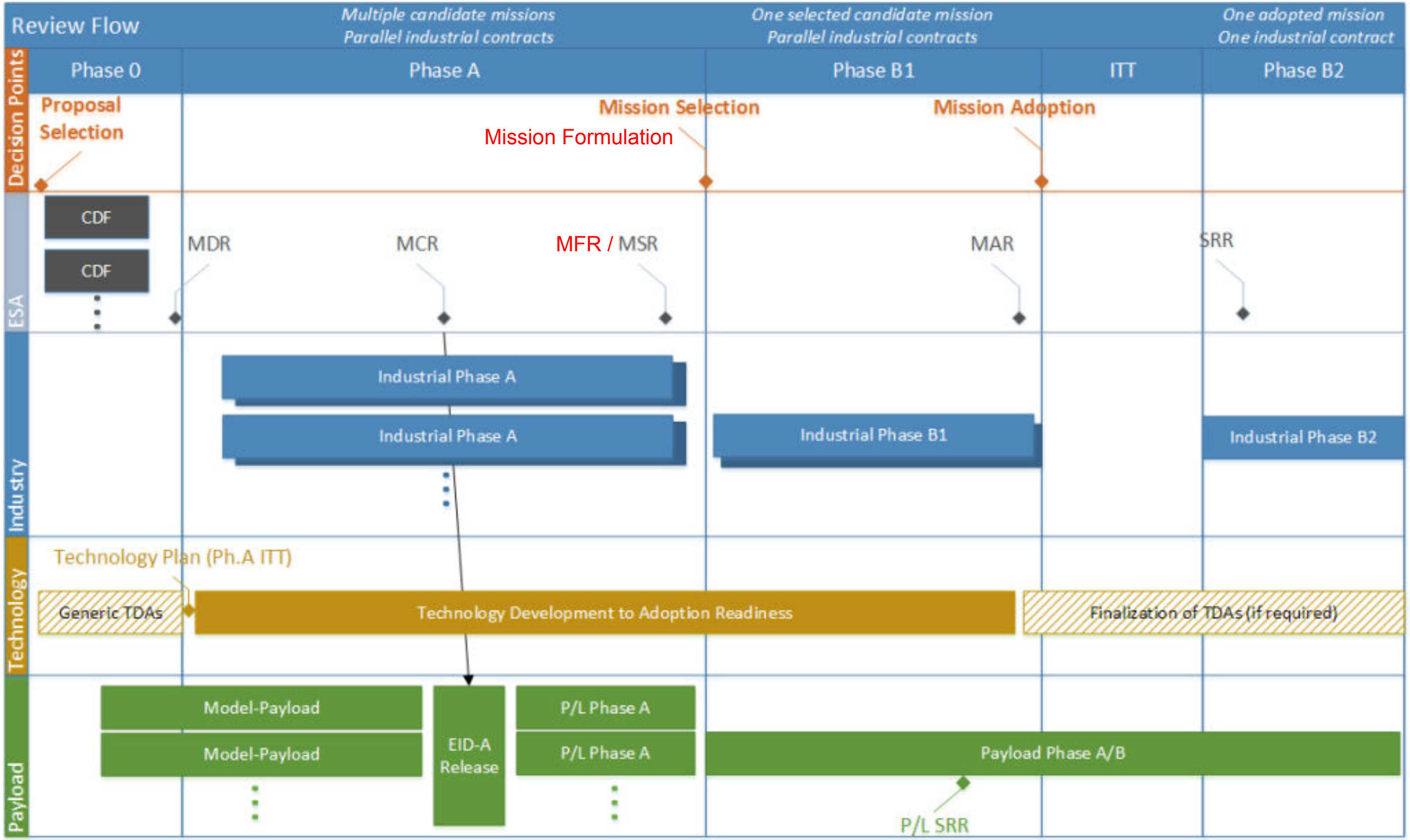




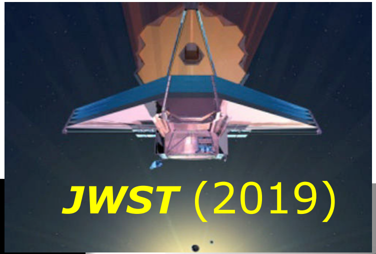


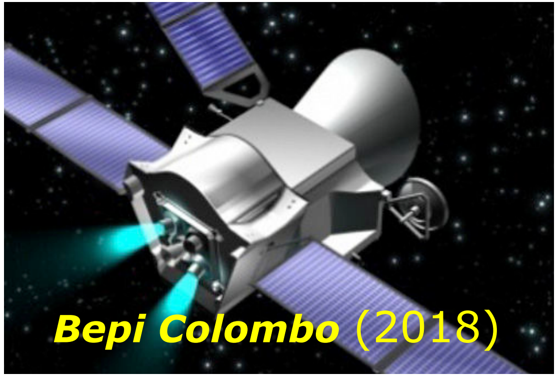


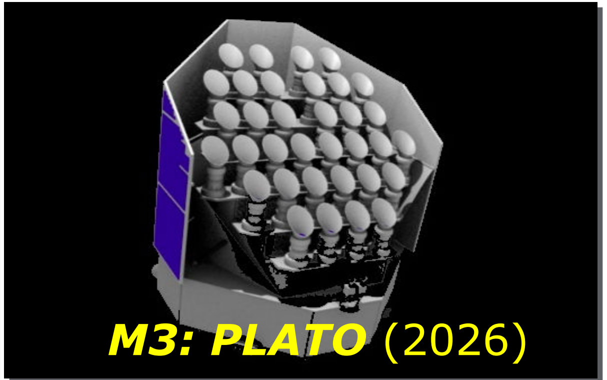
Future Missions: The Process



Science Missions in Implementation

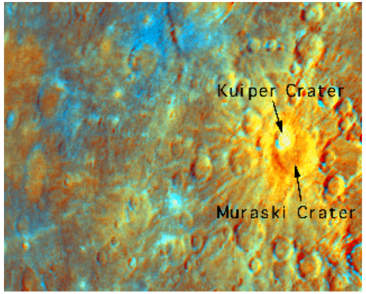




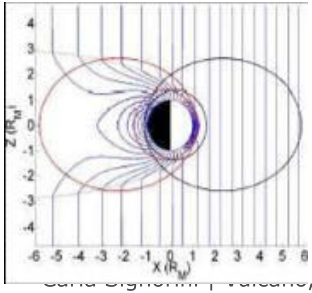


BepiColombo Scientific Objectives

- Origin and evolution of a planet close to the parent star
- Mercury as a planet: form, interior, structure, geology, composition and craters
- Mercury's vestigial atmosphere (exosphere): composition and dynamics
- Mercury's magnetized envelope (magnetosphere): structure and dynamics
- Origin of Mercury's magnetic field
- Test of Einstein's theory of general relativity

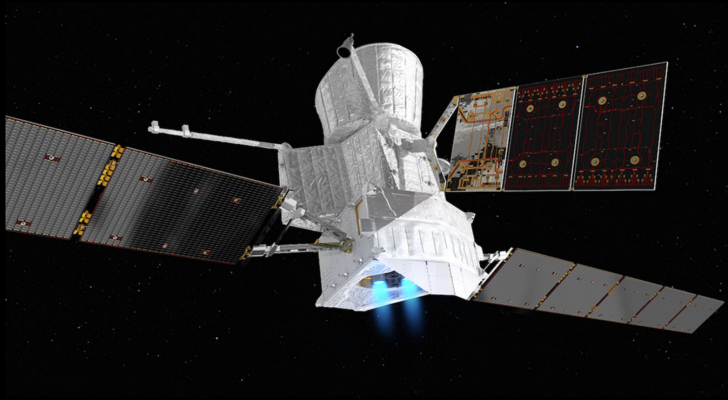


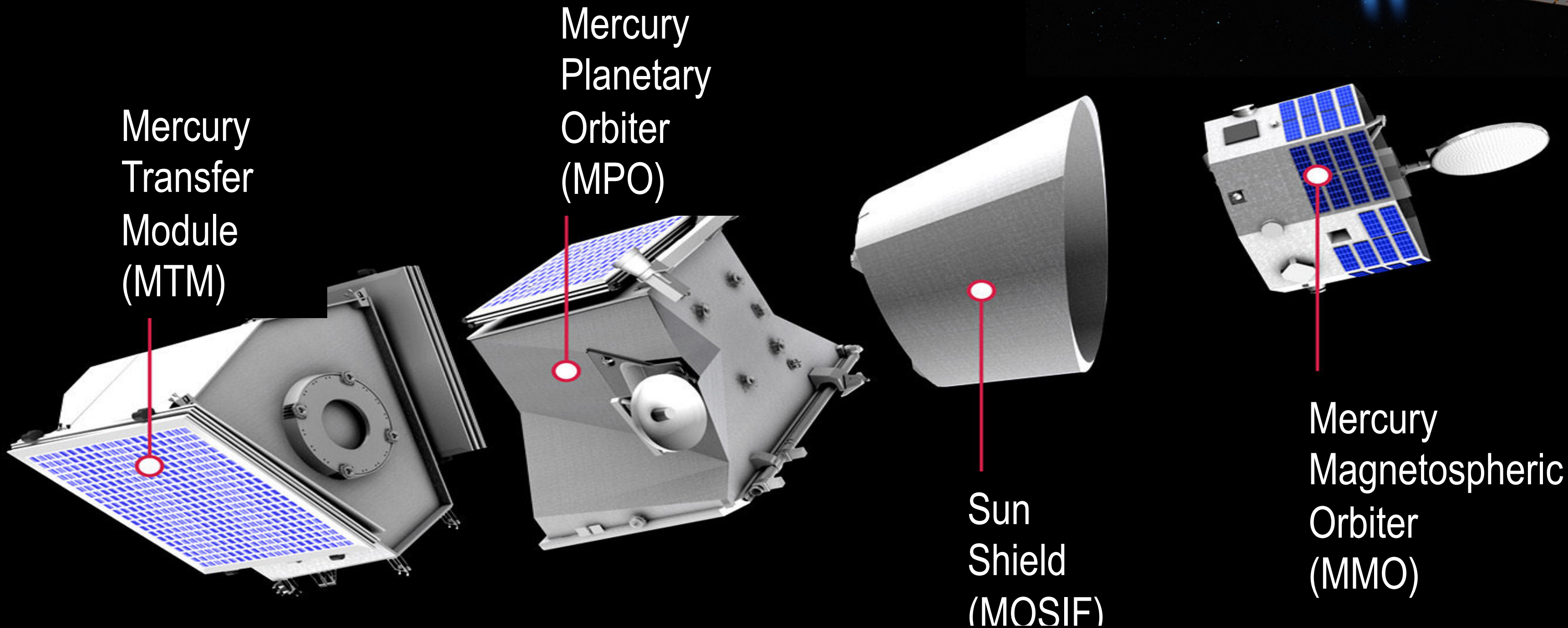
(Courtesy of Mark Robinson and Paul Lucey.)



BepiColombo

Spacecraft Configuration

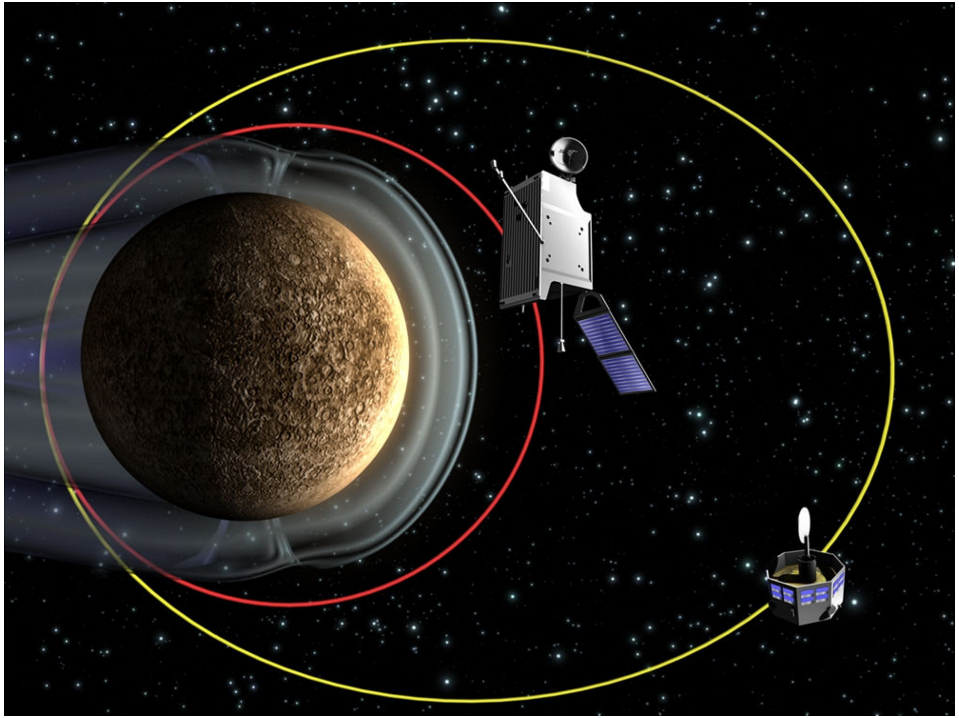




Mercury Composite Spacecraft (MCS)

BC Mission:

- **Launch**: October 2018 by Ariane 5 ECA
- **7.2 year cruise to Mercury by electric propulsion**
- 1 Earth-, 2 Venus- and 6 Mercury- gravity assists; 8.9 Billion kilometers
- **Arrival at Mercury: December 2025**



