ESSC to CAPS

Athena Coustenis, *Chair*

Nicolas Walter, *Exec Secretary*

European Science Foundation

Outline

- ESF and ESSC presentation
- Activities and projects
- The European Space Science Program (in search for habitable worlds)
  - JUICE
  - Future missions to the Saturnian system and elsewhere

ESF Member Organisations

ESF is an independent association of 13 Member Organisations

- research funding organisations
- research performing organisations
- academies and learned societies

in 11 countries

Serving Europe since 1974

A time of change, a change of focus

ESF is setting out on a new direction, providing science services contributing to the building of the European Research Area :

•after 40 years of success in stimulating European research through its scientific networking and coordination activities, it has reorganised so as to underpin scientific decision-making

•Is a provider of scientific services to support and sustain the funding and conduct of scientific research across Europe

•the aim remains to promote scientific developments through collaborative actions, but with the emphasis shifting to helping research funders and stakeholders carry out their decision making processes

Expert Boards and Committees

Hosted at ESF

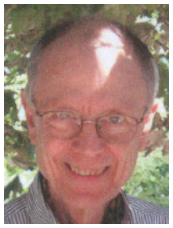
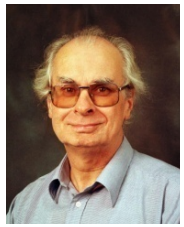
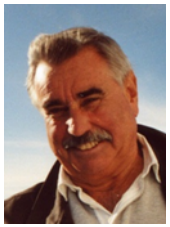
Committee on Radio Astronomy Frequencies	CRAF
European Marine Board	MARINE BOARD
European Space Sciences Committee	ESSC
Materials Science and Engineering Expert Committee	MatSEEC
Nuclear Physics European Collaboration Committee	NuPECC

The European Space Sciences Committee

Advising Europe on space science and policy

since 1974…

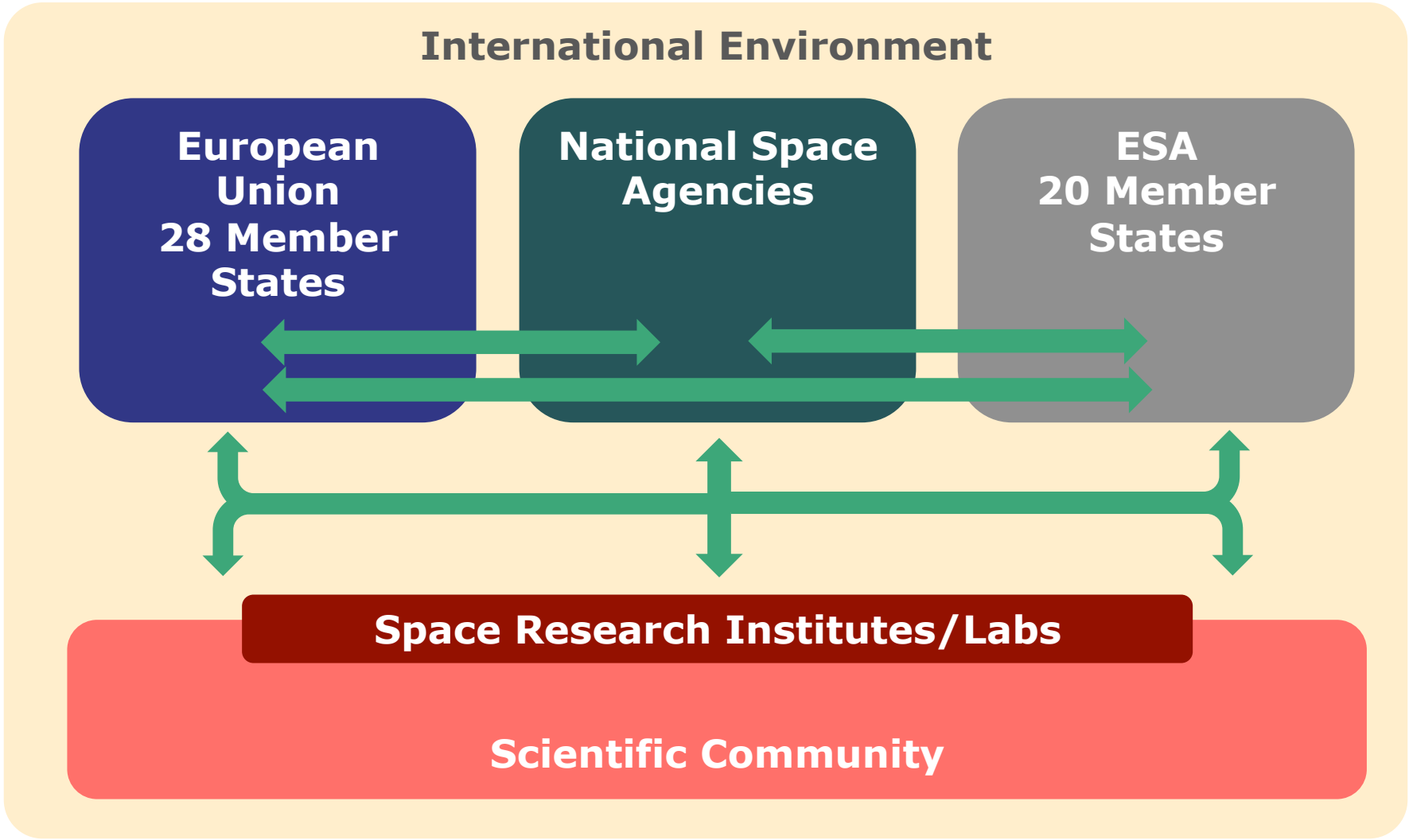
ESSC Chairs 1975-2014

			
Harrie MASSEY † United Kingdom 1975-1979	**Johannes GEISS** Switzerland 1979-1987	**Heinrich J. VÖLK** Germany 1987-1993	**François BECKER** France 1993-1997
			
J. Leonard CULHANE United Kingdom 1997-2002	**Gerhard HAERENDEL** Germany 2002-2007	**Jean-Pierre SWINGS** Belgium 2007-2014	**Athena COUSTENIS** France-Greece 2014-2017

ESSC current Mission Statement

“ The mission of the ESSC is to provide an independent European voice on European space research and policy. It is the ESF’s expert body on space research ”

European Space Sciences Context



ESSC Representation

International Environment

European Union

- FP7 Space Advisory Group (individuals)
- FP7/H2020 stakeholder consultations
- Direct interactions with programme executives

National Space Agencies

- Annual meeting with ESSC Funding Organisations
- UKSA's SPAC
- Swedish national committee

ESA

- Council at Ministerial level
- High-level Science Policy Advisory Committee (ex-Officio)
- Scientific advisory committees at programme level (ex-Officio)
- Meetings with programme executives

- COSPAR Science Advisory Committee (ex-officio)
- UN Office of Outer Space Affairs (exchange of observers and NEO Action Team 14)

- US National Academies Space Studies Board (ex-officio)

European Space Sciences Committee

- **ESSC is funded by 17 organisations (space agencies, research councils) from 13 European Countries, incl. ESA**
- **ESSC is supported by a secretariat of four staff**
- **ESSC is composed of 28 experts across four panels**
  - ***Nominated ad-personam***
  - ***Large turn-over since 2014***
- **Two plenary meetings/year**

ESSC Chair: Athena Coustenis

Solar System and Exploration

•**Hermann Opgenoorth,** Earth sciences and space physics (**Panel Chair**)

•**Mahesh Anand**, Moon
•**Ester Antonucci,** solar physics
•**Athena Coustenis**, outer planets
•**Franck Montmessin**, terrestrial planets
•**Kari Muinonen ,** small bodies
•**Gerhard Paar**, robotics
•**Petra Rettberg**: astro/exobiology, biology

Life and Physical Sciences

•**Dominique Langevin,** fluid physics and foams (**Panel Chair**)

•***Sarah Baatout, biology***
•**Alexander Chouker**, integrated physiology
•**Berndt Feuerbacher**, solid state physics
•**Helen J. Fraser**, ices & physical sciences
•***Anne Pavy-Le Traon**, neurology*
•**Roberto Piazza**, colloids
•**Peter Preu, materials**
•**Hubertus Thomas**, complex plasmas

Astronomy and Fundamental physics

•**Stéphane Udry,** exoplanets, **(Panel Chair)**

•**Conny Aerts**, asteroseismology
•**Paolo de Bernardis,** Ir/sub-mm astronomy
•**Pierre Binetruy**, fundamental physics
•**Jordi Torra**, galactic astronomy & astrometry

Earth Sciences

•**Ian Brown,** glaciology (**Panel Chair**)

•**Laurence Eymard**, ocean/atmosphere
•**Andreas Kääb,** EO and satellite based glaciology
•**Maarten Krol**, atmos. Phys. & chemistry, climate
•**Pepijn Veefkind**, Sentinel algorithms and climate

Interdisciplinarity

- **The four ESSC panels allow cutting across all/most domains of space sciences**
- **Members' interests formally declared**
- **Consensual positions and recommendations from ESSC are endorsed by representatives from various disciplines**

  → ***No bias***

  → ***Stronger positioning***

Collaborations

- **With COSPAR** the President of COSPAR is ex-officio member of ESSC and the ESSC Chair sits in CSAC (strategy, international cooperation and coordination, roadmapping, planetary protection, space weather/SSA)
- **Discussions with the ISSI Executive Board** interactions between science teams at international level
- **With China's NSSC** discussions and interactions, visits in 04/14 and 03/16 to Wu Ji and colleagues, possible coordination in the future
- **With the US NAS' Space Studies Board**
  - Long-term interaction and ex-officio mutual representation with the SSB
  - Joint reports
  - ESSC involved in committees and advisory bodies (such as the Survey of Surveys study)
  - Current projects, e.g. PPOSS activity under EC contract (planetary protection of outer solar system bodies, where SSB is an observer)

Links with the US NAS SSB

- Mutual Ex-Officio representation
- Constant interaction and regular attendance of each others' meeting
- Joint reports
- ESSC members involved *ad personam* in committees and advisory bodies (such as the Survey of Surveys study)
- Current projects, e.g. PPOSS activity under EC contract (planetary protection of outer solar system bodies, where SSB is an observer)

Cooperation and collaboration in space discussed between SSB & ESF since 1976

10 joint reports over 39 years

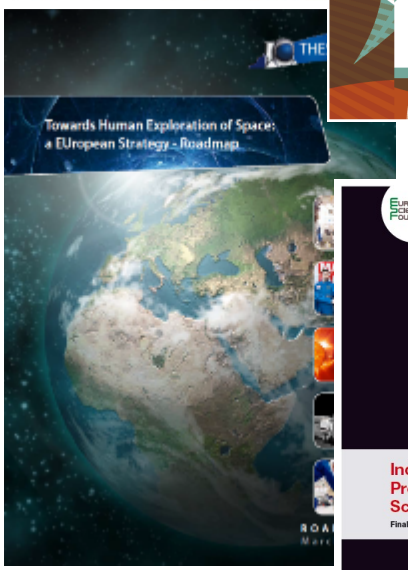
Overarching Science Policy Advice

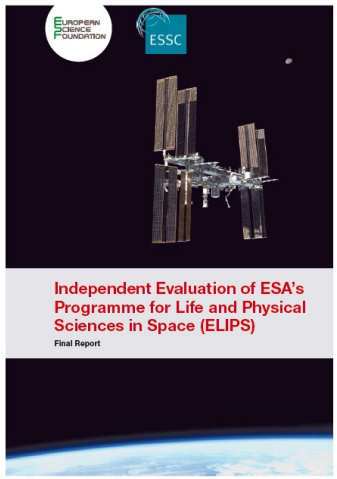
- **High level policy recommendations to ESA council at ministerial level (prepare 2016)**
- **High level policy recommendation to EC on space sciences related matters**
- ***Pro-Active* specific communications and recommendations expressed to institutions**