Mercury Planetary Orbiter (MPO)

focus on planet- surface and- interior science

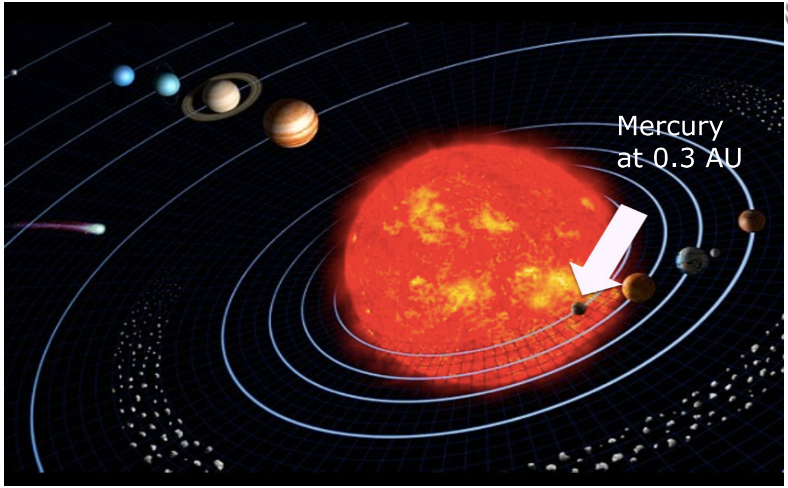
built under ESA responsibility

Mercury Magnetospheric Orbiter (MMO)

focus on the planetary environment

built under JAXA responsibility

BC Mission



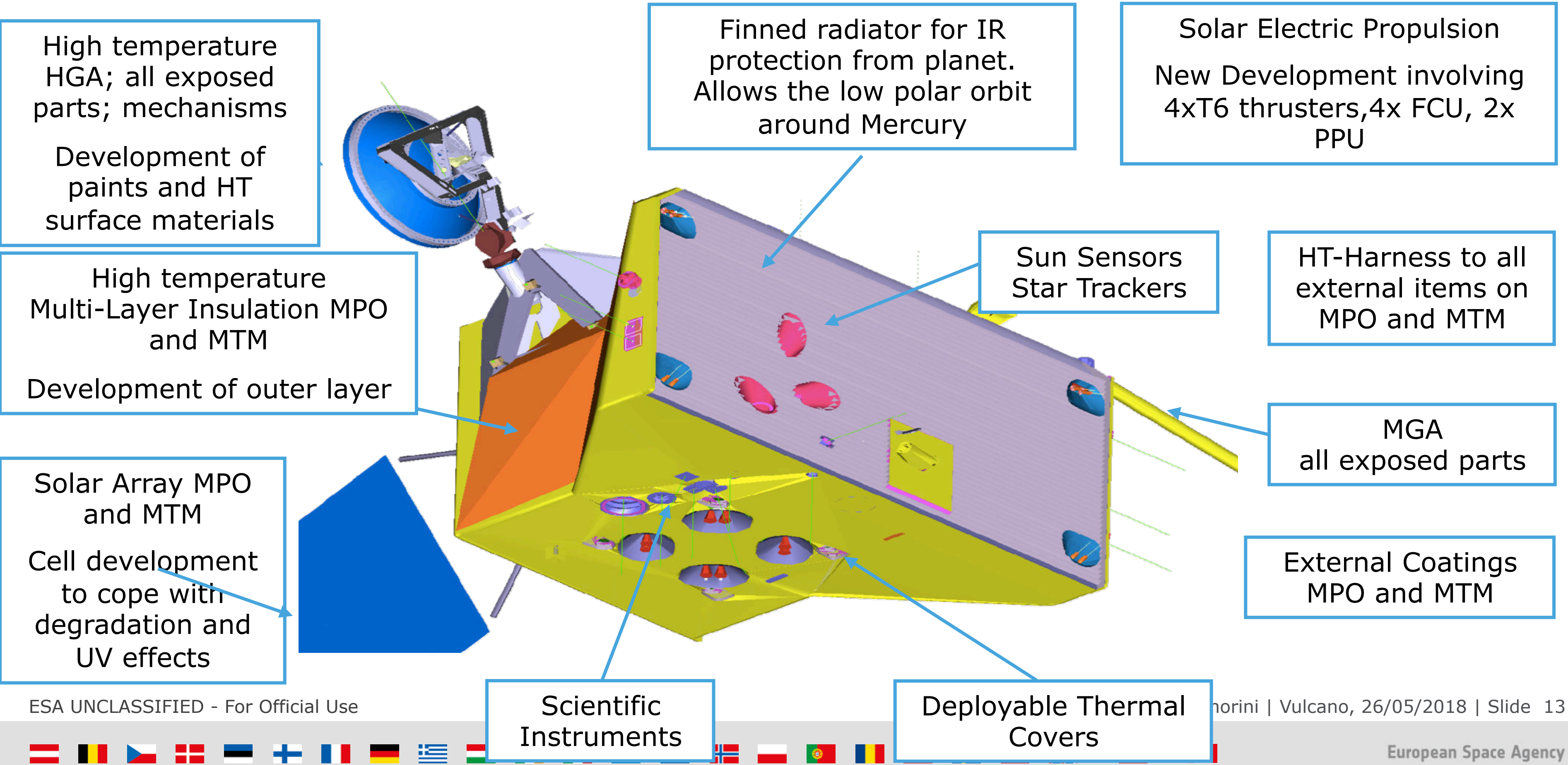
Main driving requirements:

- Dual spacecraft mission to Mercury
- Global coverage => nadir pointing
- High resolution => low orbit altitude

Main challenges:

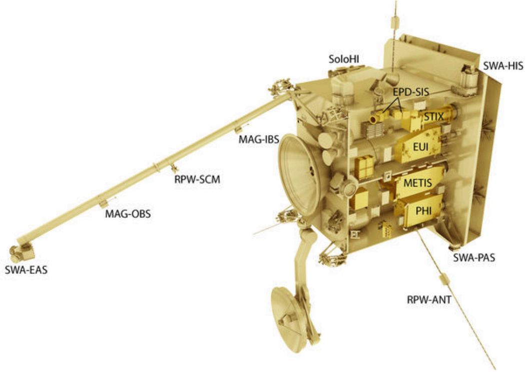
- 10 times Solar radiation and surface temperatures up to 450°C
- 5 of 6 spacecraft sides and antennas in full Sun and Mercury infra-red
- Large amount of energy required, requiring gravity assists and electric propulsion
- High percentage of hardware is specific BepiColombo development
- Complex configuration and tight mass constraint

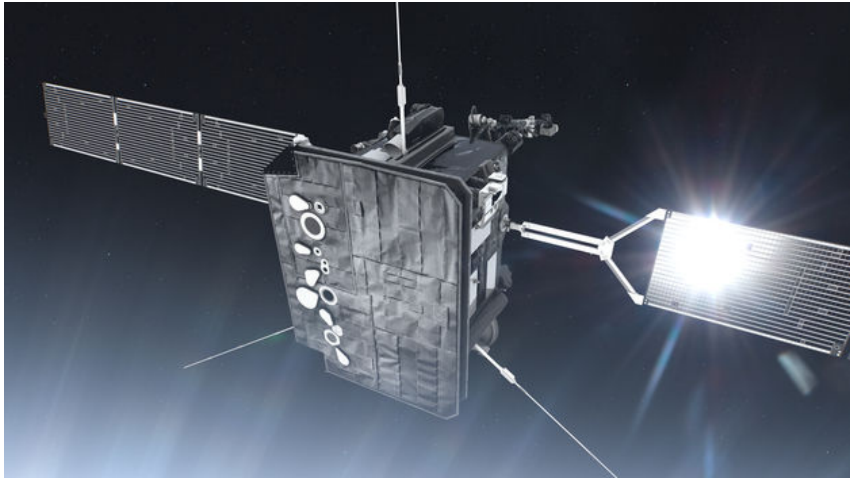
BepiColombo – Technology Challenges



SOLAR ORBITER

The *in-situ* instruments:
- **Energetic Particle Detector**
- **Magnetometer**
- **Radio and Plasma Waves**
- **Solar Wind Plasma Analyser**

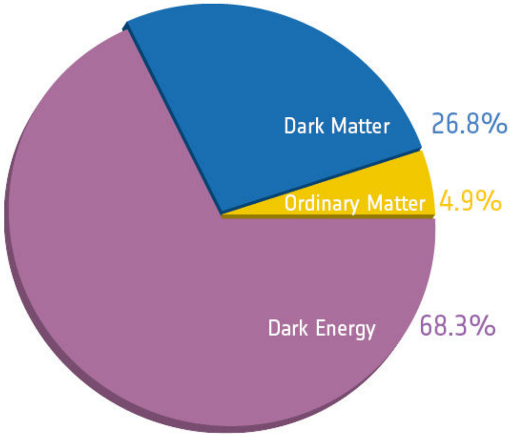


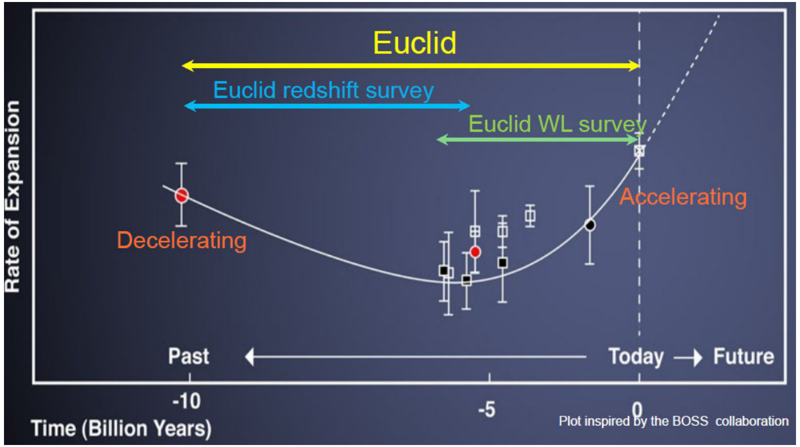


The remote-sensing instruments:
- **Extreme Ultraviolet Imager**
- **Coronagraph (METIS: INAF)**
- **Polarimetric and Helioseismic Imager (PHI: Max Planck)**
- **Heliospheric Imager**
- **Spectral Imaging of the Coronal Environment.**
- **X-ray Spectrometer/Telescope**

Euclid mission: probing 'dark matter', 'dark energy' and the expanding Universe

- Optical-NIR wide field observations can shed new light;
- Large scale survey of cosmic structures;





- Determine the dark energy equation of state, pressure over density, as a function of cosmic scale a;
- Determine the growth rate of structure formation which depends on the average density;
- Test General Relativity with a cosmological constant and cold dark matter (ΛCDM model)

Euclid Design Concept → *challenges*

- **Two complementary dark energy probes**: galaxy clustering and weak lensing;
- Minimum survey area of 15,000 deg2 (36% of the total sky);

→ **6 year nominal mission**

Weak Lensing → VIS imager + NIR imaging-photometer

- Shapes and shear of galaxies with a density of >30 galaxies/arcmin^2

→ ***limited by backgrounds & straylight***

- Minimum Systematics $\sigma^2_{sys} < 10^{-7}$, very high image quality, high stability
- Redshift range 0<z<~2, accuracy dz/(z+1) < 0.05 → ***need ground based g,r,i,z photometry***

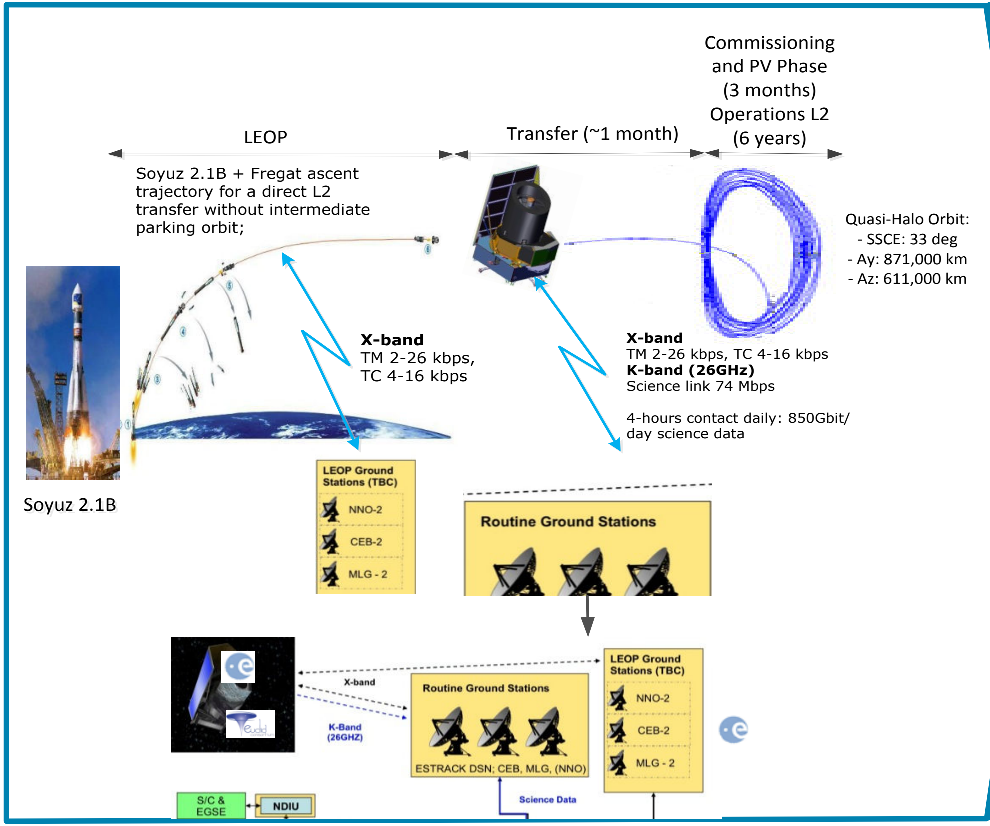
Galaxy clustering → NIR slitless spectrometer

- Redshifts for >1,700 galaxies/deg^2

→ ***purity & completeness limited by background level and source confusion***

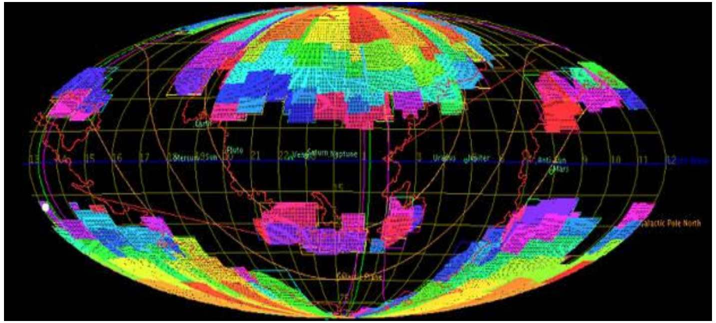
- Redshift range 0.9< z <1.8, accuracy dz/(z+1) < 0.001
- Same area as for WL→ line Flux limit < 2 10^{-16} erg $cm^{-2}s^{-1}$.

The Euclid Concept of Operations Fact Sheet

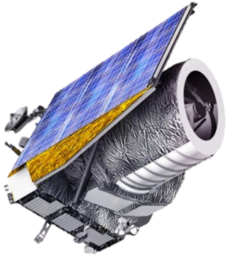


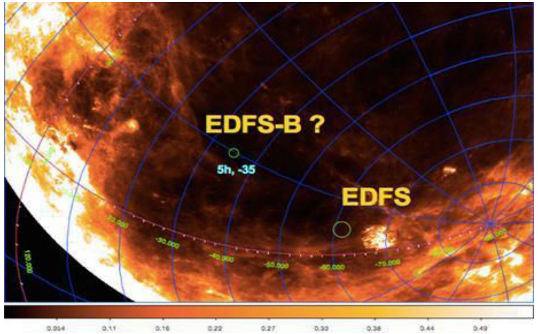
- **Launcher**: Soyuz 2.1B
- **Launch**: 2021-2
- **Orbit**: Quasi-Halo Orbit at L2
- **Data volume**: 850 Gbit/day
- **Mission Duration**: 6 years

The Euclid Survey Fact Sheet



Sky covered by Euclid Mission at completion (6 years) - Courtesy EC Consortium/ESA/Science Survey Working Group





Candidate Deep Field Locations- Courtesy EC Consortium/ESA/Science Survey Working Group

Euclid Wide Survey

15,000 deg^2

(Step and stare with single fields of 0.5 deg2)

	Imaging				Spectroscopy
Δλ	VIS (500-900 nm)	Y (920-1146nm)	J (1146-1372 nm)	H (920-1146 nm)	1250-1850 nm
Sensitivity	m_{AB} = 24.5 (10σ ext source)	m_{AB} = 24 (5σ point source)	m_{AB} = 24 (5σ point source)	m_{AB} = 24 (5σ point source)	3 10^{-16} erg cm^{-2} s^{-1} (3.5σ unresolved line flux)
Sampling/ Resolution	0.1″	0.3″	0.3″	0.3″	R > 380

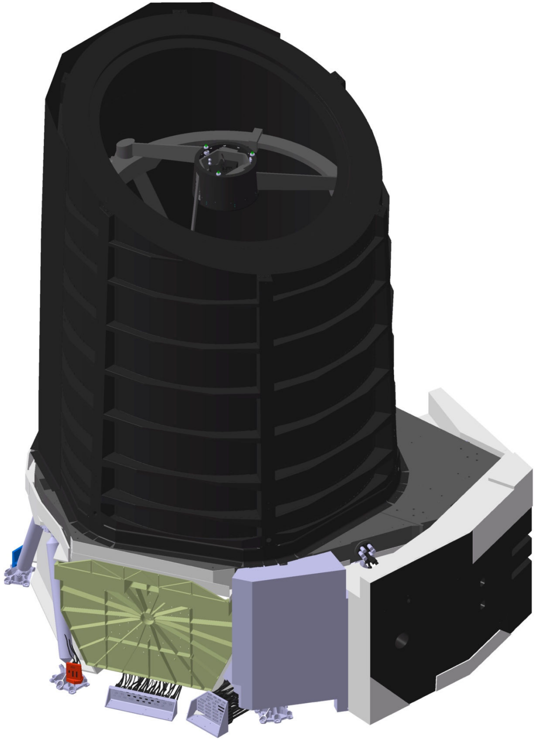
Euclid Deep Survey

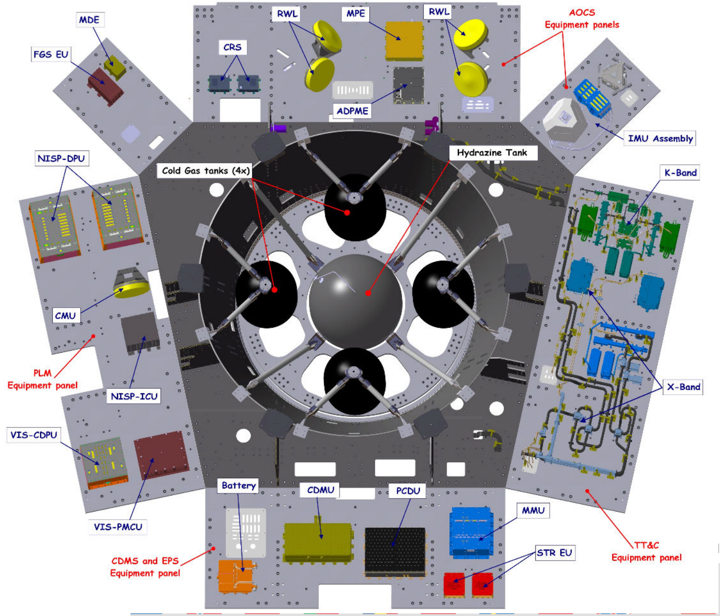
40 deg^2

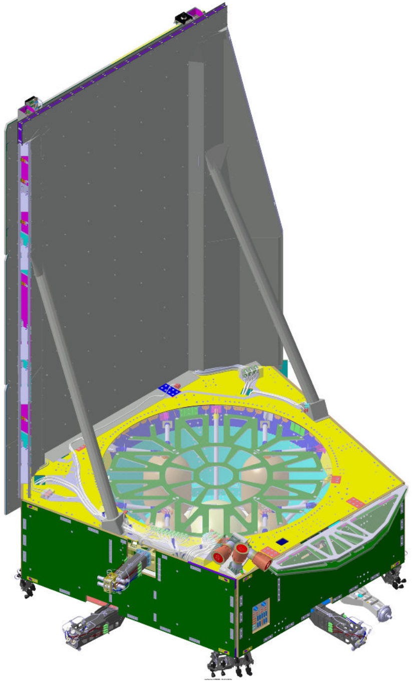
(In at least 2 patches of > 10 deg2)

	Imaging	Spectroscopy	
Δλ	VIS / Y / J / H (same as for wide survey)	920-1300 nm	1250-1850 nm
Sensitivity	2 magnitudes deeper than wide survey	6 10^{-17} erg cm^{-2} s^{-1} (3.5σ unresolved line flux)	5 10^{-17} erg cm^{-2} s^{-1} (3.5σ unresolved line flux)
Sampling/ Resolution	Same as wide survey	R > 260	R > 380

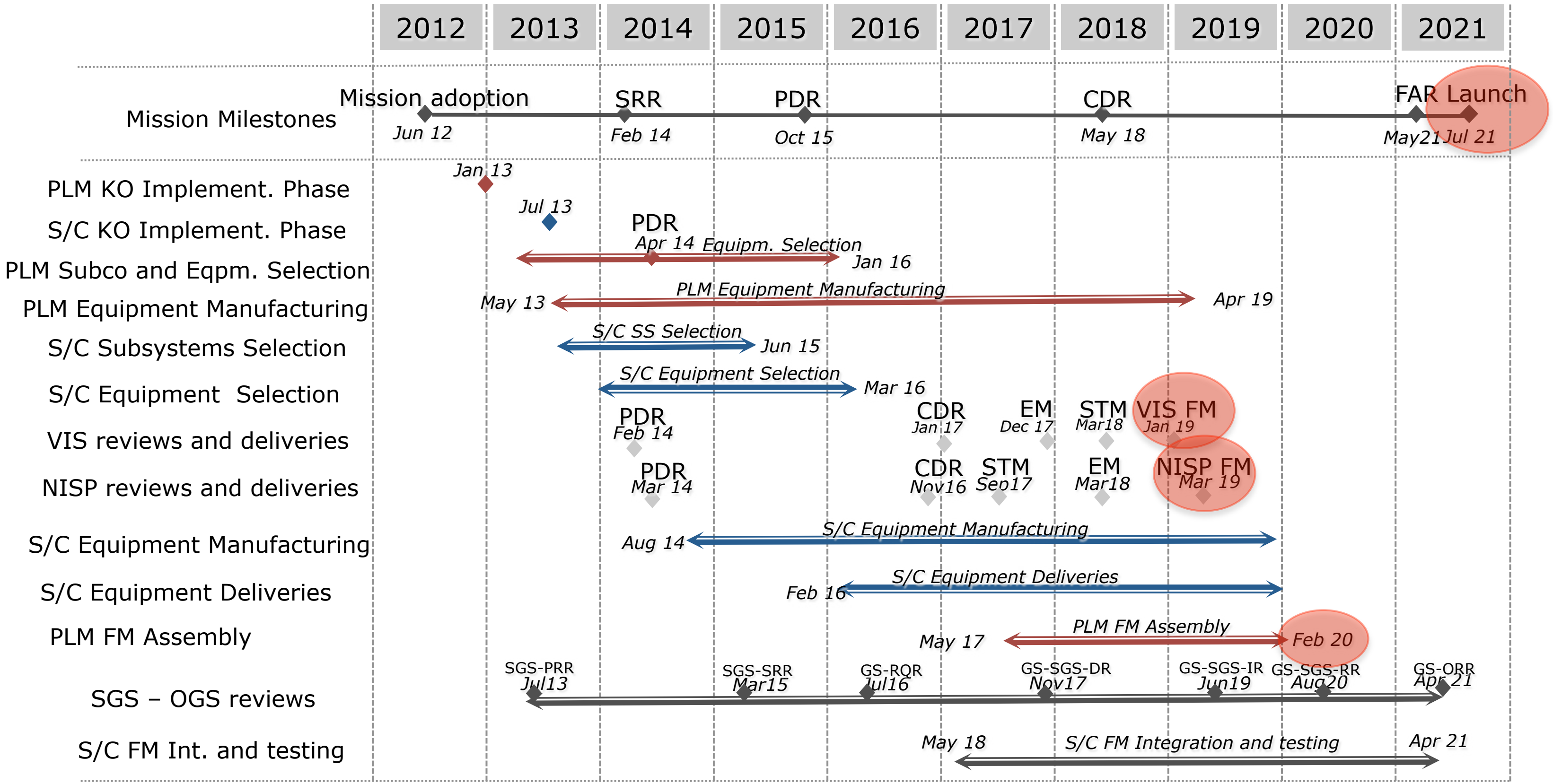
Payload and Service modules







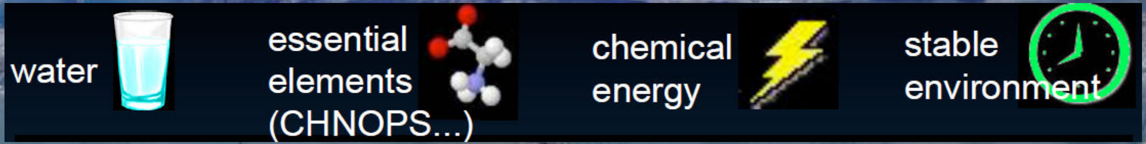
Euclid Schedule: need dates driven Launch July '21



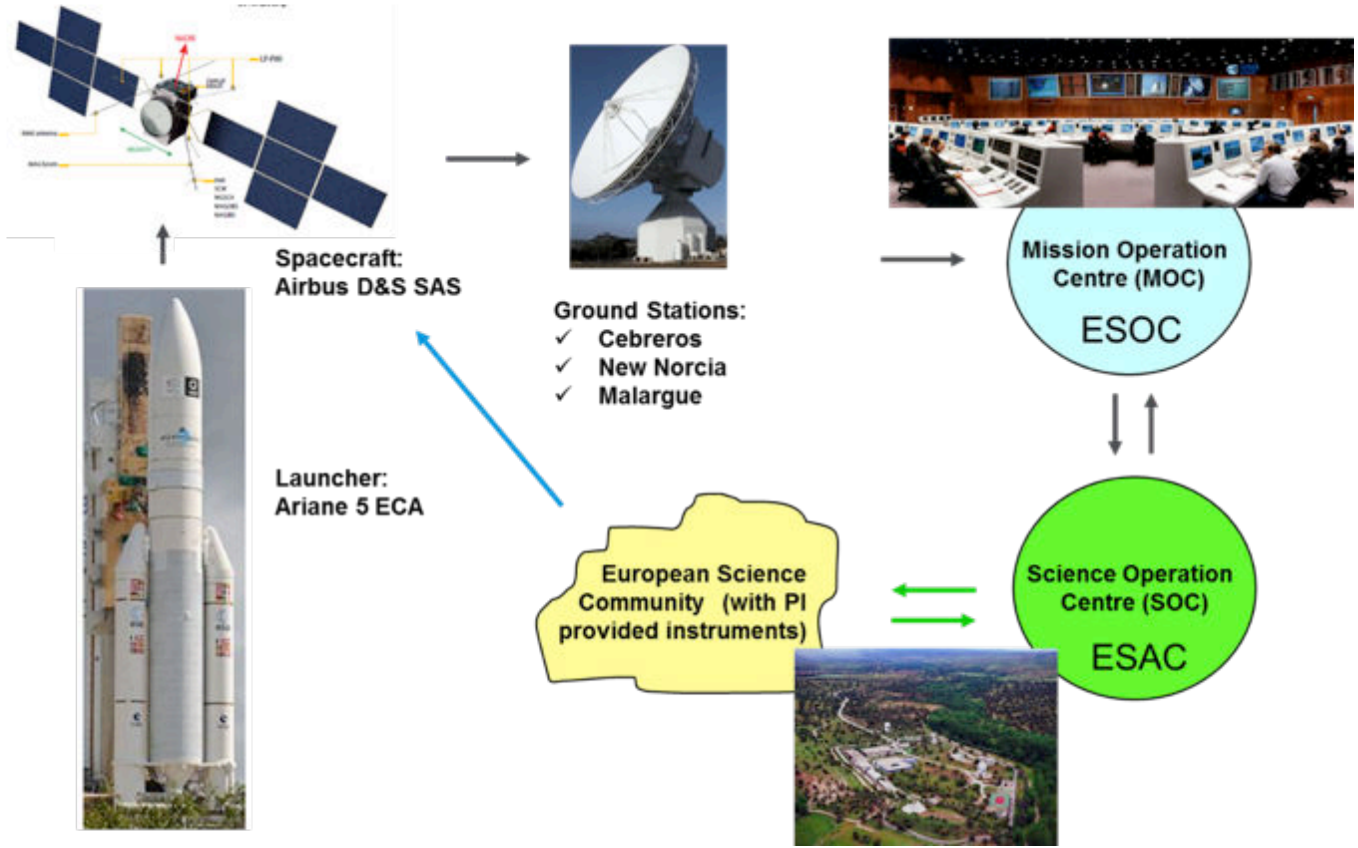
JUICE Science Objectives

- ❑ Exploration of the Jupiter system
  - ➢ Jovian atmosphere
  - ➢ Jovian magnetosphere
  - ➢ Jovian satellite and ring systems

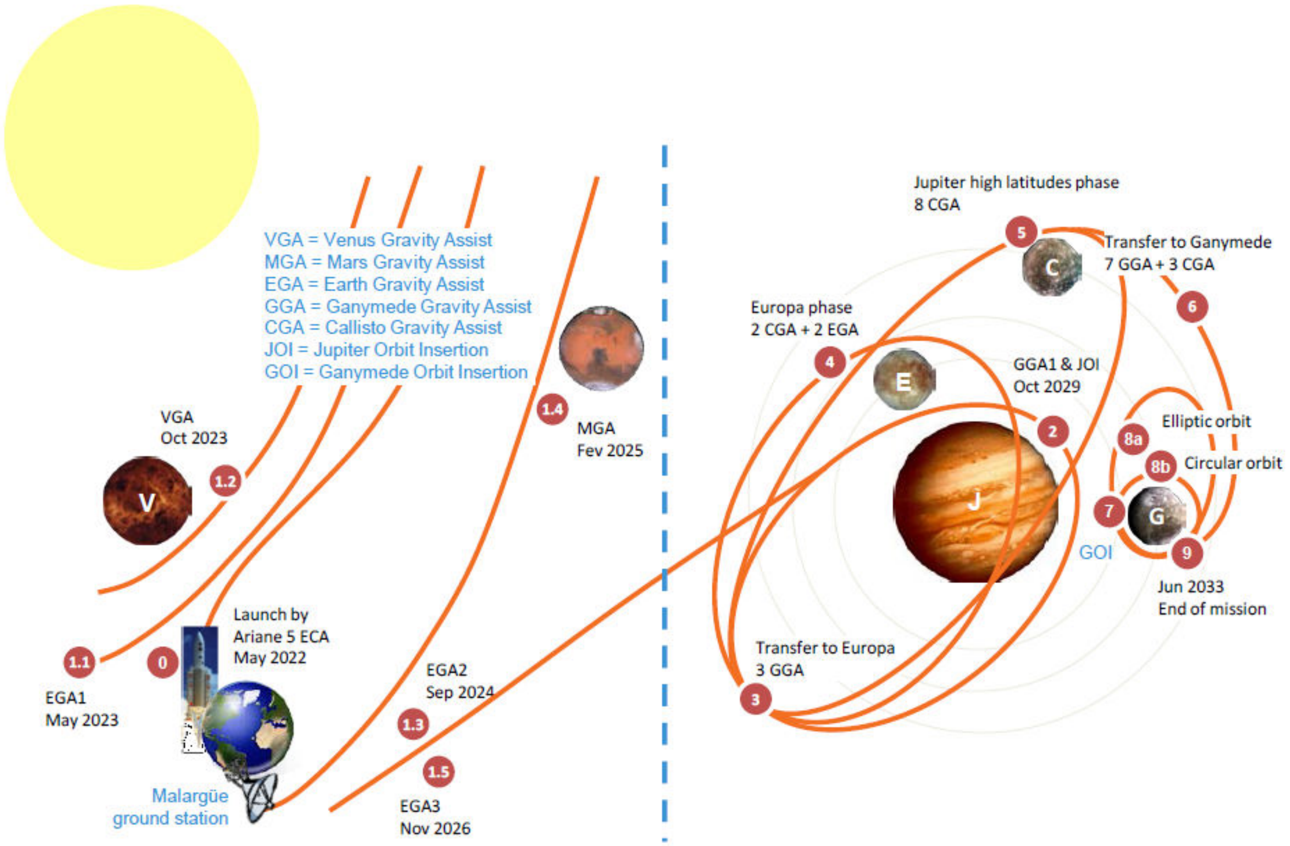
- ❑ Exploration of habitable worlds
  - ➢ Ganymede as a planetary object and possible habitat
  - ➢ Europa’s recently active zones
  - ➢ Callisto as a remnant of the early Jovian system