Specific Scientific Advice

- **When specialist targeted independent advice is required**

- **Setting up of *ad-hoc* committees, panels and projects**
- **Commissioned Studies**
  - ***Evaluation of ESA Microgravity Programme***
  - ***Strategic advice on planetary protection (two studies)***
- **Pro-Active disciplinary foresight and roadmaps**
  - ***Astrobiology (AstRoMap)***
  - ***Human space exploration (THESEUS)***
  - ***Nuclear propulsion (MEGAHITT)***
  - ***Technology development (TECHBREAK)***
  - ***Planetary Protection (PPOSS)***





Projects and Activities

Ongoing activities (ESSC Secretariat)

- Activities concluded in 2015
  - ASTROMAP (FP7 CSA) www.astromap.eu – ***major input for ELIPS' roadmapping – Published in Asyt***
  - Mars special regions (joint ESSC-SSB study for ESA & NASA) – ***available online***
  - Framework Agreement with D-TEC on Planetary Protection matters
- Ongoing activities
  - MASE (FP7 CSA) www.mase-eu.org
  - DEMOCRITOS (H2020 CSA) http://democritos.esf.org/
- Starting projects
  - BIOWYSE (H2020 R&I)
  - PPOSS (H2020 CSA)
  - EUROPLANET (H2020 RI) http://www.europlanet-eu.org/

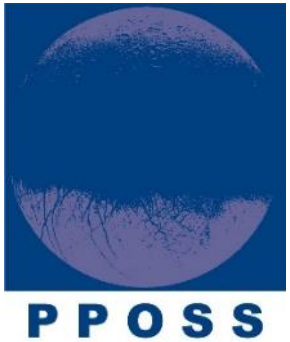
MEPAG – Mars special regions

Mars special regions

- Joint study between ESF and SSB
- Committee chaired by P. Rettberg (DLR), eight members
- Reviewed the MEPAG Special Region Science Analysis Group 2 report – Provided recommendations
- *Planetary Protection and Mars Special Regions —A Suggestion for Updating the Definition – Astrobiology Feb. 2016*

PPOSS

Planetary Protection of Outer Solar System Bodies



- **EC Horizon 2020 – 2016-1018**
- **Contractual Partners:**
  - European Science Foundation – ESF, France (Coordinator)
  - German Aerospace Center – DLR, Germany
  - Committee on Space Research – COSPAR, France
  - Eurospace, France
  - National Institute for Astrophysics – INAF, Italy
  - Space Technology Ireland Limited –STIL, Ireland
  - Imperial College of Science, Technology and Medicine – IC, UK

PPOSS

OBJECTIVES

- Describe the state of the art and good practice for implementing planetary protection requirements, identify good practices and lessons to be learnt
- Identify scientific challenges, scientific requirements and knowledge gaps related to planetary protection of outer solar system bodies, including small solar system bodies.
- Develop an European engineering roadmap
- Review of the international outer solar system planetary protection regulation structure, process and categorisation, suggest improvements
- Dissemination of knowledge

Main Deliverables

- A handbook on how to deal with Planetary Protection (targeted to the scientific and engineering communities). This handbook will represent an important and useful tool to disseminate knowledge on Planetary Protection at the global level.
- An engineering roadmap/list of technologies required to properly address PP constraints related to the exploration of the outer solar system.
- A suite of seminars
- A science white book - A survey and review of scientific issues related to Planetary Protection of outer solar system bodies. This deliverable will focus on PP-related scientific requirements for exploration as well as scientific challenges and knowledge gaps. It will also include recommendations on how to best deal with these issues
- A white book including substantiated recommendations for improvement of the COSPAR PP Policy for outer solar system bodies.

MASE

Mars Analogue for Space Exploration

- **EC FP7 – 2014-2017**
- **Contractual Partners:**
  - European Science Foundation – ESF, France (Coordinator)
  - University of Edinburgh – UK Centre for Astrobiology, UK
  - DLR, Germany
  - Universidad Autónoma de Madrid, Spain
  - MATIS, Iceland
  - Leiden University, Netherlands
  - INTA-CAB, Spain
  - EANA, France
  - University of Graz, Austria
  - CNRS, France
  - British Antarctic Survey, UK

MASE
Mars Analogues for Space Exploration

Project Overview

- **Isolate and characterise** anaerobic microorganisms from selected sites that closely match environmental conditions that might have been habitable on early Mars.
- **Study their responses** to realistic combined environmental stresses that might have been experienced in habitable environments on Mars.
- **Investigate their potential for fossilisation** on Mars and their detectability by carrying out a systematic study of the detectability of artificially fossilised organisms exposed to known stresses.

MASE
Mars Analogues for Space Exploration

- MASE will also consider thoroughly the following cross cutting aspects i) optimised methodologies for **sample management and experimental process** and ii) optimised methodologies for **life detection.**

AstRoMap

Astrobiology Roadmap

- **EC FP7 – 2012-2015**
- **Contractual Partners:**
  - Instituto Nacional De Técnica Aeroespacial – Centro De Astrobiología (Inta-cab), Spain (Coord.)
  - The European Science Foundation (ESF) – Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR)
  - Belgian User Support and Operations Centre (B-USOC)
  - Istituto Nazionale di Astrofisica (INAF)
  - European Astrobiology Network Association

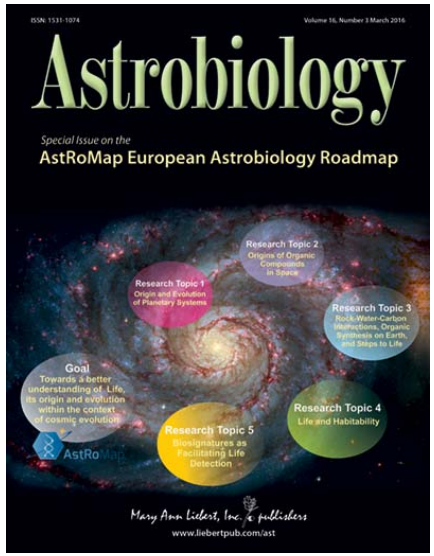
AstRoMap

(See talk by G. Hornek)

AstRoMap

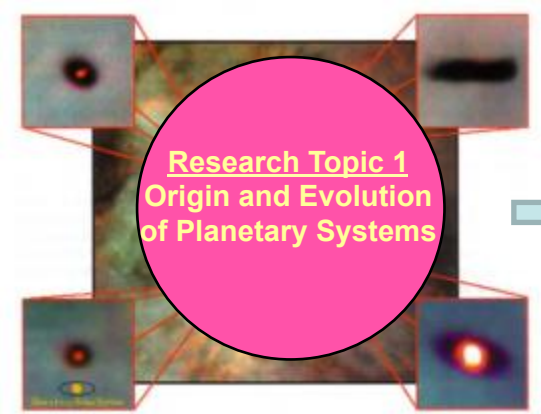
Objectives

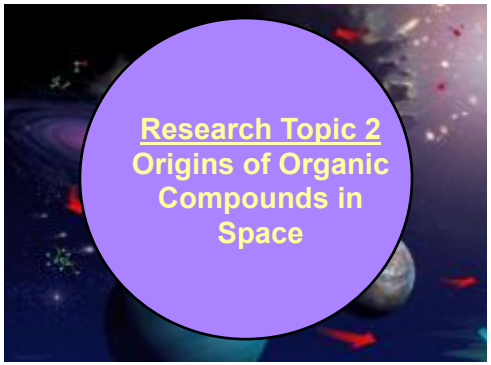
- Mapping scientific knowledge related to astrobiology in Europe
- Identify the main astrobiology issues to be addressed by Europe in the next decades in relation with space exploration
- Identify potential mission concepts that would allow addressing these issues
- Identify the technology developments required to enable these missions
- **Provide a prioritised roadmap integrating science and technology activities as well as ground based approach**

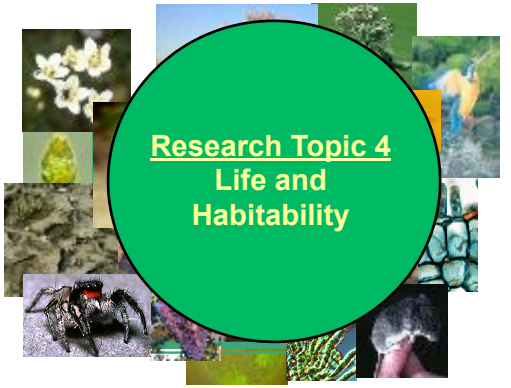


AstRoMap

AstRoMap







To better understand Life, its origin and evolution within the context of cosmic evolution

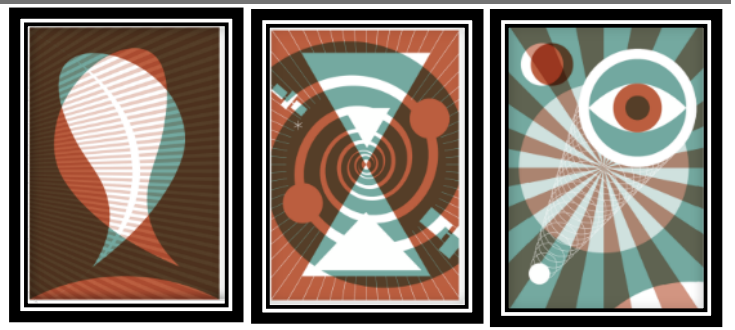
Exo-oceans

Studying the worlds in the outer solar system with possible undersurface liquid water oceans

- Concept for a joint working group between ESSC and the European Marine Board
- Would involve marine scientists (geo/bio), planetary scientists and astrobiologists.
- Objectives: provide recommendations on issues of common scientific interest and opportunity to foster collaborations between programmes

Foresight Activity (Completed in 2014)

- Identified Space Overwhelming Drivers
- Identified the main issues for space
- Suggested some potential solutions



- Reduce mass, maintain stiffness
- Build a spacecraft and space missions that can last 50 years
- Deploy a 30m+ telescope into space (assembling, deploying, self-supporting, positioning, maintaining)
- Autonomous geophysical survey of planets
- Enable humans to stay in space for more than two years (Mars mission)

A research community and infrastructure for PLANETARY SCIENTISTS

www.europlanet-2020-ri.eu

H2020 Europlanet RI

Nigel Mason, Athena Coustenis
(coordinators)
ESF (N. Walter) is evaluation office

Europlanet :
a growing « business », an expanding community

FP6 2005-2008: 2 M€ - ISSI 90 k€
Coordination action -> only networking activities (NA)

The « fundamental equation » of EC RI networks!