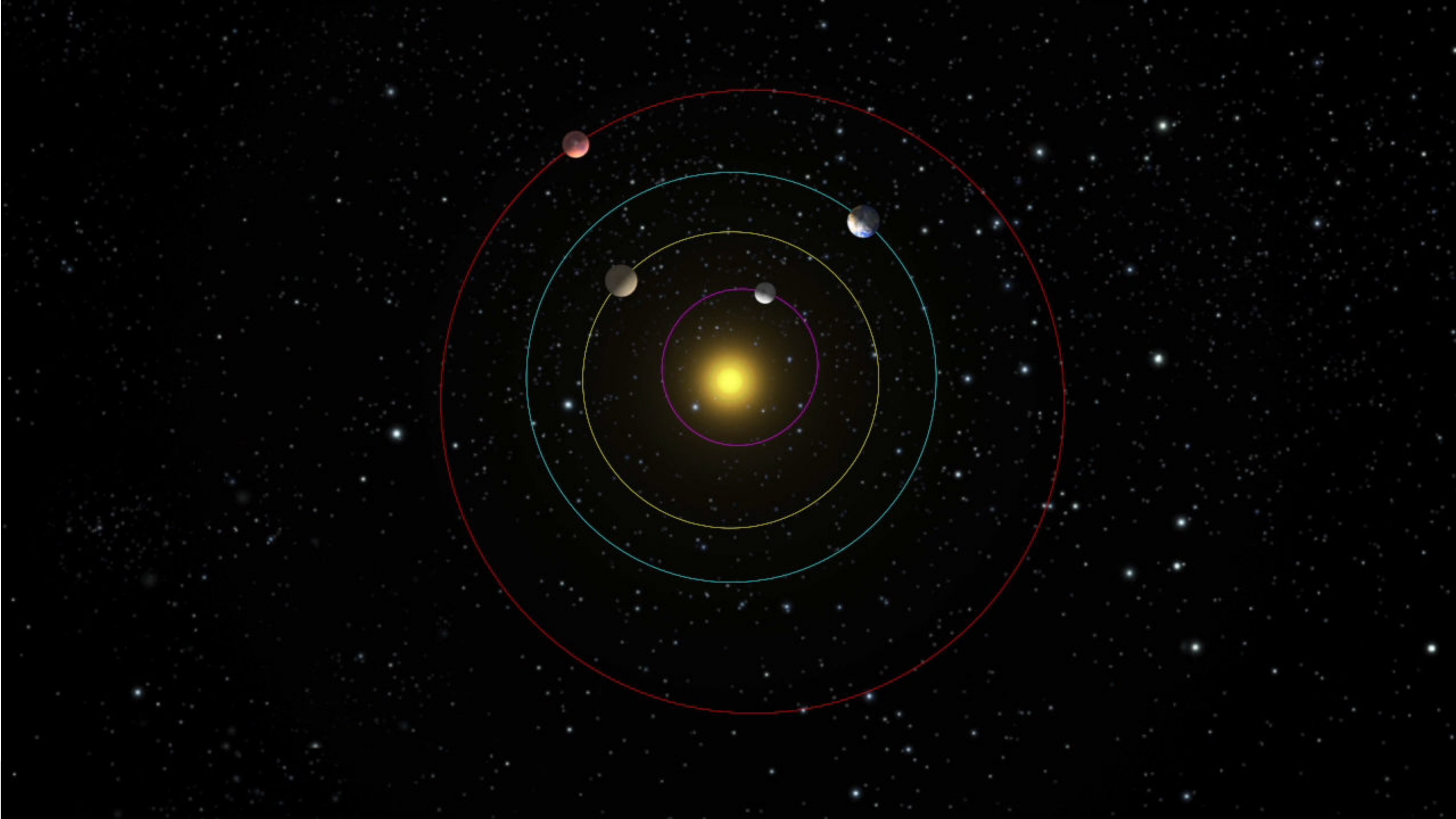


Elements of the JUICE program



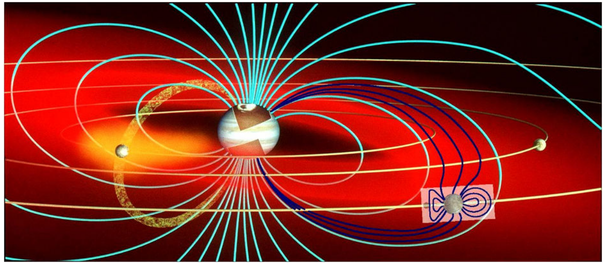
Mission overview





JUICE design drivers (1/2)

- Power availability
  - Jupiter is at 778.5 million km from the Sun
- High and low temperatures
  - Very hot around Venus fly-by (0.64 AU) → 3.3 kW/m^2 → solar array at 150 C
  - Very cold at Jupiter (5.5 AU) → 50 W/m^2 → solar array down to -220 C
- Radiation Environment
  - Harsh radiation environment in the Jovian system
  - Careful selection of radiation resistant electrical component and materials
  - Shielding → mass
- Electro Magnetic Cleanliness
  - Instruments measuring fields and particles are very sensitive to EMC disturbances
  - Wish to measure the space electric/magnetic fields and not the spacecraft disturbances
  - E.g. the spacecraft generated magnetic field shall be < 1 nT (10^{-9} Tesla) which is 50000 times less than the Earth magnetic field.



Juice design drivers (2/2)

- Navigation and autonomy
  - 5 fly-by during the cruise to Jupiter
  - 26 fly-by during the Jupiter Tour: Europa (2x), Ganymede (11x), Callisto (13x)
  - Ganymede orbit insertion and 500 km polar orbit
  - Signal turnaround time at Jupiter (Earth station-spacecraft-Earth station) 1.5 h
  - Navigation Camera for autonomous operation

- Propulsion
  - Overall ΔV about 2.6 km/s
  - Large amount of propellant, in the range of 2.9 tons for a 2.2 tons spacecraft
  - Highest ΔV manoeuvres:
    - ✓ Jupiter orbit insertion 900 m/s
    - ✓ Ganymede orbit insertion 600 m/s

JUICE instruments suite

		Instrument Name	Scientific purpose
Remote Sensing	1	Jovis, Amorum ac Natorum Undique Scrutator (**JANUS**)	Moons geology, cloud morphology and dynamics
	2	Moons And Jupiter Imaging Spectrometer (**MAJIS**)	Chemistry - Atmospheric & surface composition
	3	UV Spectrograph (**UVS**)	Atmosphere of moons & Aurora of JUPITER
	4	Sub-mm Wave Instrument (**SWI**)	JUPITER Wind + JUPITER Moons atmospheric temperatures and composition
Geophysics	5	GAnymede Laser Altimeter (**GALA**)	Moons shape & topography
	6	Radar for Icy Moons Exploration (**RIME**)	Moons sub-surface study
	7	Gravity & Geophysics of Jupiter and Galilean Moons (**3GM**)	Gravity field and moon interiors (S/C position)
	11	***PRIDE***	*Ephemerides of the Jovian system*
In situ Particles and Fields	8	JUICE Magnetometer (**J-MAG**)	Magnetic field (& Ganymede ocean)
	9	Particle Environment Package (**PEP**)	Plasma environment & Study of the neutral and ion composition of exospheres
	10	Radio & Plasma Wave Investigation (**RPWI**)	Plasma environment

JUICE overall mission schedule

May 2nd 2012, Selection of the JUICE mission,

Study Phase

November 6th 2014, Adoption of the JUICE mission

July 29th 2015, Start of the industrial phase

Design Phase

March 1st 2016, System Requirements Review

March 1st 2017, Preliminary Design Review

Manufacturing, Integration and Test Phase

March 1st 2019, Critical Design Review

March 1st 2022, Flight Acceptance Review

May 20th 2022, Launch

Cruise to Jupiter

October 2029, Jupiter Orbit Insertion

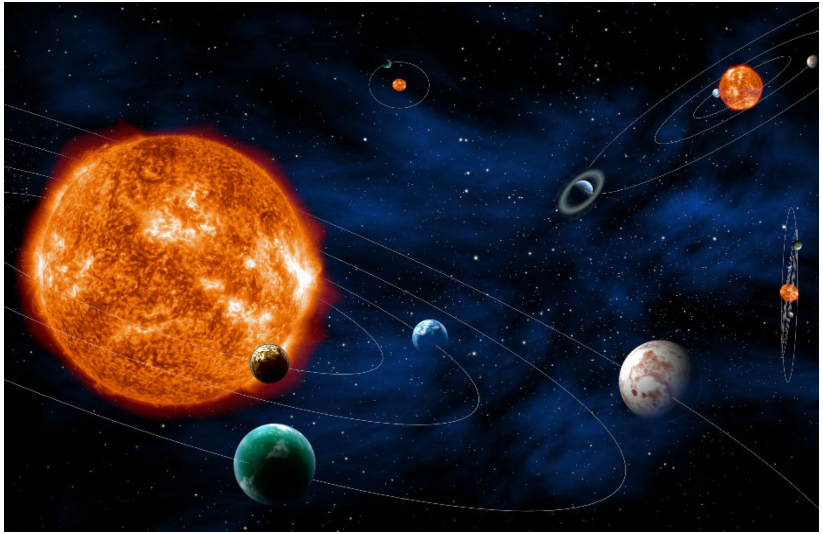
Science Exploration Phase

June 2033, End of Mission

Science Objectives

PLATO is a mission to detect and characterise exoplanets and study their host stars

- Determination of bulk properties (mass, radius, mean density) of exoplanets, including terrestrial planets in the habitable zone of solar-like stars
- Planet evolution with age
- Internal structure of stars
- Architecture, formation, and evolution of planetary systems
- Identification of good targets for spectroscopic follow-up of planet atmospheres



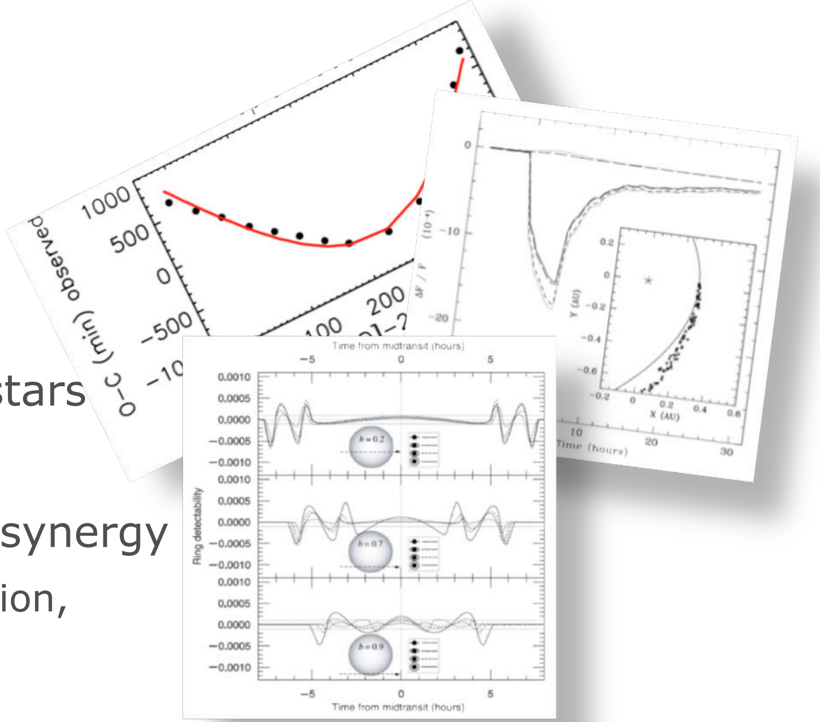
Additional Science

Other topics in planetary science:

- Circumbinary planets
- Exo-moons
- Rings/comets
- Misaligned planets
- Planets around young and evolved stars

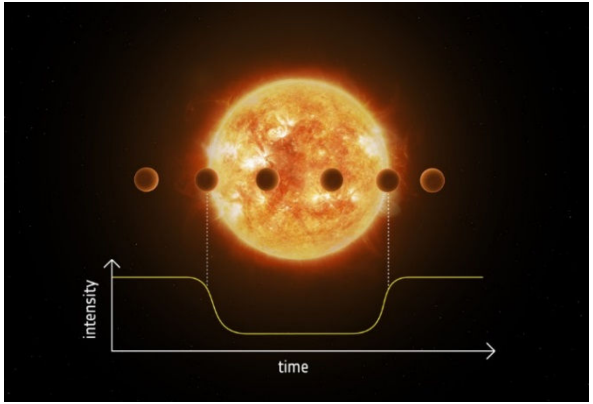
Complementary science (e.g.):

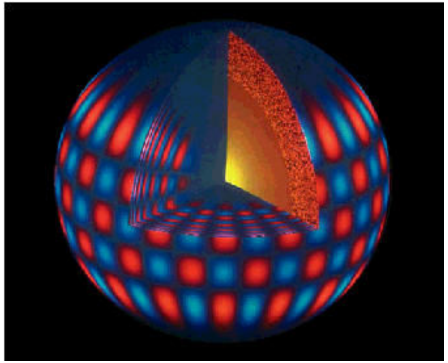
- Stellar and Galactic evolution: Gaia synergy
  - Gaia: radius, distance, proper motion, luminosity, T_{eff}, log g
  - PLATO: stellar masses, ages
- Accretion physics near compact objects

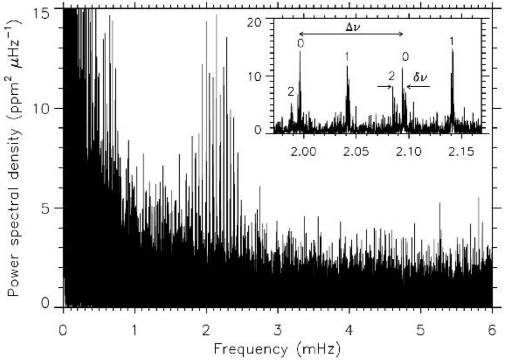


PLATO Techniques

1. Transit method
   - ➢ Planet radius (~3% accuracy)
2. Asteroseismology analysis
   - ➢ Stellar radius, mass, and age
   - ➢ Planet age (~10% accuracy)
3. Radial velocity observations with ground-based telescopes
   - ➢ Planet mass (~10% accuracy)

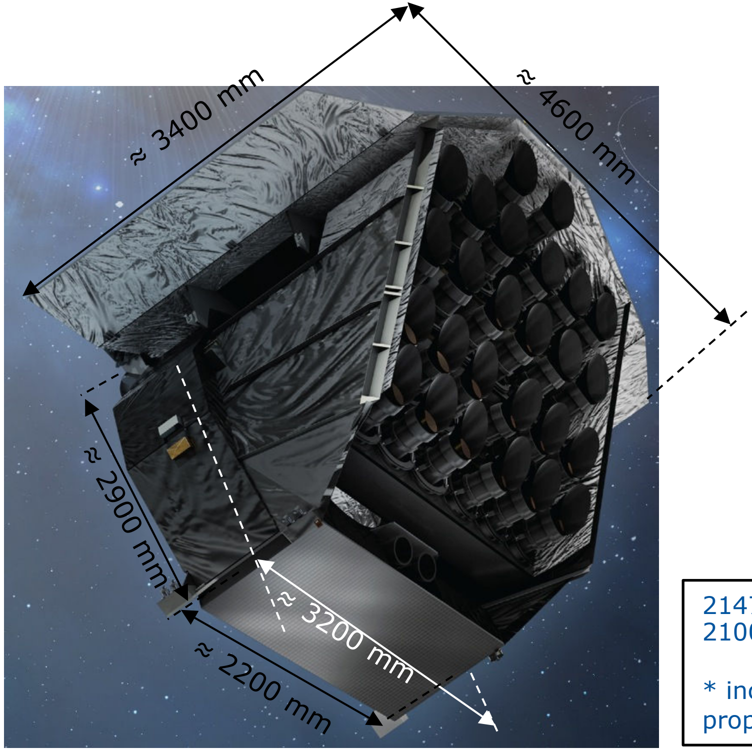




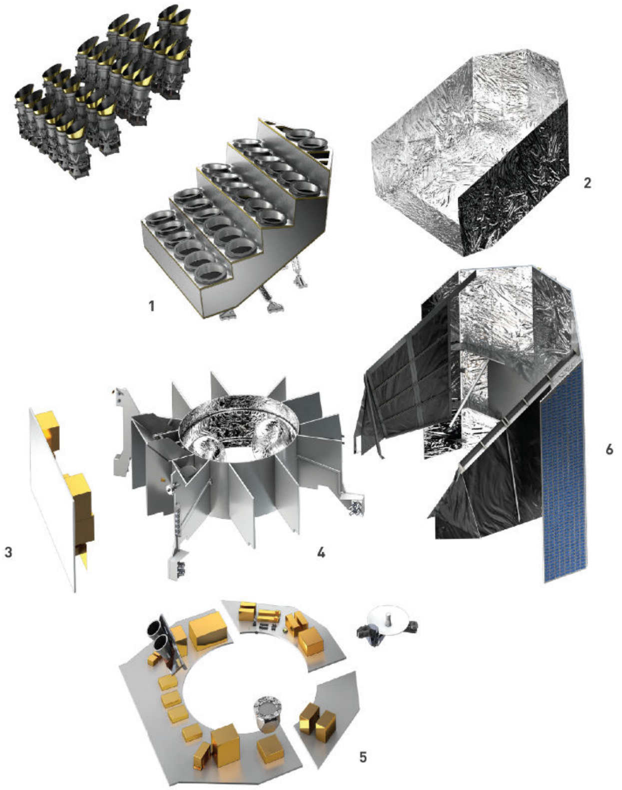


Spacecraft Overview: OHB System AG

Spacecraft design: PLM and SVM separation



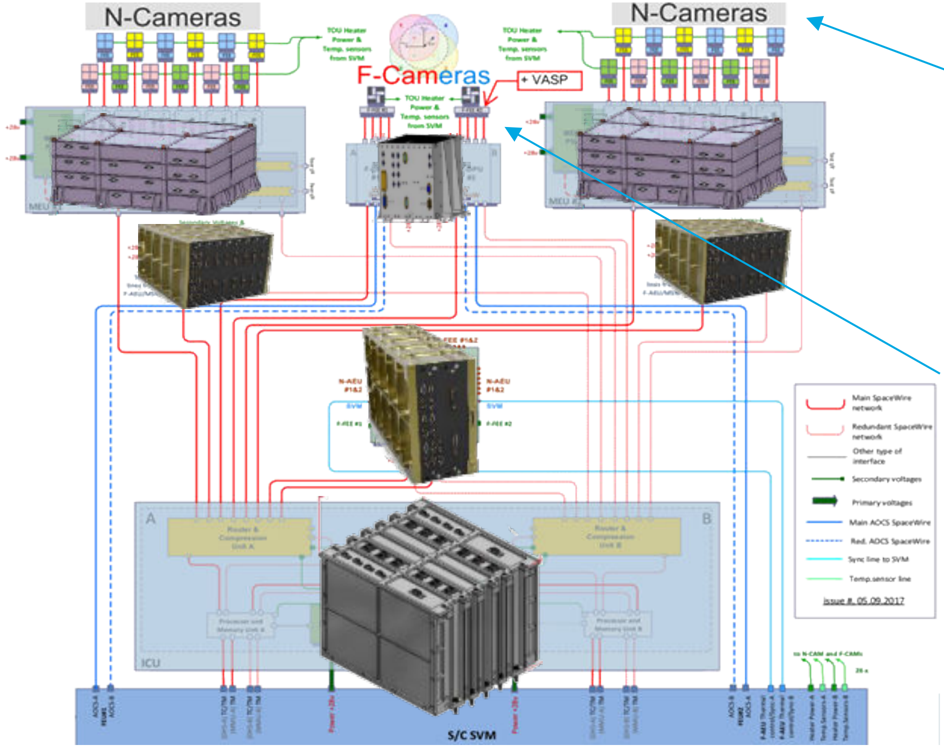
1 Optical Bench Assembly
2 Payload Thermal Shield
3 Payload Electronics Panel
4 Central Module (structure and propulsion)
5 Avionics and Electronics panels
6 Sunshield and Solar Array

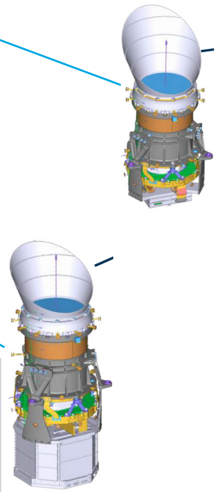


2147 Kg* Spacecraft at launch
2100 W Generation

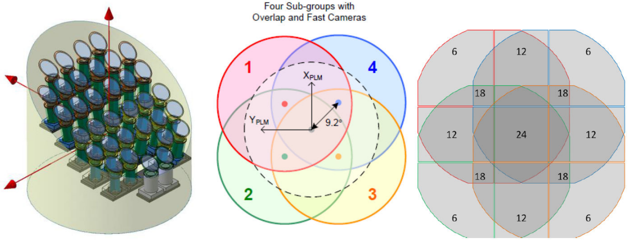
* including 80 kg LVA and 126 kg propellant

Instrument fact sheet





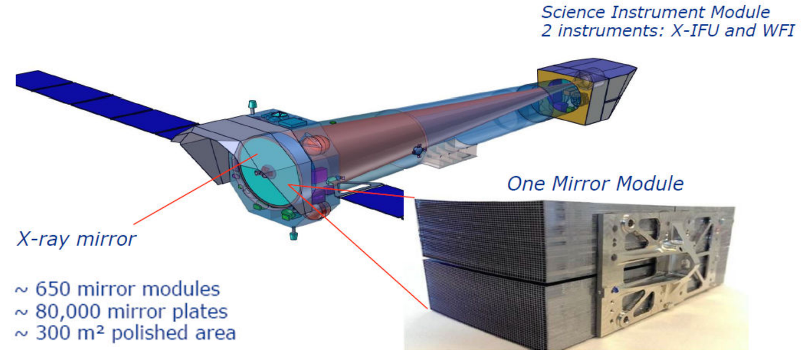
Fact Sheet	
Number of cameras	24 Normal + 2 Fast
Field-of-View	2232 deg^2 (Overlap Normal) 619 deg^2 (Fast)
Δλ	Visible: 500-1000 nm (Normal) Blue: 505 – 700 nm (Fast) Red: 665 -1000 nm (Fast)
Spatial Resolution	15.0”
Data Volume	435 Gbit/day
Mass	580 kg
Power	873 W



Future Science Missions

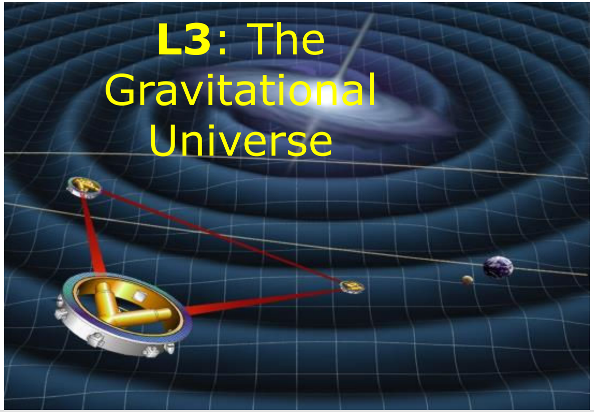
L2: The Hot and Energetic Universe

Mapping hot gas structures and determining their physical properties. Searching for supermassive black holes



L2 ATHENA (2031)

- In Phase A, Mission Adoption: 2022
- Wide Field Imager (WFI): APS camera with 40' FoV
- X-ray Integral Field Unit (X-IFU): cryo-cooler TES detector-based spectroscopy



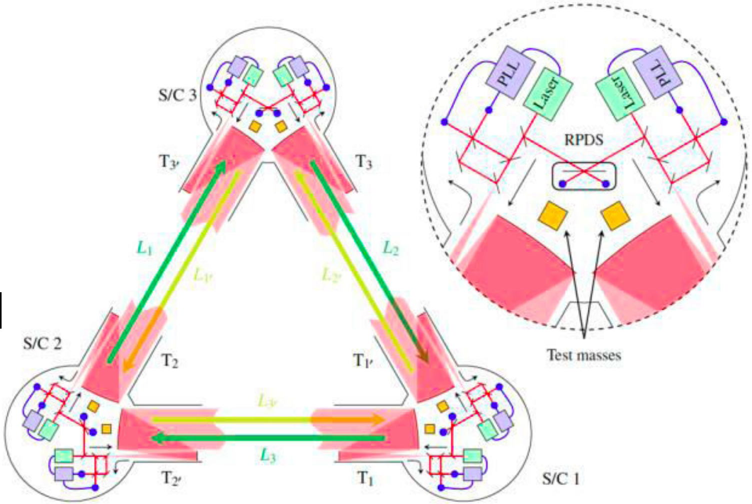
L3 LISA (2034)

- Ph. A starting now, Adoption 2024
- Measurement of Gravitational Waves based on laser interferometry
- 3 identical SC in equilateral triangle
- Test masses displacement noise ~10pm/sqrt(Hz)
- Test masses acceleration noise ~3fm/s2/sqrt(Hz)

@ 0.1 mHz to 100 mHz

LISA Measurement concept

- **Measurement of the distance between free-falling reference masses** with picometer range accuracy, over frequency range 0.1 mHz to 1 Hz
- **Laser interferometry** (1064 nm) using heterodyne detection for phase measurements, all lasers are phase-locked to a master laser



- **Full configuration: 3 arms, 6 links**

- Variable Doppler shift due to S/C relative motion to be taken into account in the measurement (+/-10 m/s, or +/- 10 MHz)
- Post-processing on ground to cancel laser noise

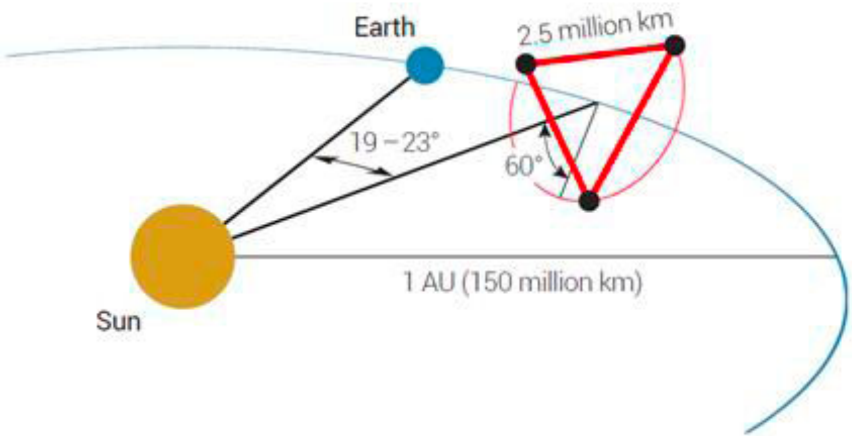
LISA mission profile and critical technologies

Launch: Ariane 6.4

•**Earth-trailing (or heading) heliocentric orbit**: 1 AU, 20 deg away from Earth

•**Constellation:** 3 identical SC in equilateral triangle (2.5 Mkm arm-length)

•**Nominal lifetime**: 6.5 years (4 yrs science) EoL disposal to deep-space



SPACECRAFT critical tech.:

- High Gain Antenna
- Constellation Acquisition
- AOCS / Micropropulsion

PAYLOAD critical tech.:

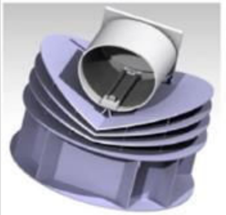
- Lasers
- Telescopes
- Metrology System, Optical Bench
- Gravitational Reference Sensors

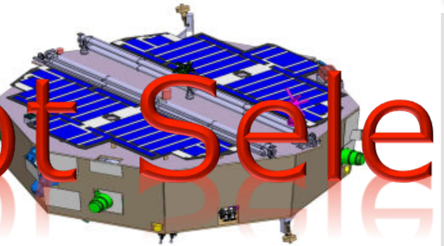
Future Missions M4 candidates (2028)

Selected

M4: ARIEL measurement of exoplanets atmosphere by transit spectroscopy *(λ =1.25-8 μm)*

- *Ariane 6.2 launch, eclipse free SEL2*
- *0.6 m^2 mirror aperture*
- *Detectors at 35 K*
- *Pointing < 100 mas over 10h*

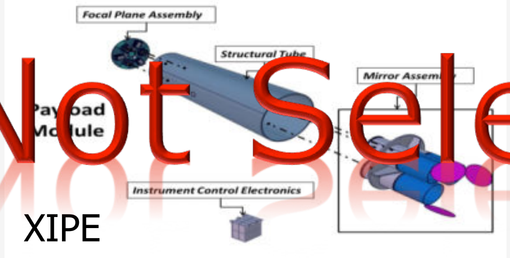




Not Selected

M4: THOR Turbulence Heating Observer

- *Highly Elliptical Earth orbit , Ariane 6.2 launch*
- *6x15 R_e (y1), 6x26 R_e (y2) and 6x45 R_e (y3) orbit*
- *10 instruments, EMC sensitive*
- *2 rpm spinner*



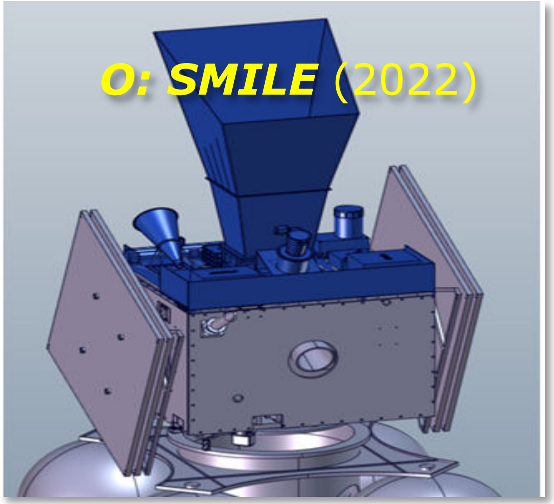
Not Selected

M4: XIPE X-ray polarisation in the range 2-8 keV

- *Low Earth orbit (550km), low incl., VEGA-C launch*
- *Gas Pixel Detector, Wolter-I x-ray mirror*
- *A_{eff} ~ 1100 cm^2 at 3 keV*

SMILE

- ESA / CAS cooperation
- Phase A/B1, Adoption: end 2018
- Objective: Investigate the dynamic response of the Earth's magnetosphere to the solar wind impact
- Payload: 4 Instruments for X-ray and UV observations, magnetic field



- Two imaging instruments:
  - Soft X-ray Imager (SXI)
  - Ultraviolet Imager (UVI)

Imaging the solar wind - magnetosphere interaction zones & northern aurora.

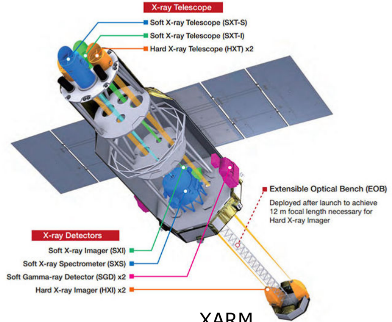
- In-situ measurement package:
  - Light Ion Analyser (LIA)
  - Magnetometer (MAG)

Measure the solar wind properties simultaneously with imagers.