FP7 2009-2012: 6 M€ - ISSI 240 k€
Research Infrastructure network -> **RI = NA + TNA + JRA**

H2020 2015-2019: 10 M€
Research Infrastructure network -> NA, TNA, JRA and services

Engagement with other H2020 Space projects (COMPET);
Eurocares/PPOSS; Upwards; MiARD;
EUSpaceAwareness ; Neoshield/ASTERIX

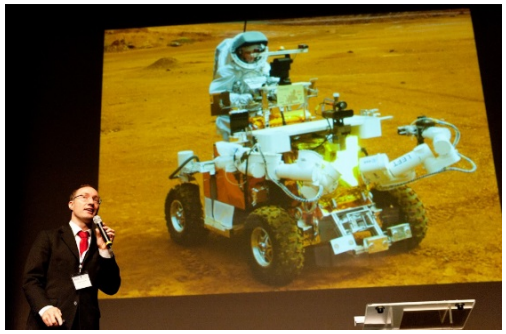
- Europlanet is Europe's permanent community consortium for planetary science. Any institute can join by signing the MOU
- It has its own annual conference: the EPSC
- It takes all actions to promote European planetary science
- It helps the community to seize all adequate funding opportunities:

2015-19: Europlanet 2020 RI

- **Budget 9.945 million Euros 2015-2019,**

  start date 1 September 2015, to:

- **Support scientific meetings and workshops**
- **Foster Academia-industry collaborations through technology workshops**
- **Support and develop a unique Outreach programme including support pilot projects.**
- **Provide access to 5 field sites and 11 labs (open calls + peer review selection): TNA's**
- **Develop and run two new on-line services**
- **Fund the necessary developments through Joint Research Activities (JRA)**
- **INTERNATIONAL COLLEAGUES ARE WELCOME IF WITHIN A EU TEAM !!**



Access to field sites and lab facilities: EUROPLANET

Access to 5 field sites and 11 laboratories:

- Planetary Field Analogues
- Distributed Planetary Simulation Facilities
- Facilities & Equipments

(for high precision or high spatial resolution analyses)

Develop such facilities through Joint Research projects

Dallol depression (Ethiopia)

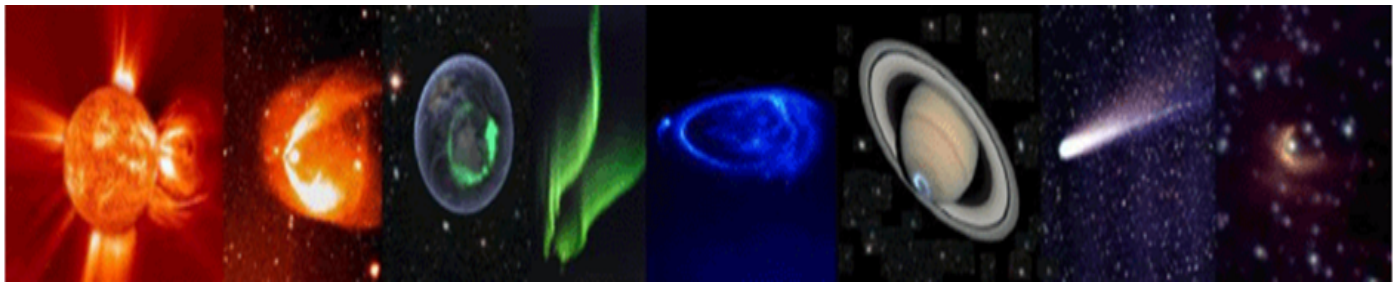
Mars simu;ation chamber – OU, Milton Keynes

On-line services

Europlanet 2020 RI will develop and provide access to on line tools and data of interest to planetary science through:

- **Virtual European Solar and Planetary Access (VESPA)**

- **Planetary Space Weather Services (PSWS)**



VESPA

- It will provide the first multi-thematic Solar System and Planetary Science virtual/ online portal.

- It will also improve the connections between existing VO tools taking into account the specificities of Solar System Science.

VESPA – examples of benefits

- Searching in a methane lake region of Titan, the user will be able to retrieve the atmospheric conditions depending on season or altitudinal density and composition profiles

- looking for auroral images at Jupiter, the user will have also access to observations in the low frequency radio range, as well as thermospheric models, upstream solar wind or magnetospheric conditions;

- Characterising planetary/comet ices ,the user will also be able to get laboratory **observations for various composition of ices.**

PSWS – Planetary Space Weather Service

http://planetaryspaceweather-europlanet.irap.omp.eu/#

PSWS will provide;

- European planetary scientists with new methods, interfaces, functionalities and/or plug-ins dedicated to planetary space weather
- Space weather services will be operational in Europe at the end of the programme.

http://www.europlanet-2020-ri.eu/

Peer Review Process

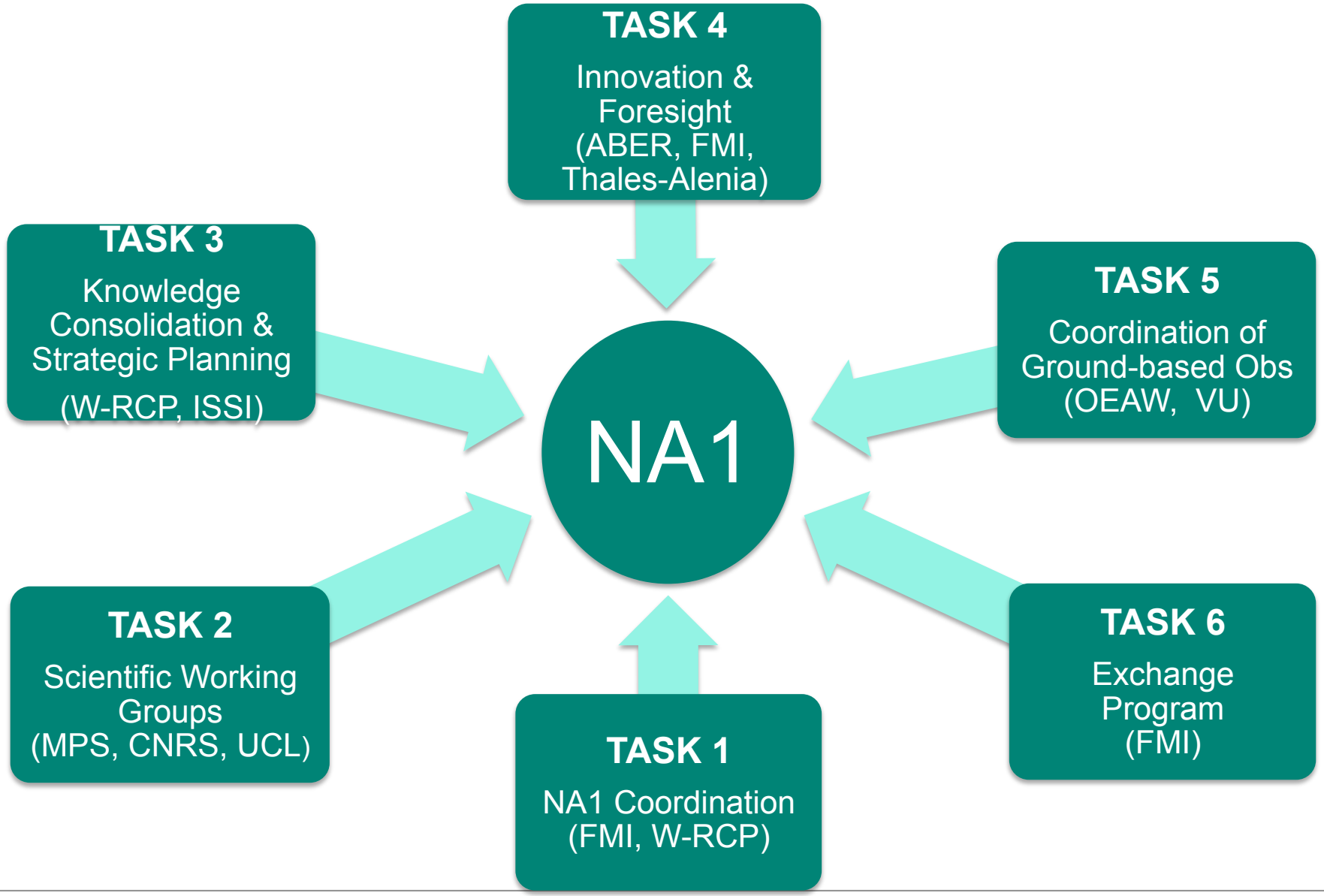
Administered by ESF: (Nicolas Walter)

4 Open Calls: competitive bidding process for access to the TA's. Fully anonymous process

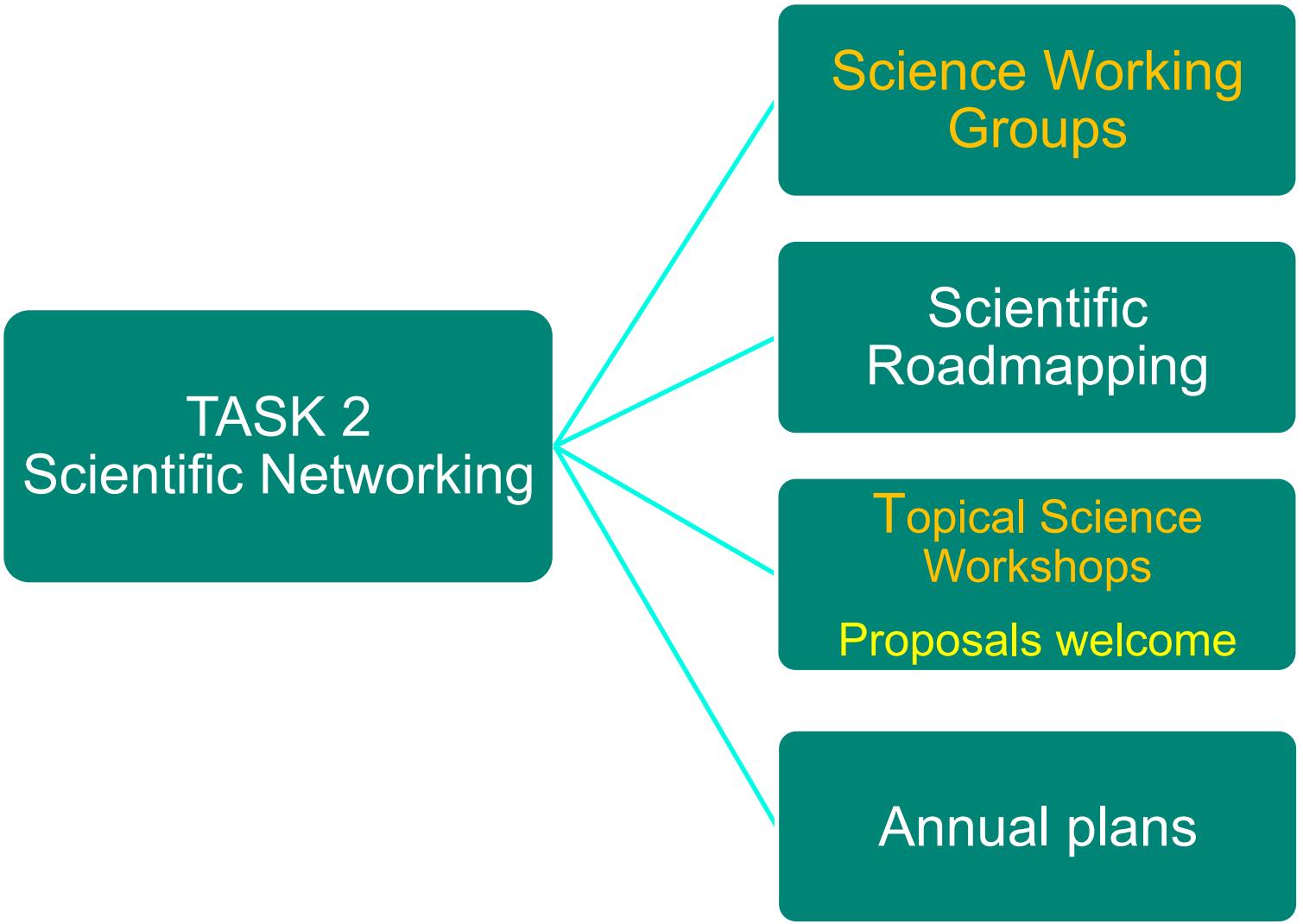
Institutes can only advise if a project proposal is NOT viable or should be undertaken elsewhere.