Missions of Opportunity

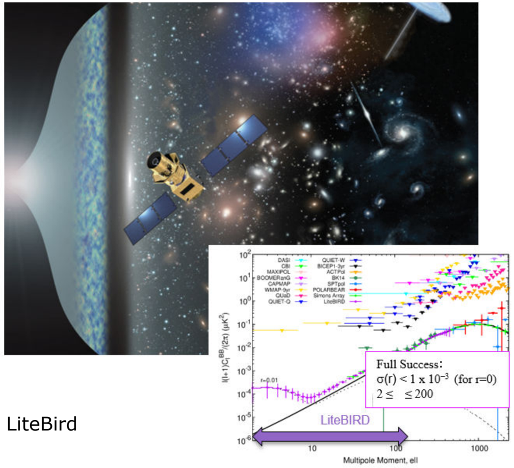
- XARM (X-ray Astronomy Recovery Mission, JAXA, launch 2021)
  approved by SPC June 2017; Currently in Phase B, prep. of procurement:
  Loop Heat Pipes, AOCS equipment (Star Tracker, MagnetoTorquers+ Magnetometer)
- LiteBird (MoO candidate) with JAXA, launch 2027, currently in CDF
  - CMB polarisation mission with 2 telescopes (LFT: 40-140GHz, HFT: 100-402GHz)
- WFIRST (NASA, 2025), Large Wide Field IR Observatory
- CAS’s Einstein Probe Small X-ray all-sky monitoring mission,

launch early 2023, ESA potential participation: X-ray camera Mirror



XARM

WFIRST



LiteBird

Future Missions M5 candidates (2032)

Candidate

M5: Theseus

Transient High Energy Sky and Early Universe Surveyor

Candidate

M5: Spica

SPace Infrared telescope for Cosmology and Astrophysics

Candidate

M5: EnVision

Orbital mission to Venus

See for details:
http://sci.esa.int/cosmic-vision/60257-esa-selects-three-new-mission-concepts-for-study/

Call for New Science Ideas

- Open call to scan for new ideas which not necessarily have to fit TRL, schedule, budget constraints as for M, L, S & O missions

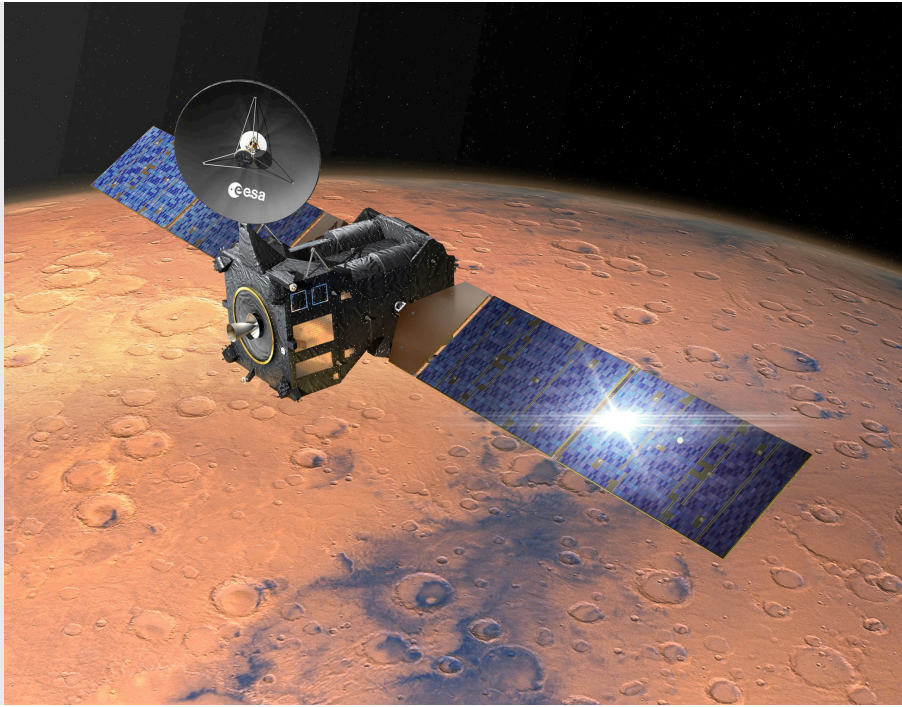
- Call issued in 2016 ⇨ received proposals ⇨ evaluation done ⇨ Three topics selected:
  1) GAIA-NIR: GAIA in the Near-IR
  2) Small Planetary Platform (SPPF): multi-point/multi-target observation with small sats
  3) Quantum Physics (QPPF): De-Coherence in Space

- Progress
  ⇨ Workshops done for QPPF & SPPF (June 2017, Sep 2017)
  ⇨ CDF done for GAIA-NIR (completed) and SSPF (work ongoing)
  ⇨ CDF for QPPF in preparation (KO 15-May 2018)

- Technology development for selected cases

Robotic exploration

In cooperation with Roscosmos (Russia), two ExoMars missions (2016 and 2020) investigate the martian environment, particularly astro-biological issues, and develop and demonstrate new technologies for planetary exploration with the long-term view of a future Mars sample return mission.



2016 Mission Objectives

E X O M A R S

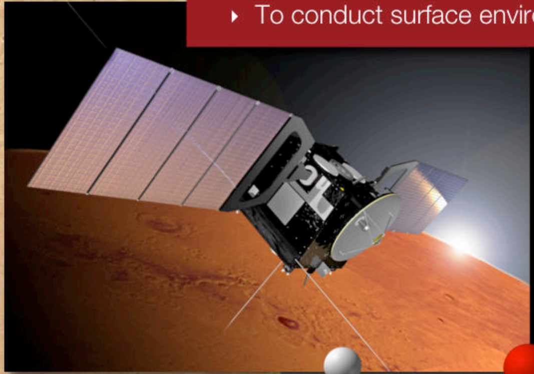
2016

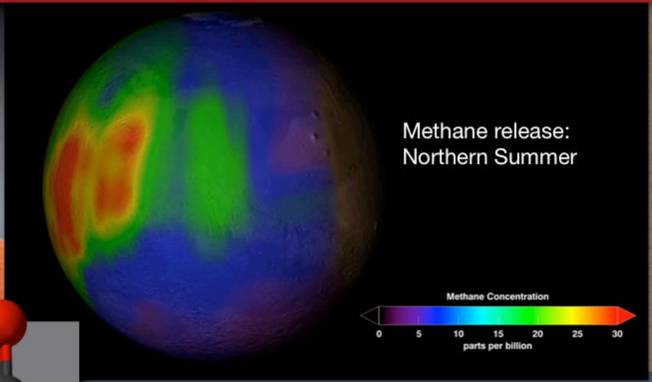
TECHNOLOGY OBJECTIVE

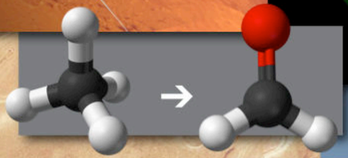
- Entry, Descent, and Landing (EDL) of a payload on the surface of Mars.

SCIENTIFIC OBJECTIVES

- To study Martian atmospheric trace gases and their sources;
- To conduct surface environment measurements.







- Data relay services for landed missions until 2022.

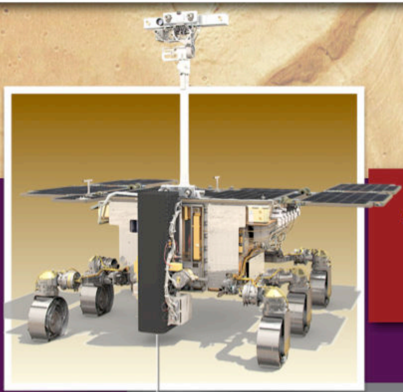
Mamers Valles, MEX / HRSC

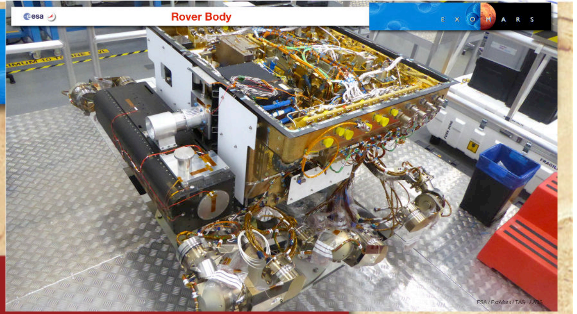
Trace Gas Orbiter Status

- TGO overall status is excellent.
- All instruments were utilised from the Mars capture orbit (during Nov 2016 and Feb-Mar 2017).
- Aerobraking started with a “walk in” phase on March 2017.
- End of aerobraking was accomplished on 20 Feb 2018.
- The final orbit was reached on 7 Apr 2018.
- First atmospheric sun occultation measurements took place on 21 Apr 2018. We now move into the science phase.

Credit: ESA/Medialab, Kees Veenenbos

2020 Mission Objectives





2020

SCIENTIFIC OBJECTIVES

- To search for signs of past and present life on Mars;
- To investigate the water/subsurface environment as a function of depth.

TECHNOLOGY OBJECTIVES

- Surface mobility with a rover (having several kilometres range);
- Access to the subsurface to collect samples (with a drill, down to 2-m depth);
- Sample acquisition, preparation, distribution, and analysis.

- To characterise the surface environment.

- Throttleable braking engines for planetary landing.
- Russian deep-space communications stations working in combination with ESA's ESTRACK.

. ESA's ExoMars rover will be launched in 2020. Roscosmos will be responsible for the 2020 descent module and surface platform, and provides Proton launcher.

Mamers Valles, MEX / HRSC

Would you like to know more?

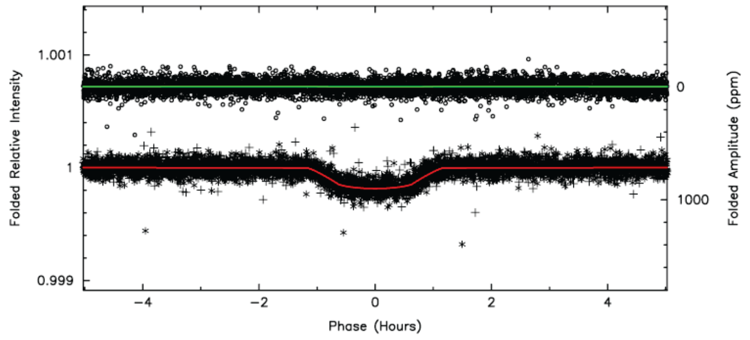
Visit **www.esa.int**

BACK UP SLIDES

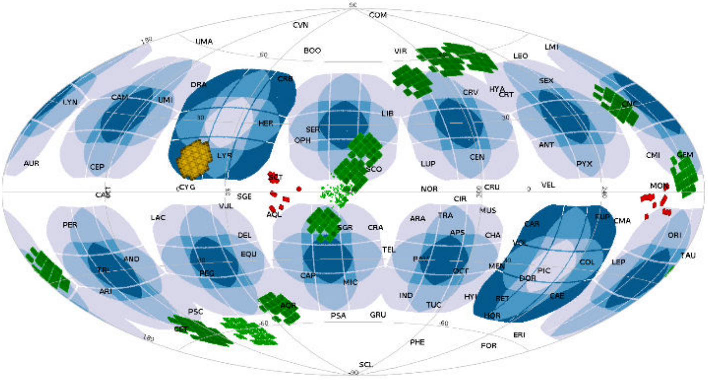
PLATO Science Overview – Observing strategy

Long uninterrupted photometric monitoring of bright stars in the visible band

- Core sample: ~15,000 stars of $m_V < 11$
  to be complemented with radial velocity ground-based observations
- Statistical sample: >245,000 stars of m_V <13(16)



Example: Kepler-10b (Batalha et al. 2011)
$R_p = 1.416 \pm 0.03\ R_E$, $M_p = 4.6 \pm 1.2\ M_E$



Baseline strategy:
2 long pointing periods, 2 years each
(will be fixed two years before launch)

Cryogenic system for Athena/X-IFU

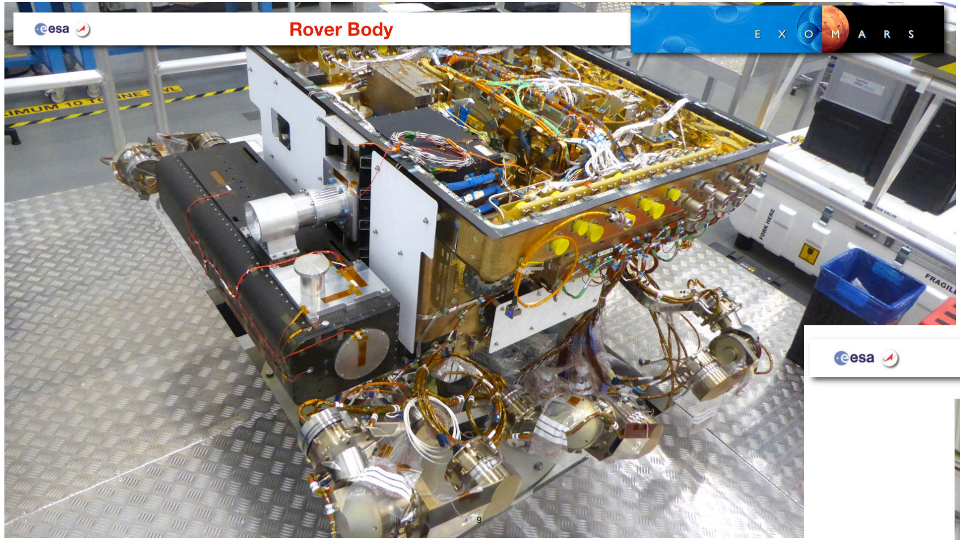
•The X-IFU instrument is an X-Ray spectrometer using superconducting Microcalorimeters operating at 50mK

•The X-IFU instrument is mounted on top of the satellite, requiring a compact solution for the cooling (contrary to Herschel/Planck)

- Mechanical cooling needed + vibration isolation

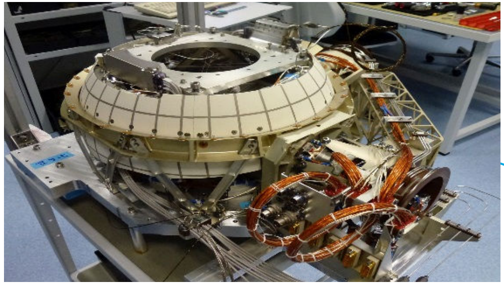
•A similar system has been developed by JAXA for the SXS instrument on-board Hitomi \ several technology developments are required in Europe to reach the required maturity for mission adoption

•Due to complexity of the payload design (including cryogenics) and delays in ongoing developments, Phase A is now extended to 2019



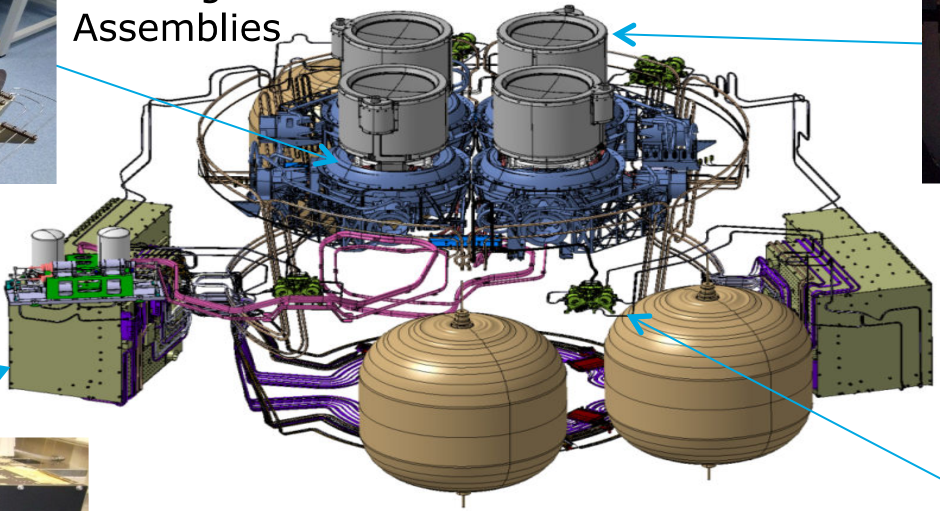
Credit: LAV

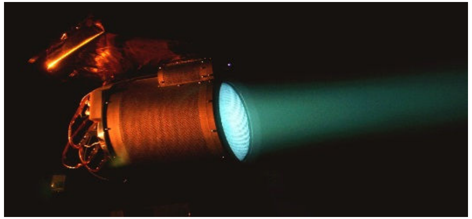
Technology Challenges: Electric Propulsion System

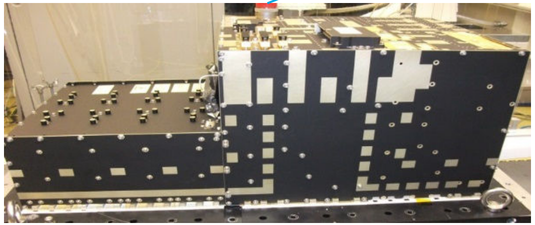


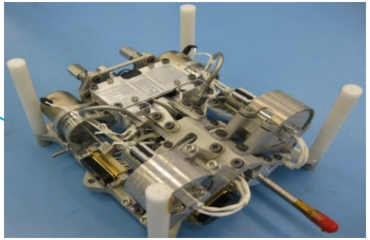
Thruster
Pointing
Assemblies

EP
Thruster





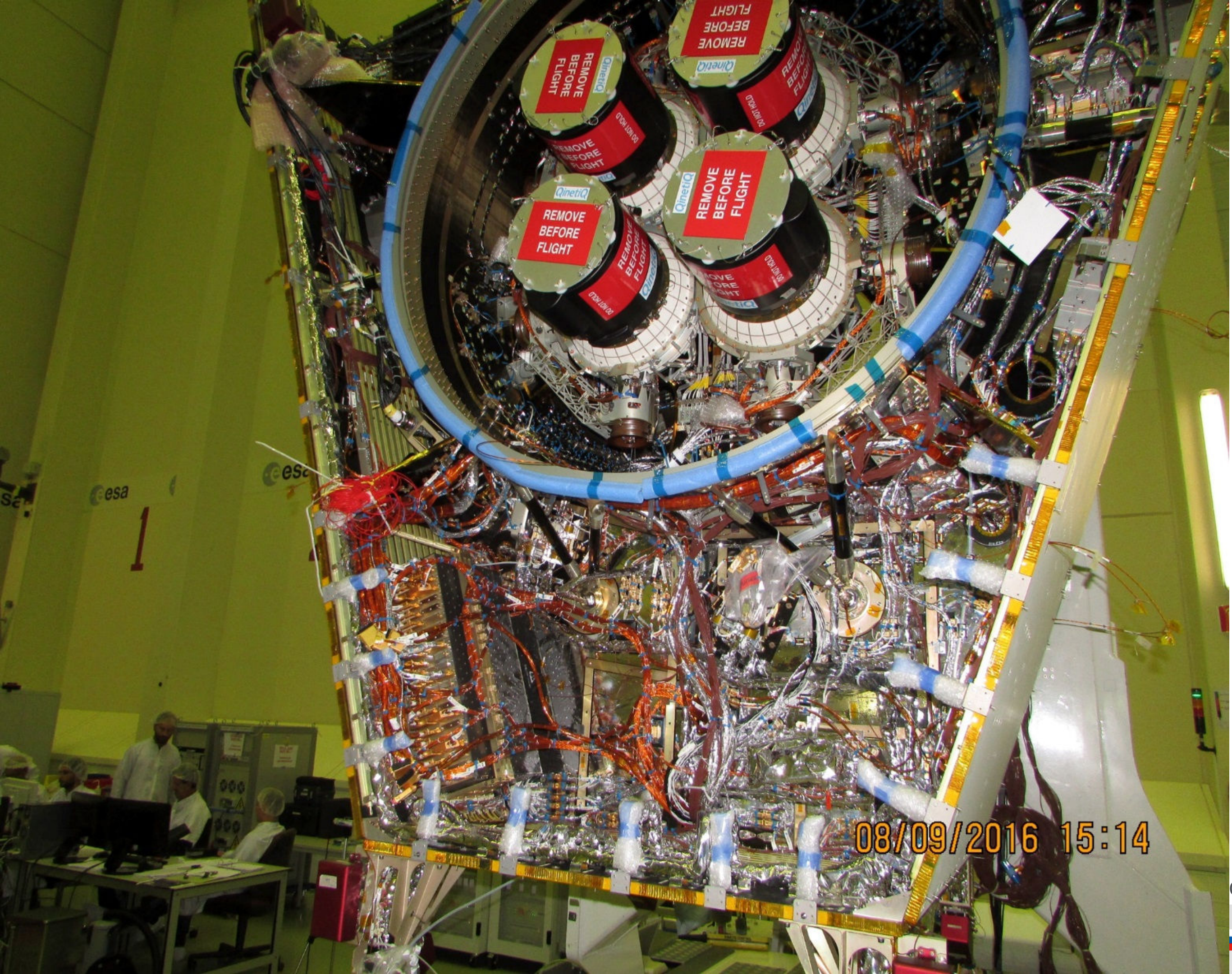




Power
Processing
Unit

Harness
and
Pipework

Flow
Control
Unit

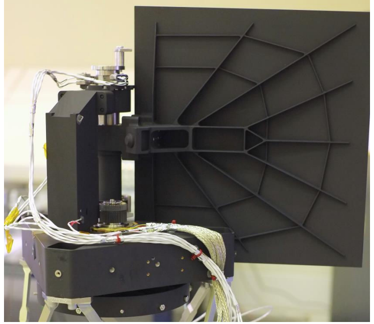
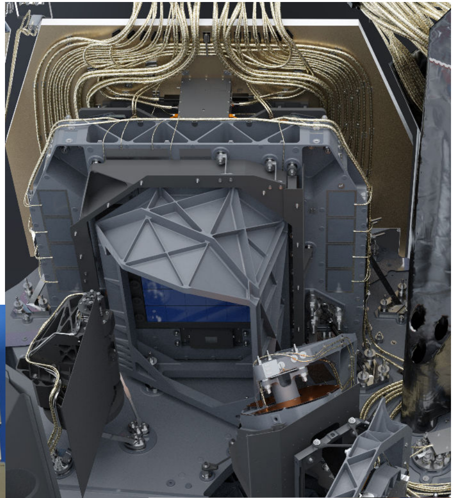
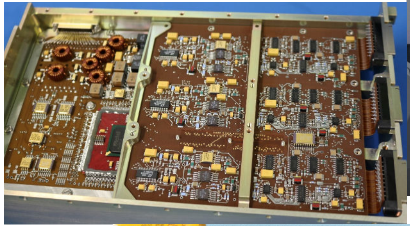
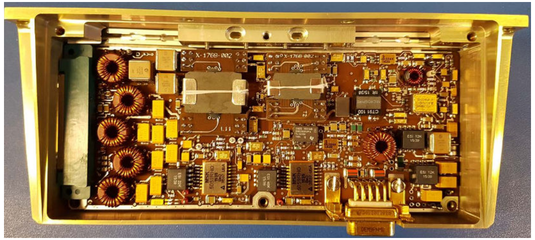
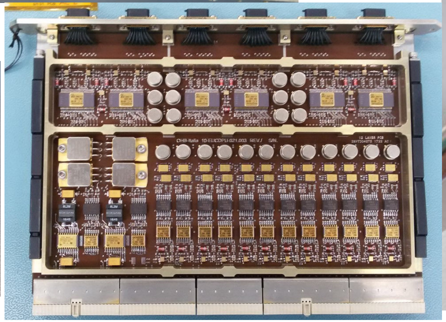


BC Transfer Module

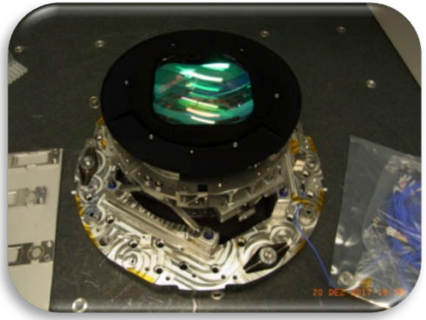
- MTM interior with integrated thruster floor
- Not visible: power processing units and chemical propulsion and Xenon tanks
- Ion thrusters can be throttled to a max of 145 mN and are steerable as well; the chemical ones thrust with 10 N and are used for flyby's and AOCS course correction

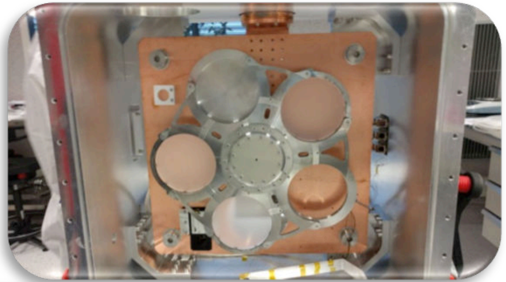
EUCLID instrument VIS

- Focal plane instrument, no optics;
- limiting magnitude: m_{AB}=24.5 extended sources at 10σ
- spectral range λ: 550–900nm
- focal plane: 6x6 CCDs (e2v, 12x12μm^2 pixels, 4096x4096 pixels)
- plate scale: 0.1 arcsec/pix
- FOV: FoV=0.787x0.709 deg^2
- focal length: f=24.5 m
- Datarate: ≤ 520 Gb/day

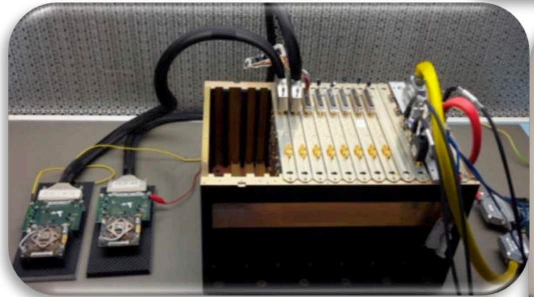

EUCLID instrument NISP





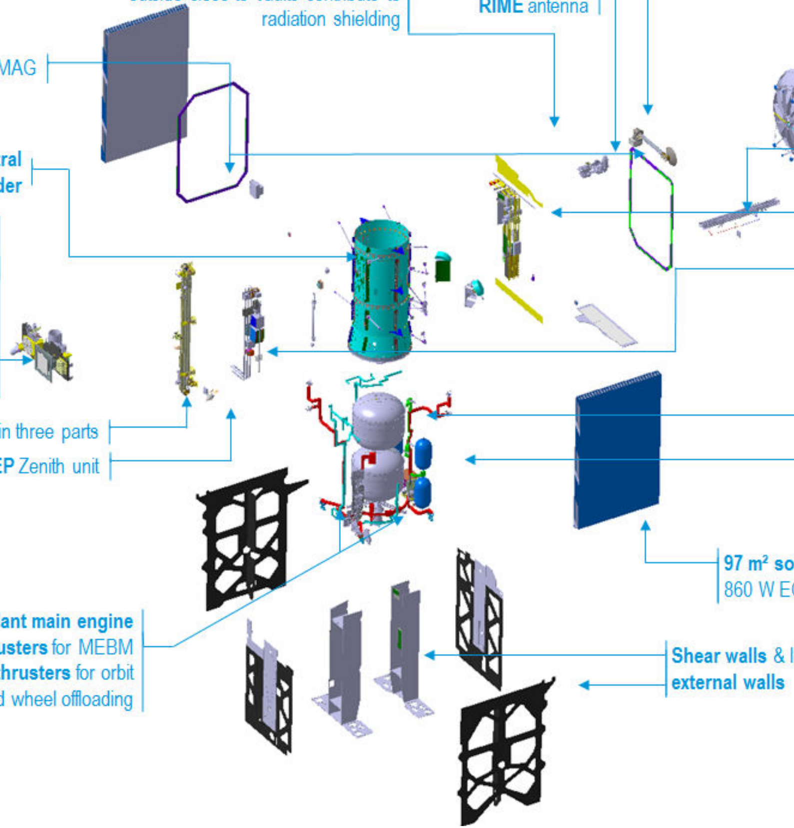
Photometry

- limiting magnitude: m_{AB}=24
- redshift resolution: dz/(1+z)=5%
- spectral range Δλ: 920–1146nm (Y), 1146–1372nm (J), 1372–2000nm (H)

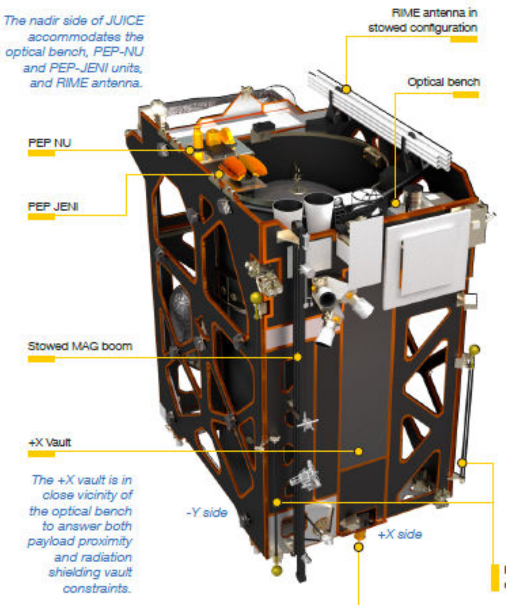


Spectroscopy

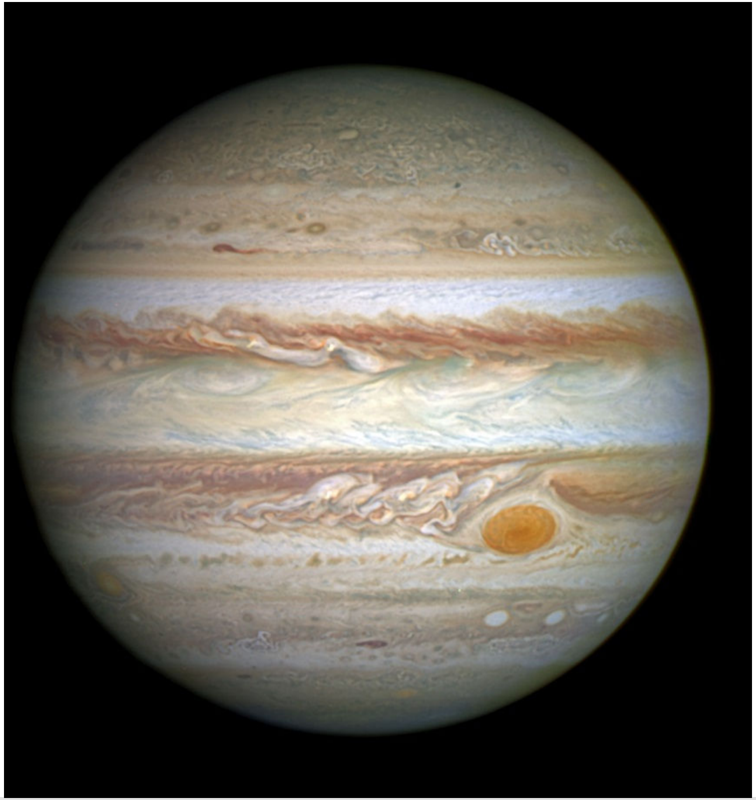
- limiting magnitude: m_{AB}=19.5
- Red-shifted H_{α} (656 nm) at z=0.8-1.8
- redshift resolution: dz/(1+z)=0.1%
- spectral range Δλ : 920–1850nm
- focal plane: 4x4 H2RG, 2048x2048 pixels, 2.3μm cut-off
- plate scale: 0.3 arcsec/pix, focal length: f~6.1 m