Activity NA 1: Innovation through science networking

NA1 Science through networking



TASK 2:
Scientific Networking



TASK 2:
Topical Science Workshops (cont.)

- **Cometary science** (Rosetta oriented). Focus on cometary activity?
- **Mercury science** (Bepi Colombo oriented). Review of the state of knowledge, including modelling
- **Mars science** (from Curiosity and MAVEN via Exomars to Mars2020).
- **Giant planets science**. Galileo/Cassini/Juno/ links with Hinode (auroral physics at giant planets and related processes).
- **Astrobiology, life in extreme environments** (related to EXOMARS but also habitability with JUICE). Modelling this in laboratory.
- **Future instruments and methods in planetology**.
- **Future mission concepts to Outer planets**: Why do we need to (re)visit Uranus and Neptune.
- **From planets to exoplanets**, how diverse planets can be.... and how diverse are their interactions with their star. Future observational capabilities.
- **Preparing sample returns and their analysis** (including meteorite analysis).

OUTREACH programme

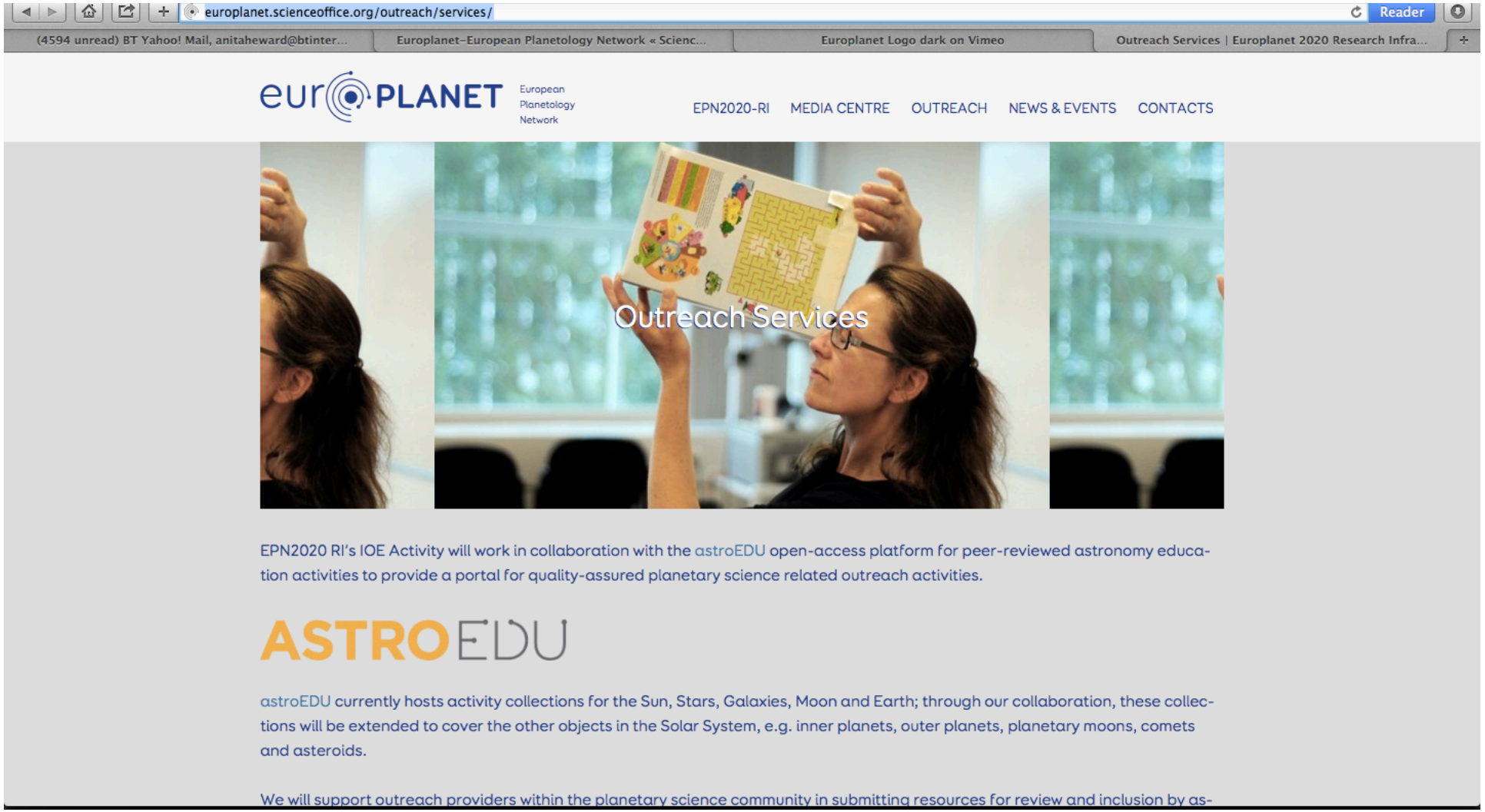
NA2 - Impact through Outreach and Innovation

- Broken down into three strands:
  - **Outreach Services and Community Support**
  - Dissemination to Stakeholders
  - Development of Outreach Tools

- Target audiences:
  - Outreach providers
  - Educators
  - Informal learning
  - Media
  - Policy Makers
  - Industry
  - General Public
  - Students

- Team:
  - Science Office
  - Observatoire de Paris
  - University College London
  - University of Latvia
  - Institute of Accelerating Systems & Applications Athens
  - CAB-INTA
  - University of Vilnius
  - University of Leiden

Outreach website redesign



www.europlanet-eu.org

A research community and infrastructure for YOU

www.europlanet-2020-ri.eu

Outcomes and advice from ESSC


cnes
CENTRE NATIONAL
D'ETUDES SPATIALES

ESSC Plenary meeting
7-9 Dec 2015, Paris, France

- ESSC is finalising the Strategic/Operational Plan 2016-2019
- Consolidating Expert Boards position and activities in continuing ESF → joint session at last plenary (e.g. joint ESSC-NuPECC Working Group on radiation/ hadrontherapy/nuclear medicine; joint ESSC-EMB WG on « exo-oceans »)
- Preparing the ESA Ministerial Council 2016
- Strengthening the existing partnership with our international partners and seek similar relation with other countries where possible
- Offering coordination between the various space science roadmaps

Agenda of the 50th ESSC plenary meeting, Paris, 7-9/12/15

Presentations by

- **Jean-Yves LE GALL**, CNES President
- **Len FISK**, COSPAR President
- **Alvaro GIMÉNEZ**, Director ESA D-SCI
- **Marc HEPPENER**, Chief Science Officer ESA D-HRE
- **Maurice BORGEAUD**, ESA D-EOP
- **Mark McCAUGHREAN**, ESA D-SCI
- **Fabienne CASOLI**, Deputy Director CNES-DSP
- **Oleg KORABLEV**, Deputy Director IKI
- **Jean-Louis FELLOUS**, COSPAR Executive Director
- **Chi WANG**, Deputy Director NSSC, representing Ji WU (by teleconference)
- **Michael MOLONEY**, Director SSB/ASEB, The National Academies (USA)
- **Nicolas PETER**, EC DG-GROW Space
- **Catherine CESARSKY**, Chair SSAC
- **Chris RAPLEY**, Chair HiSPAC
- **Berndt FEUERBACHER**, Former Chair HESAC

Panels/interactions with

- **Angela BRACCO**, Chair NuPECC
- **Jan MEES**, Chair EMB
- **Hans van der MAREL**, Chair CRAF
- **Wim van DRIEL**, Chair Elect CRAF

ESSC Living Document

We are preparing a full « living » « ESSC Recommendations Document » for distribution by May 2016 to our partners and stakeholders, EFOs etc and presentation at the ESA 2016 Ministerial.

This will include thematic recommendations that are also currently being prepared by the ESSC panels.

ESSC recommendations to the ESA Ministerial Council Luxembourg 2/12/14

- **Regarding ESA and EC relationship** ESSC favoured the solution of a step-wise evolution of ESA that would enhance the coordination on space projects within Europe (with EC)
- **Regarding the ISS utilisation** major funding cuts in the ELIPS programme have endangered timely realisation and exploitation of several European experiments and Europe's leading role world-wide in the fields of Life and Physical Sciences. ESSC thus strongly recommended that the full additional subscriptions necessary for ELIPS Period 4 be approved. This would have guaranteed Europe's return on investment until 2020 - and beyond, should Europe decide to continue its commitment
- **Regarding European Launchers** ESSC expressed support for the flexible approach of the Ariane family

ESSC recommendations to the ESA Ministerial Council Luxembourg 2/12/14

- **Regarding Europe's Exploration Programme** ESSC supported Europe's participation to the Luna-Resurs and Lunar Sample Return missions with Russia, as an integral part of ESA's broader exploration strategy. ESSC continued to recognise the importance of ExoMars missions and urged ESA member states to ensure that funding is sufficient for the launch of the ExoMars rover in 2018. The ESSC also emphasized the great scientific value of other mission concepts such as the network mission to Mars and the Phobos sample return mission and recommend that they proceed into the next phase
- **Regarding Copernicus** ESSC underlined the importance of the Copernicus Space Component to Europe's economic competitiveness and the technological advances that give its space industry a leading position in many areas. The ESSC therefore strongly recommended that participants maintain or increase their commitments to GSC-2 to ensure successful delivery of the programme, and that ESA MS consider entering or maintaining their involvement in the GSC-3 programme phase.