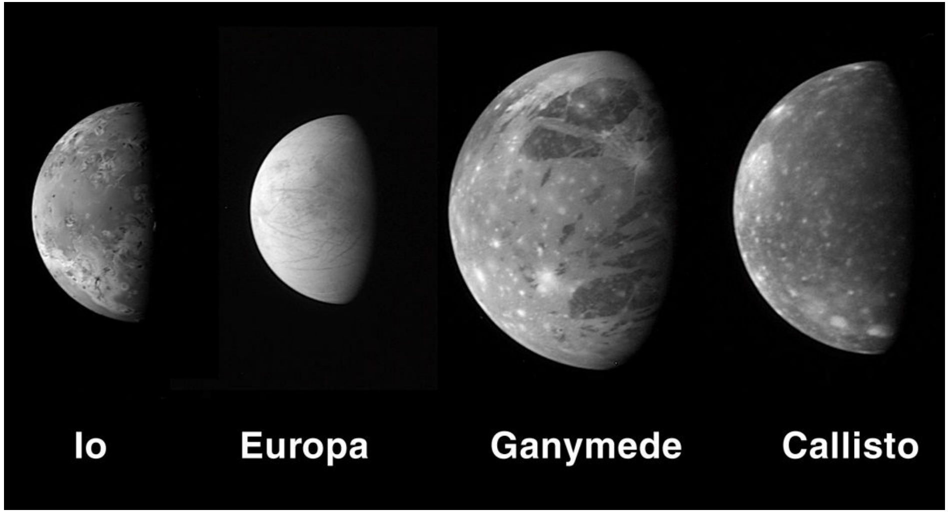


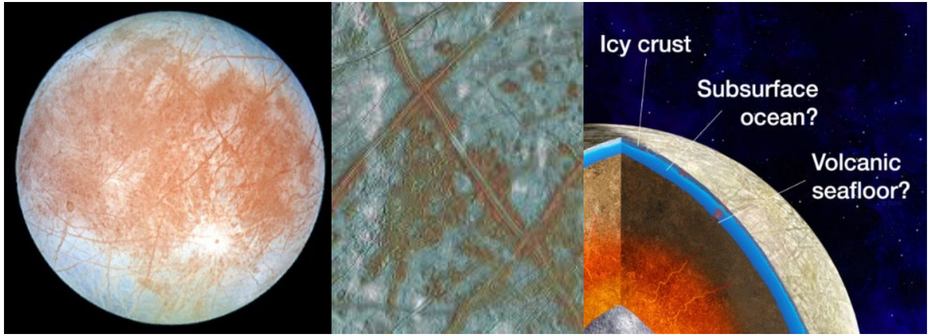
Wheels & batteries accommodated outside close to vaults contribute to radiation shielding
PEP Nadir units & **RIME** antenna
∅0,5 m two axis **MGA**
∅2,54 m **HGA** in X- and Ka-band for nominal operations, Science data download & RSE. Used as sunshield when close to the Sun
Calibration coils for JMAG
∅1666 mm **central cone/cylinder**
RIME antenna
Optical bench accommodated instruments with stringent pointing requirements close to STR-OH and NAVCAM and their proximity electronics inside +X vault
Vault gathering most of the **electronic units** for radiation, ESD & EMC mitigation as well as to ensure a warm thermal environment throughout mission
10,6 m MAG boom in three parts
PEP Zenith unit
Propellant tanks (2x1630l) & **pressurant tanks**
97 m² solar generator
860 W EOL @ Jupiter
450 N bi-propellant main engine with **2x4 22 N thrusters** for MEBM and **2x6 10 N thrusters** for orbit control and wheel offloading
Shear walls & lighten **external walls**

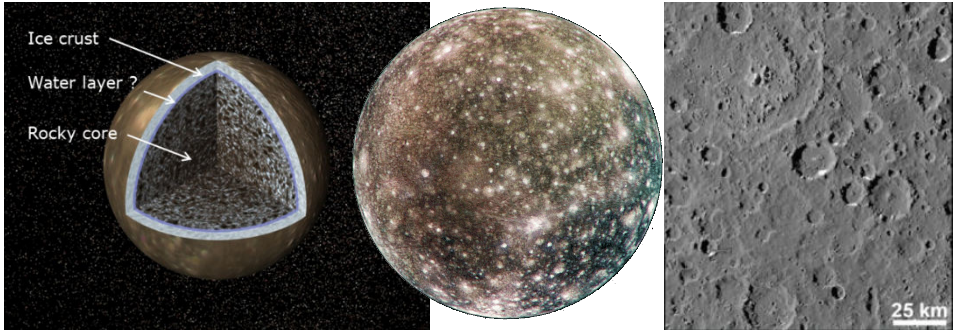


The nadir side of JUICE accommodates the optical bench, PEP-NU and PEP-JENI units, and RIME antenna.
RIME antenna in stowed configuration
Optical bench
PEP NU
PEP JENI
Stowed MAG boom
+X Vault
The +X vault is in close vicinity of the optical bench to answer both payload proximity and radiation shielding vault constraints.
-Y side
+X side




Io
Europa
Ganymede
Callisto

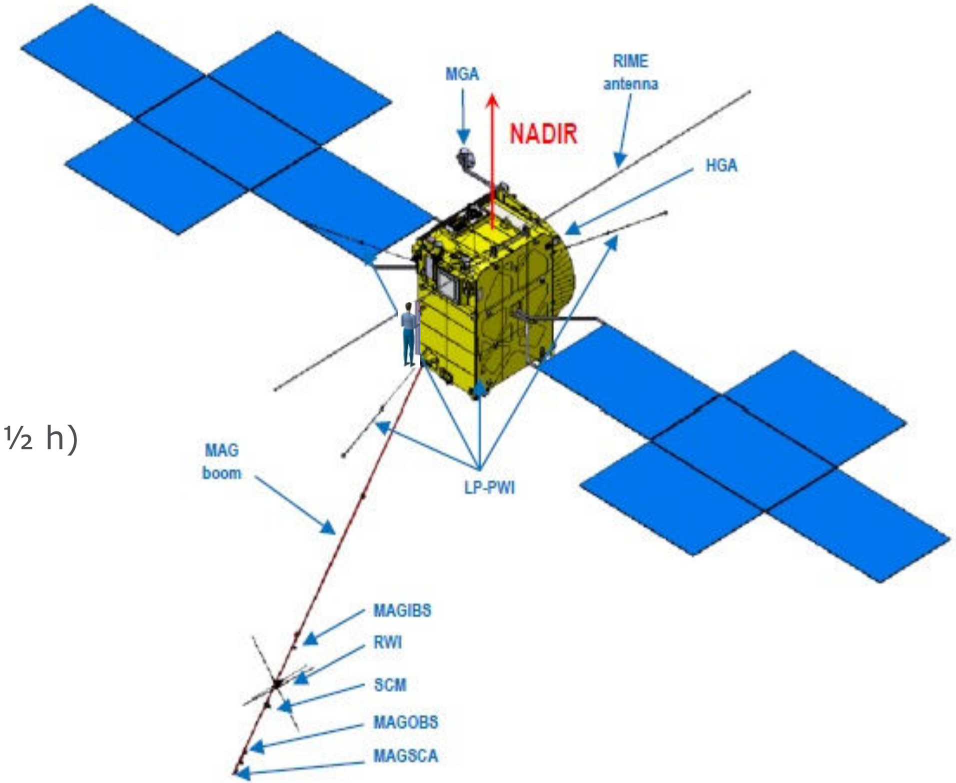

Icy crust
Subsurface ocean?
Volcanic seafloor?


Ice crust
Water layer ?
Rocky core
25 km

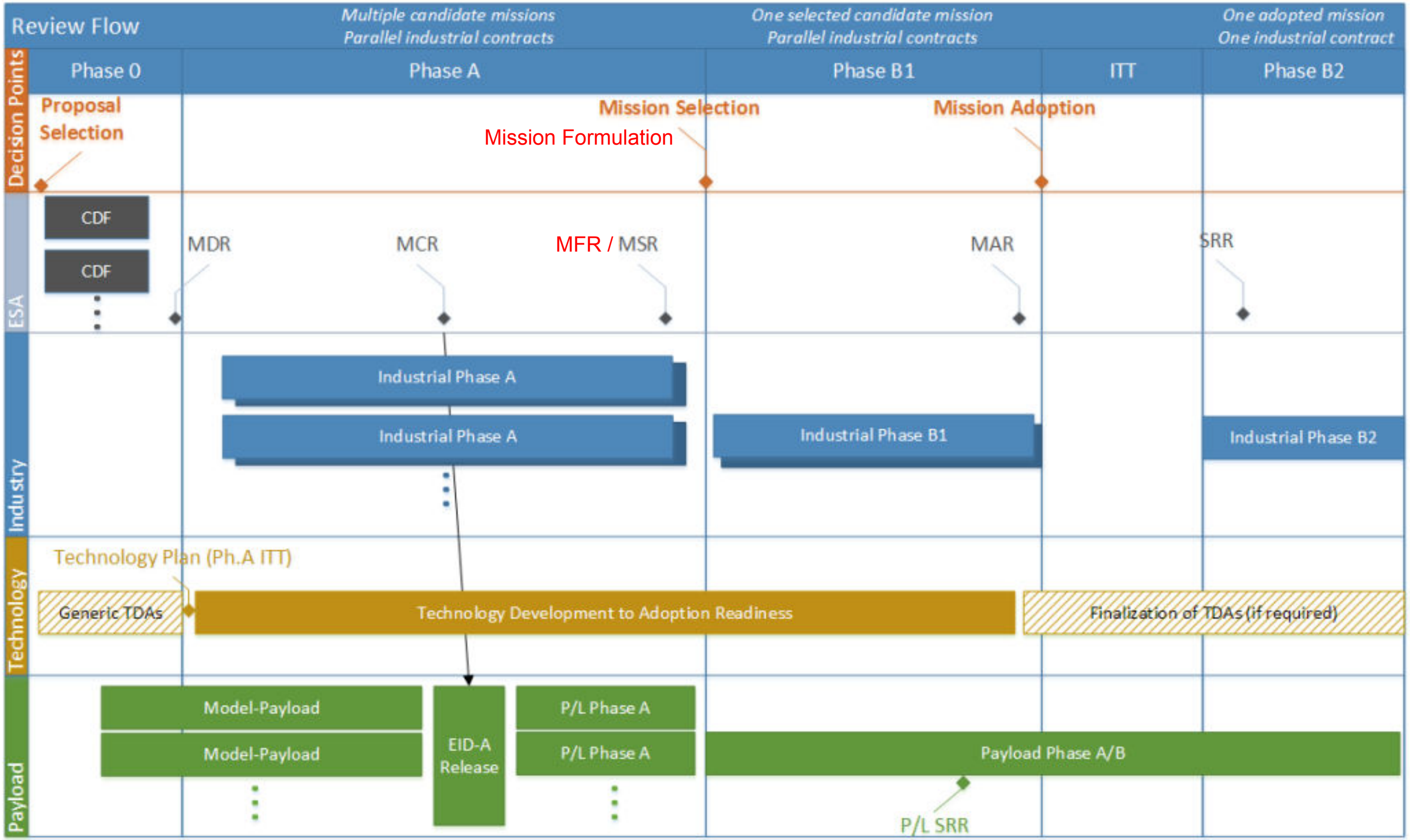

100 km
Ganymede Interior
Ice crust
Saline ocean
Ice mantle
Rocky mantle
Iron core

JUICE spacecraft configuration

- Mass
  - ✓ Dry ≈ 2200 kg
  - ✓ Propellant ≈ 2900 kg
  - ✓ Total > 5000 kg
  - ✓ Instruments = 260 kg
- Power
  - ✓ Solar Array ≈ 725 W EOL
  - ✓ Instruments GCO500 = 180 W
  - ✓ Instruments fly-by = 230 W (360 W for ½ h)
- Memory = 1 Tbit EOL
- $\Delta v \approx 2400$ m/s
- Data Rate: 1.4 Gb/24 h



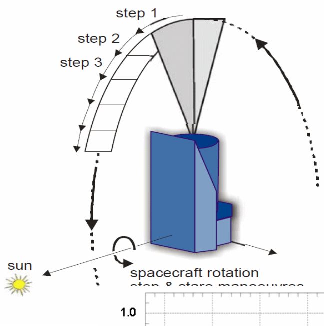
The Process

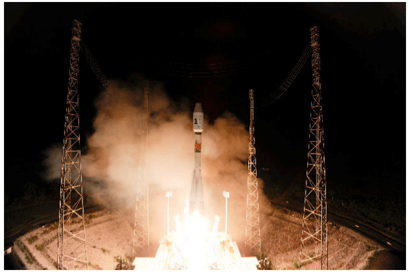


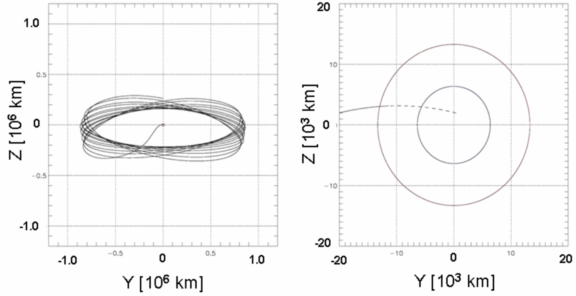
Review Flow
Multiple candidate missions
Parallel industrial contracts
One selected candidate mission
Parallel industrial contracts
One adopted mission
One industrial contract
Decision Points
Phase 0
Phase A
Phase B1
ITT
Phase B2
Proposal Selection
Mission Selection
Mission Formulation
Mission Adoption
ESA
CDF
CDF
MDR
MCR
MFR / MSR
MAR
SRR
Industry
Industrial Phase A
Industrial Phase A
Industrial Phase B1
Industrial Phase B2
Technology
Technology Plan (Ph.A ITT)
Generic TDAs
Technology Development to Adoption Readiness
Finalization of TDAs (if required)
Payload
Model-Payload
Model-Payload
EID-A Release
P/L Phase A
P/L Phase A
Payload Phase A/B
P/L SRR

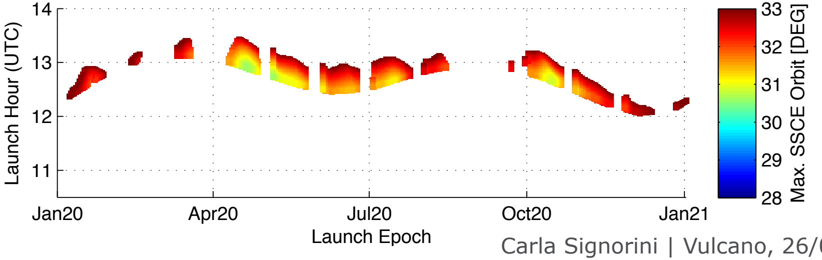
Euclid Mission Design

- Soyuz 2.1B + Fregat ascent trajectory and direct SEL2 transfer orbit;
- Y-Z plane of the co-rotating frame;
- Sun-spacecraft-Earth angle of 35º;
- Step-and-stare scanning of the sky;
- Telescope LOS is kept perpendicular to the Sun direction (87º < SAA< 121º)
- Launch window constraints: perigee velocity, SSE angle, no eclipses, telescope vs. sun direction ≤ 30º.









The remote-sensing instruments:

Extreme Ultraviolet Imager

Coronagraph

Polarimetric and Helioseismic Imager

Heliospheric Imager

Spectral Imaging of the Coronal Environment.

X-ray Spectrometer/Telescope

Future Missions preparation – main activities

1. **Calls (bottom up approach of selection)**
   - M5 mission candidates selected: Theseus, Spica and EnVision
   - Call for New Science Ideas: 3 themes selected: Quantum Physics, Small Planetary Platform, GAIA-NIR
   - Call for F-missions: Q3/4 2018 (TBC)

2. **System studies:** for defining the mission space segment:
   - Parallel industrial studies,
   - Iterations with the science community, ESOC (MOC), ESAC (SOC)
   - Convergence on requirements and interfaces

3. **Science and instrumentation related activities:**
   - Achieved by the science community, under Member States funding
   - Includes the Science Ground Segment
   - ESA funded Phase A P/L studies (new)

4. **Technology developments:** to reach TRL 5/6 prior to Mission Adoption
   - Mission driven technology work plans, in parallel to the studies
   - TRP/CTP joint work plan, with a yearly update (more if needed)

5. **Independent reviews:** to control the achievements and enable decisions
   - Assessment of the definition maturity, the technology readiness and cost/risks
   - Mission Selection/Formulation Review (MSR/MFR) end Phase A; Mission Adoption Review (MAR) end Phase B1