EUROPEAN SCIENCE FOUNDATION

Press Release on climate change (Dec 2015)

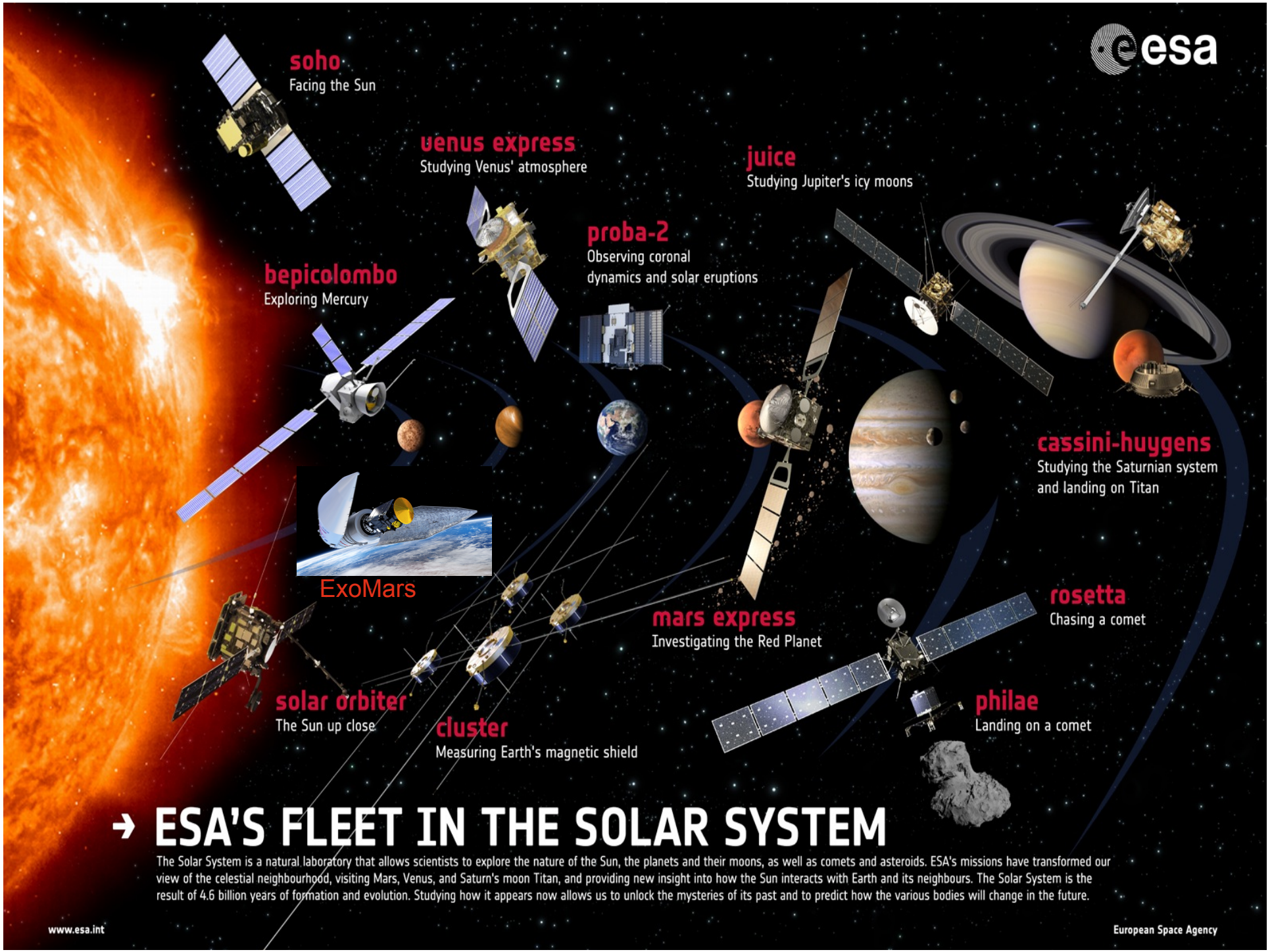
The European Space Sciences Committee supports the Article (2) agreement on climate change of the Declaration of the "2015 Budapest World Science Forum on the enabling power of science" and encourages and urges such a universal agreement aiming at stabilizing atmospheric concentrations of greenhouse gases by inciting countries to reduce their emissions in order to avoid dangerous anthropogenic interference with the climate system, which could lead to disastrous consequences as witnessed in other objects of our solar system.

The Committee recognizes in particular the Copernicus program and Sentinel missions as an unprecedented commitment to Earth Observation in the service of stakeholders. The Sentinel satellites will provide European scientists, decision makers and citizens with information on the state of our climate and environment of unparalleled detail and quality. To maximise the impact of these programs, Europe needs to make archived and near-real time data easily accessible, and should ensure its quality through a comprehensive and ongoing program of calibration and validation. Mission planning should be transparent and updated regularly with the needs of all stakeholders considered. Europe and the GEOS nations must continue to develop operational programs, such as Copernicus, that allow us to monitor the progress of climate change and its impact, through the mapping of important indicators. GEOS must also continue to develop thematic platforms, such as the ESA Earth Explorer missions that target specific scientific questions helping us better understand the mechanisms that link the natural and human processes with greenhouse gases emissions and climate change".

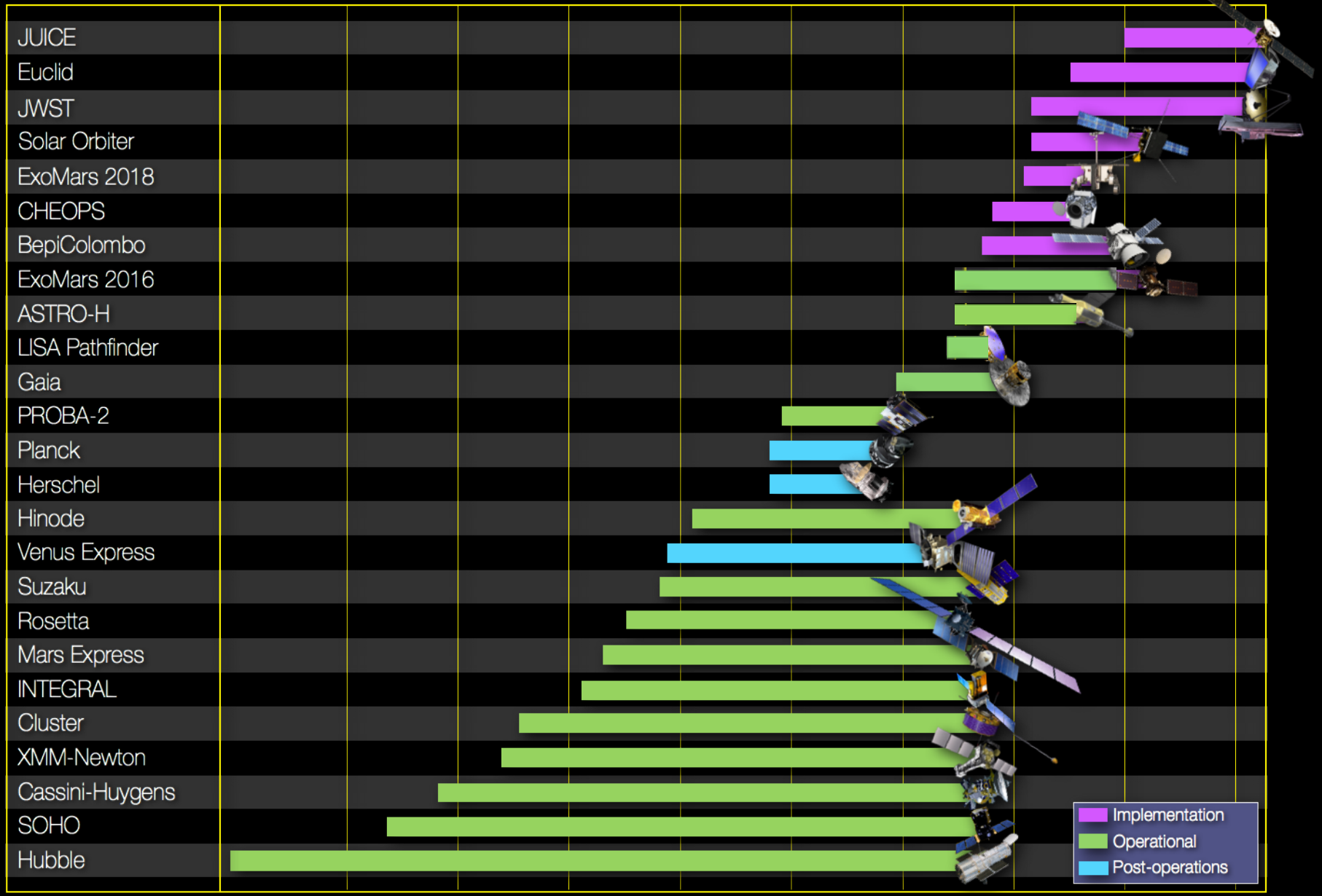
ESSC and HESAC on nuclear power

- ESSC is very supportive of the the development of **nuclear power** sources and propulsion for European space missions, which was discussed and also promoted by ESA's Human and Exploration Science Advisory Committee (HESAC). This would enable a number of missions where solar power is inadequate or impossible to use (e.g. deep space missions and long-term in-situ operations in dark areas)
- ESSC Secretariat at ESF is involved in EU-funded activities in the domain of advanced (nuclear) propulsion for space (MEGAHIT, DEMOCRITOS)
- Discussion on call for ideas to explore new partnership between ESA and the private sector, which is a very complex issue, was also brought forth to ESSC. Discussion has started

On the European Space Science Program


esa
soho
Facing the Sun
venus express
Studying Venus' atmosphere
juice
Studying Jupiter's icy moons
proba-2
Observing coronal
dynamics and solar eruptions
bepicolombo
Exploring Mercury
cassini-huygens
Studying the Saturnian system
and landing on Titan
ExoMars
rosetta
Chasing a comet
mars express
Investigating the Red Planet
solar orbiter
The Sun up close
cluster
Measuring Earth's magnetic shield
philae
Landing on a comet
→ ESA'S FLEET IN THE SOLAR SYSTEM
The Solar System is a natural laboratory that allows scientists to explore the nature of the Sun, the planets and their moons, as well as comets and asteroids. ESA's missions have transformed our view of the celestial neighbourhood, visiting Mars, Venus, and Saturn's moon Titan, and providing new insight into how the Sun interacts with Earth and its neighbours. The Solar System is the result of 4.6 billion years of formation and evolution. Studying how it appears now allows us to unlock the mysteries of its past and to predict how the various bodies will change in the future.
www.esa.int
European Space Agency

ESA science & robotic exploration missions

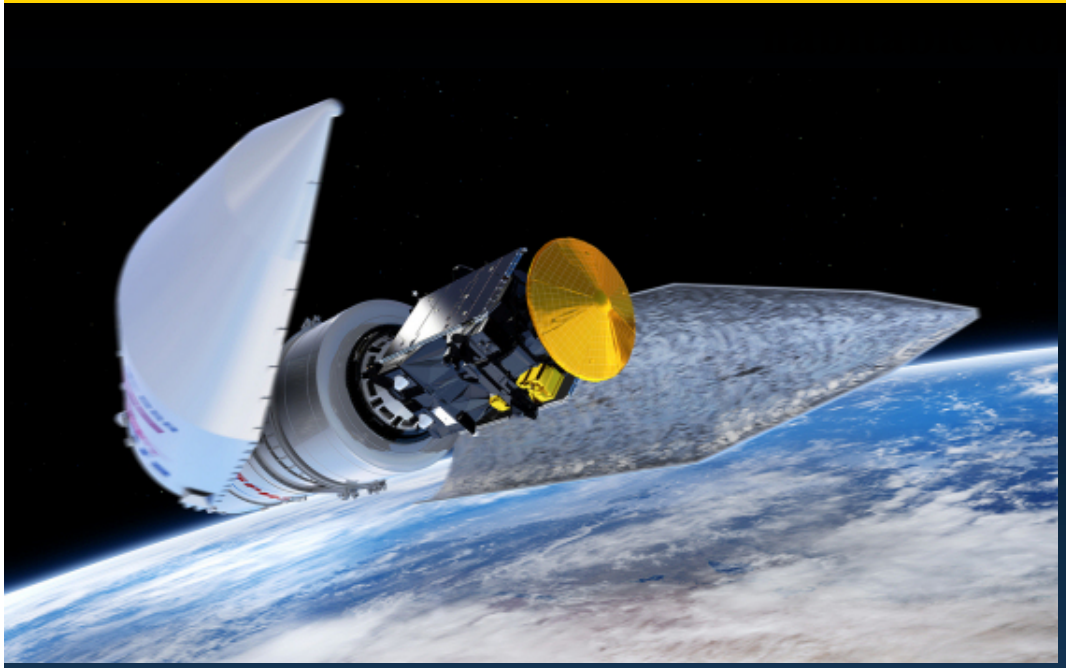


ESSC's Solar System and Exploration panel

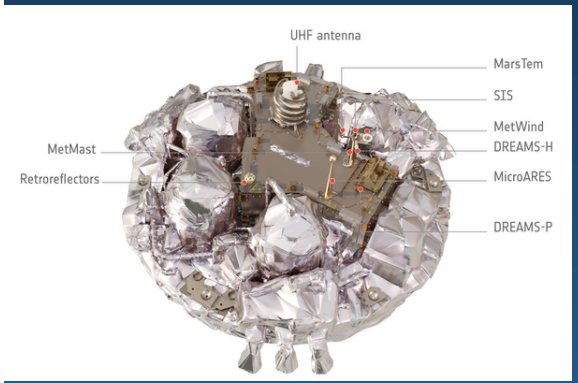
- ESSC commends ESA on its Solar System and Planetary Exploration programme which is recognized by all space agencies as having the most diverse portfolio and steady cadence
- The medium and large missions/themes compose an excellent science programmewith significant technology achievements. ESSC recommends building on the success of Cassini-Huygens, MEX, VEX, Rosetta, etc compounding the excellency with an exciting programme that will ensure the financial support by the member states
- Europe and ESA should participate in the global development of a coordinated robust space system of Sun-heliosphere monitoring in order to acquire exhaustive real-time data sets, to improve Space Weather understanding and predictions and to monitor solar activity, solar eruptions, and their effects with similar standard payload
- ESSC recommends focused research on the physical and chemical properties of NEOs and SDOs in the near-Earth space, increasing our knowledge-based preparedness for mitigating the threats posed by these objects
- The ESSC supports efforts by the ESA Executive to secure funding for Europe's continued participation to the Luna-Resurs and Luna Glob missions. These, along with the proposed Phobos Sample Return and the Lunar Polar Sample Return missions with Russia should be an integral part of ESA's wider exploration strategy. The ESSC also recommends widening collaboration in this area to include other international partners with expertise in lunar and other small body exploration, in the spirit of Global Exploration Roadmap
- The ESSC strongly supports further development of the EREP programme as it provides the technologies for Europe to play a major role in the future sample return programme with an ultimate goal of Mars Sample Return (MSR), including the timely design, building and commissioning of sample receiving and curation facilities

ExoMars 2016: an orbiter and a descent module: Schiaparelli

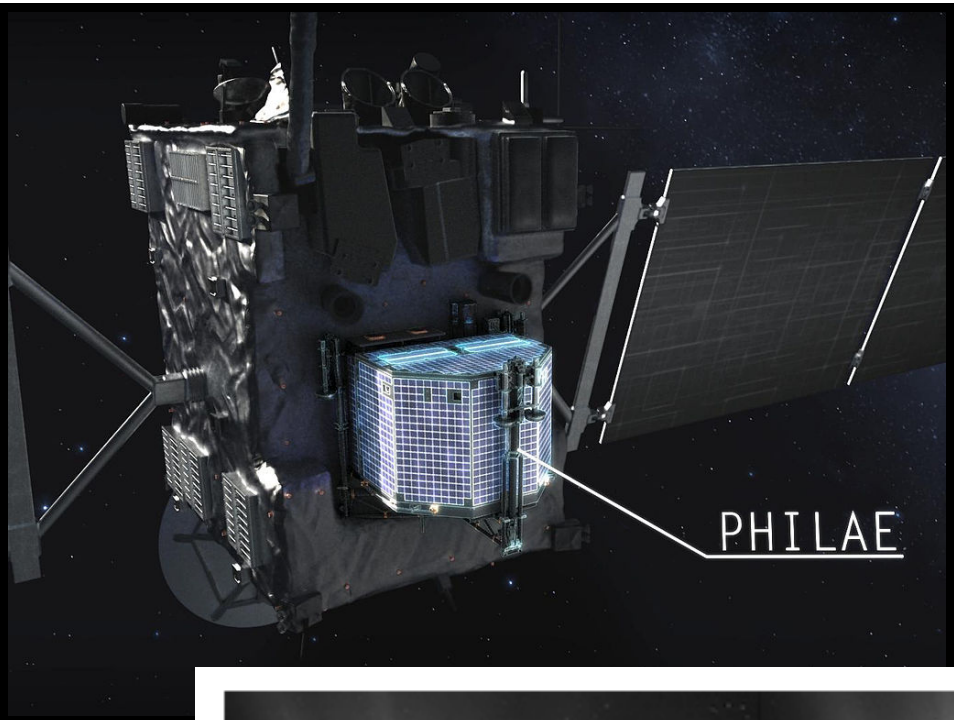
MARS and EXOMARS



Launch : 14 March 2016 at around 10:30 CET

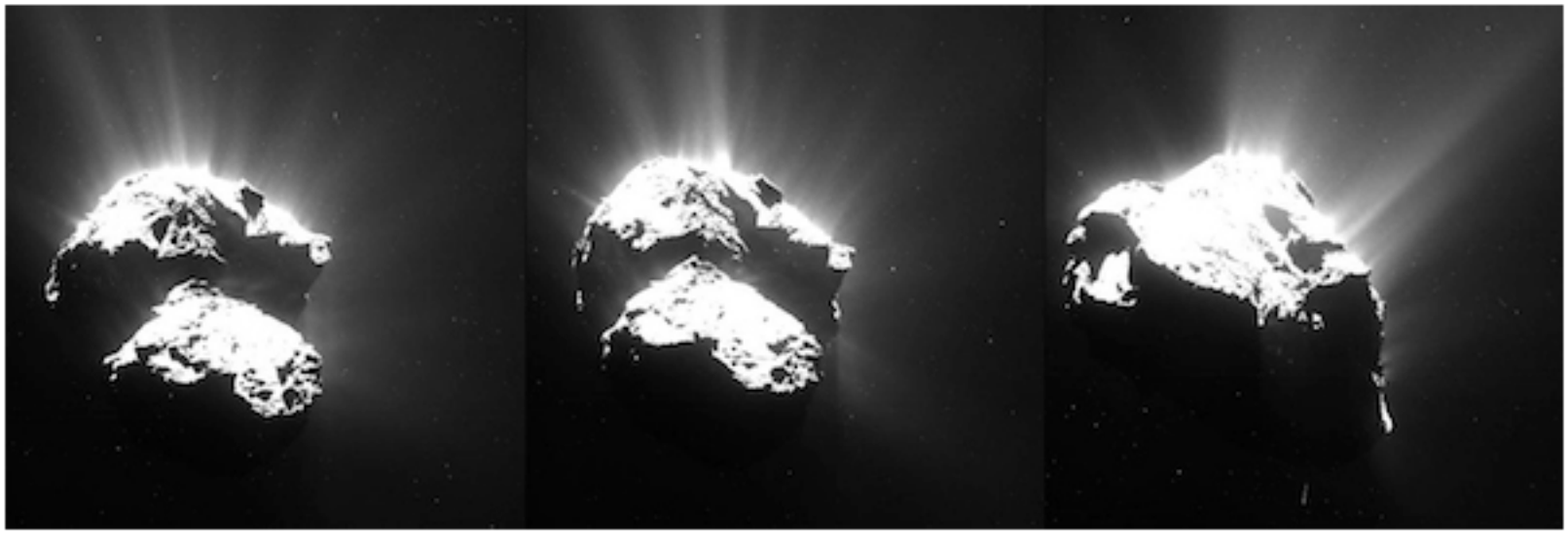


- Mission from December 2017 until end of 2022. Orbiter will serve as relay for the 2018 rover mission
  - will study the Maritan atmosphere for evidence of biological gases (CH4, etc)
- The EDLM will provide technology for controled landing on Mars (orientation and velocity)
  - will maximise use of technologies like material for thermal protection, parachute, radar Doppler altimeter system, braking system with liquid propulsion



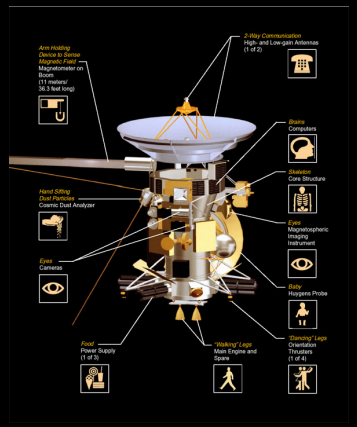
ROSETTA

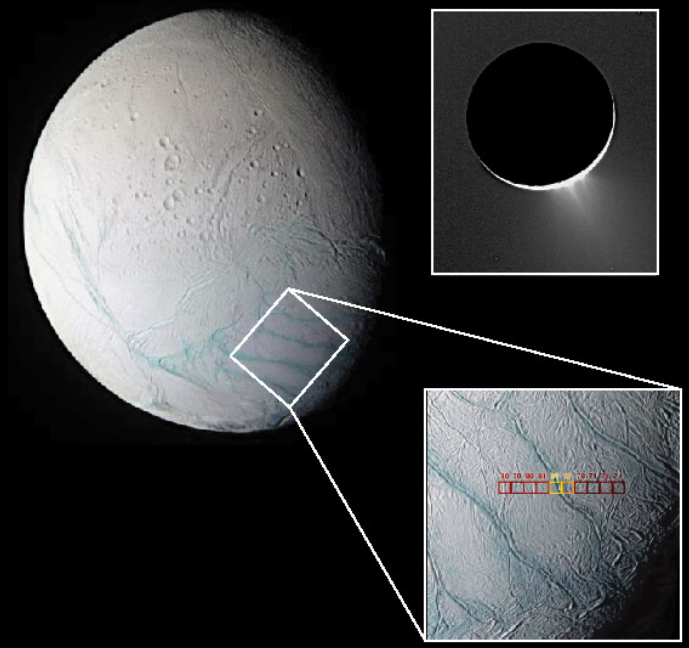
ESA PR March 2016



OSIRIS images of Comet 67P/C-G taken on 26 July 2015, before, during and after the detection of the diamagnetic cavity. *Credit: ESA/Rosetta/MPS for OSIRIS Team MPS/UPD/LAM/IAA/SSO/INTA /UPM/DASP/IDA*

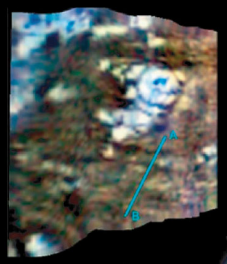
Cassini-Huygens (2004-2017) reveals Titan and Enceladus





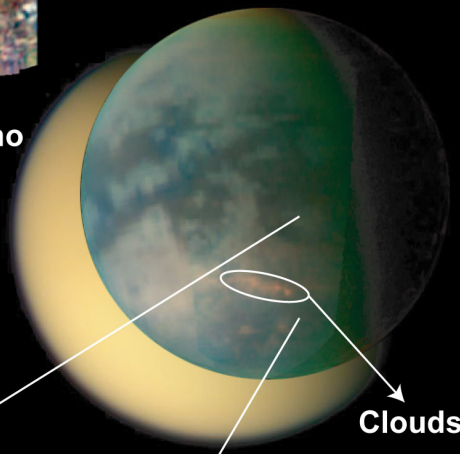
Enceladus

Hydrocarbon lakes



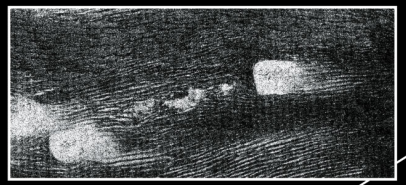
Cryovolcano

Titan: a frozen Earth ?

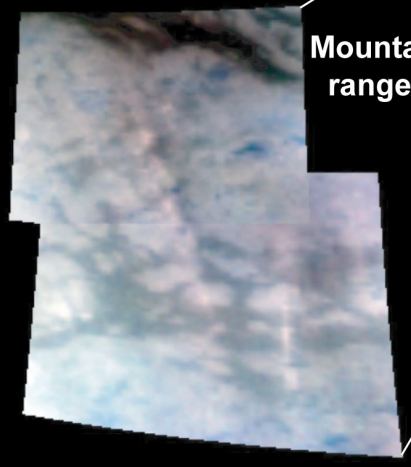


Clouds

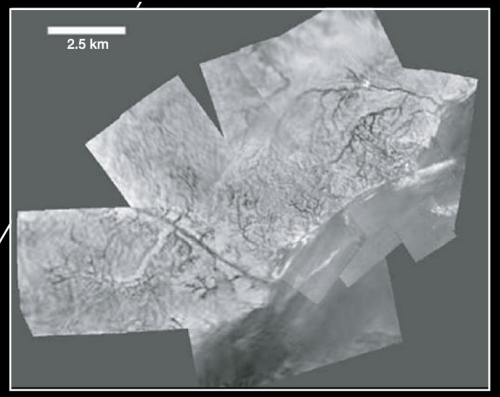
Dune fields



Mountain ranges

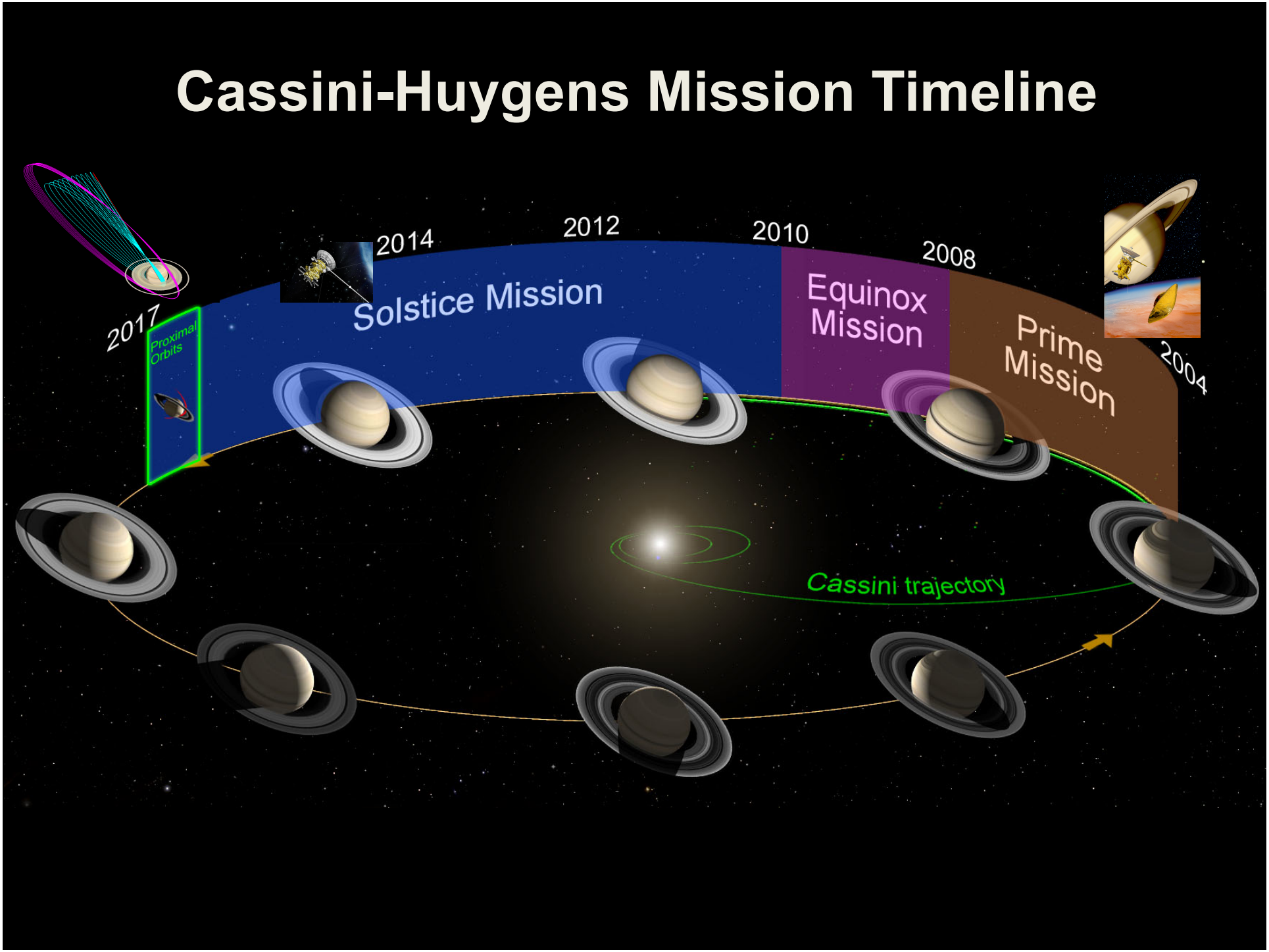


River networks



Titan

Cassini-Huygens Mission Timeline

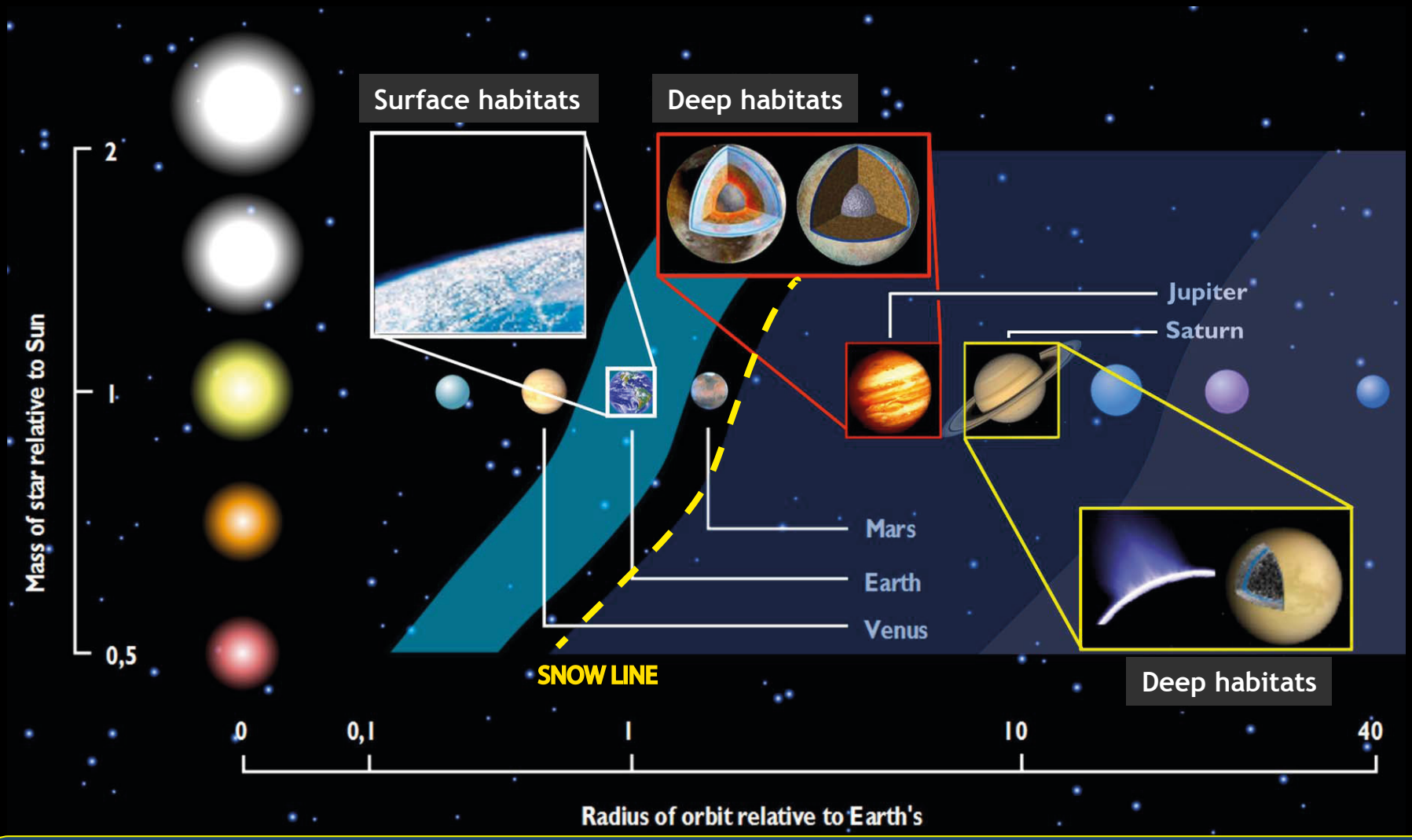


Habitable worlds in the outer solar system ?

Future exploration

Need for further in-depth and in situ exploration of the deep habitats and the extended habitable zone around gas giants

Icy moons : deep habitats in the solar system



Classes I-II: habitable zones on the surface, not much water, small domain
Beyond the snow-line: deep habitats within the hydrospheres. Icy moons, Ganymede and Europa and Titan and Enceladus, are the archetypes of classes III-IV of habitable worlds

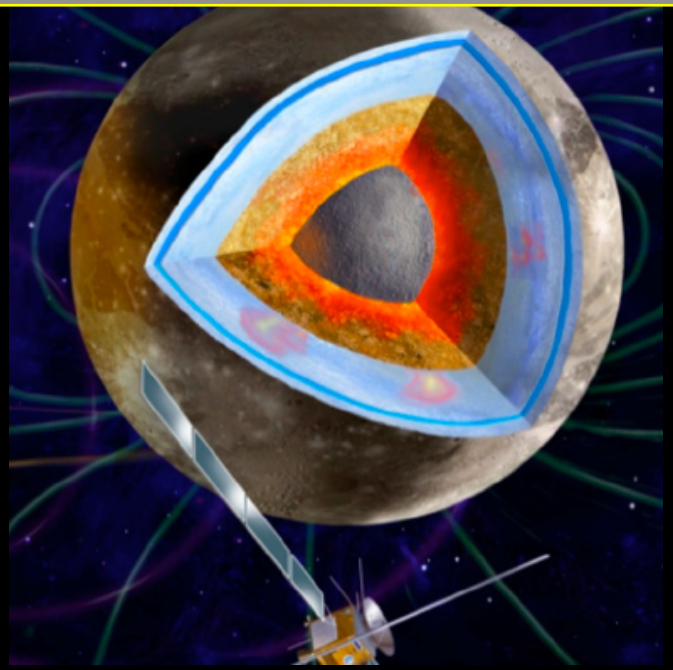
Emergence of the habitable zone around Jupiter

Three large icy moons to explore

Ganymede - class IV

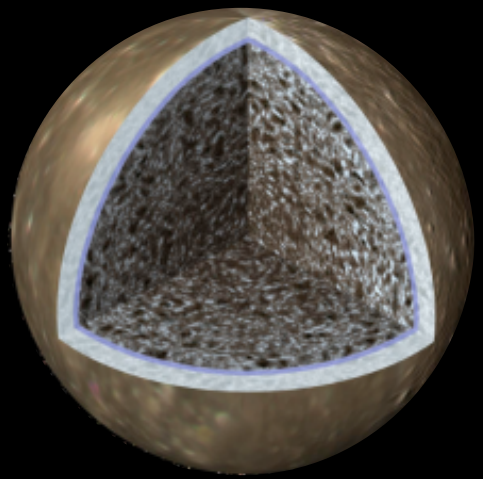
- Largest satellite in the solar system
- A deep ocean
- Internal dynamo and an induced magnetic field – unique
- Richest crater morphologies

- Best example of liquid environment trapped between icy layers



Callisto - class IV

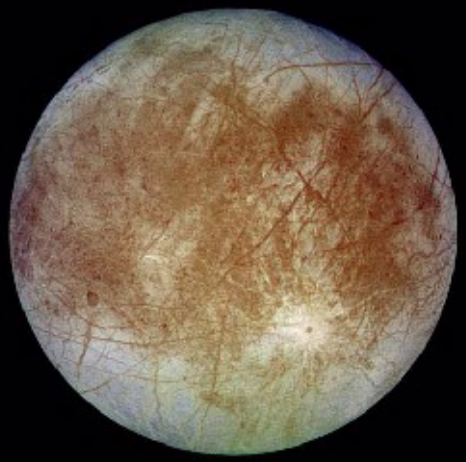
- Best place to study the impactor history
- Differentiation – still an enigma
- Only known example of non active but ocean-bearing world
- The witness of early ages



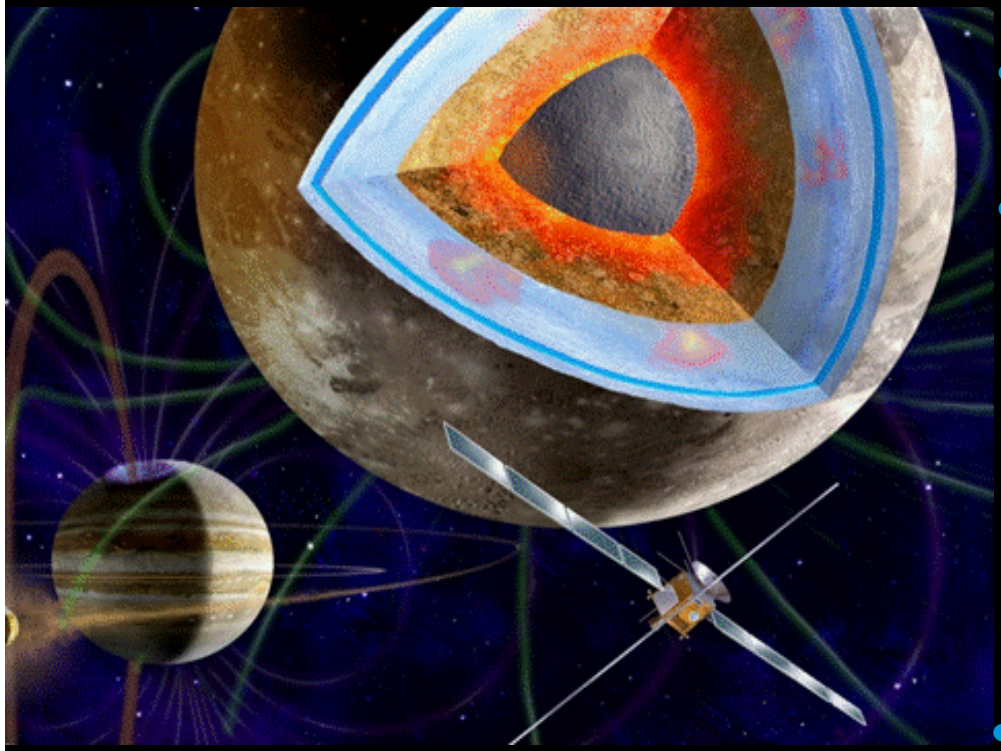
Europa - class III

- A deep ocean
- An active world?

- Best example of liquid environment in contact with silicates

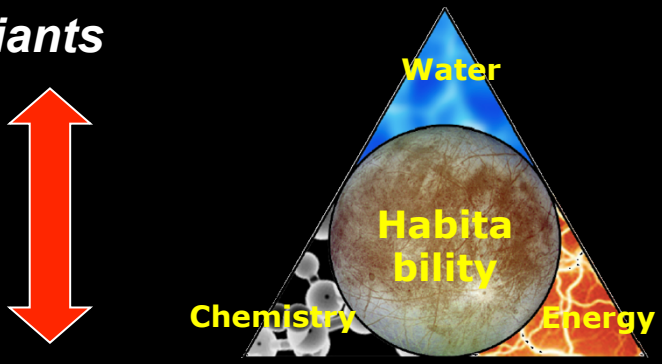


JUICE: JUpiter Icy moons Explorer



JUICE Science Goals

- *Emergence of habitable worlds around gas giants*
- *Jupiter system as an archetype for gas giants*



Cosmic Vision Themes

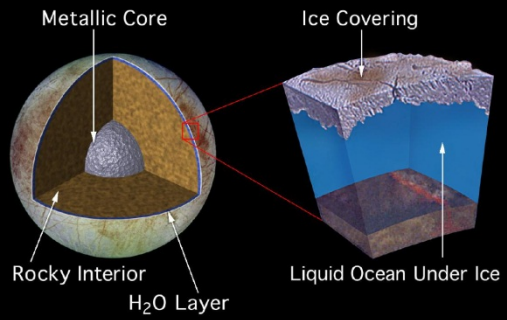
- *What are the conditions for planetary formation and emergence of life?*
- *How does the Solar System work?*

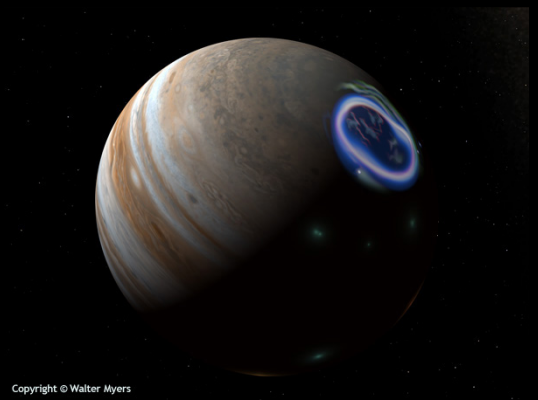
JUICE : the 1st Large CV mission concept

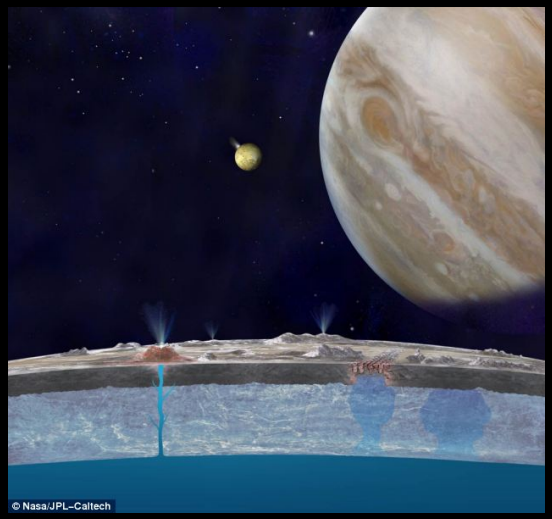
- *Single spacecraft mission to the Jovian system*
- *Investigations from orbit and flyby trajectories*
- *Synergistic and multi-disciplinary payload*
- *European mission with international participation*

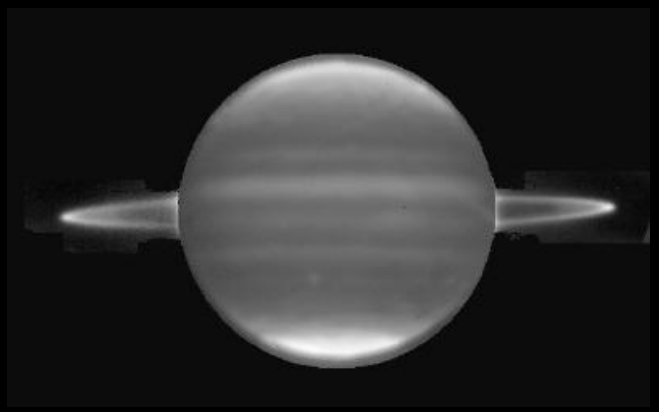
Topics:
Planet, moons, rings, magneto

- Interior
- Subsurface
- Geology
- Atmosphere
- Plasma
- Habitability
- Link to exoplanets









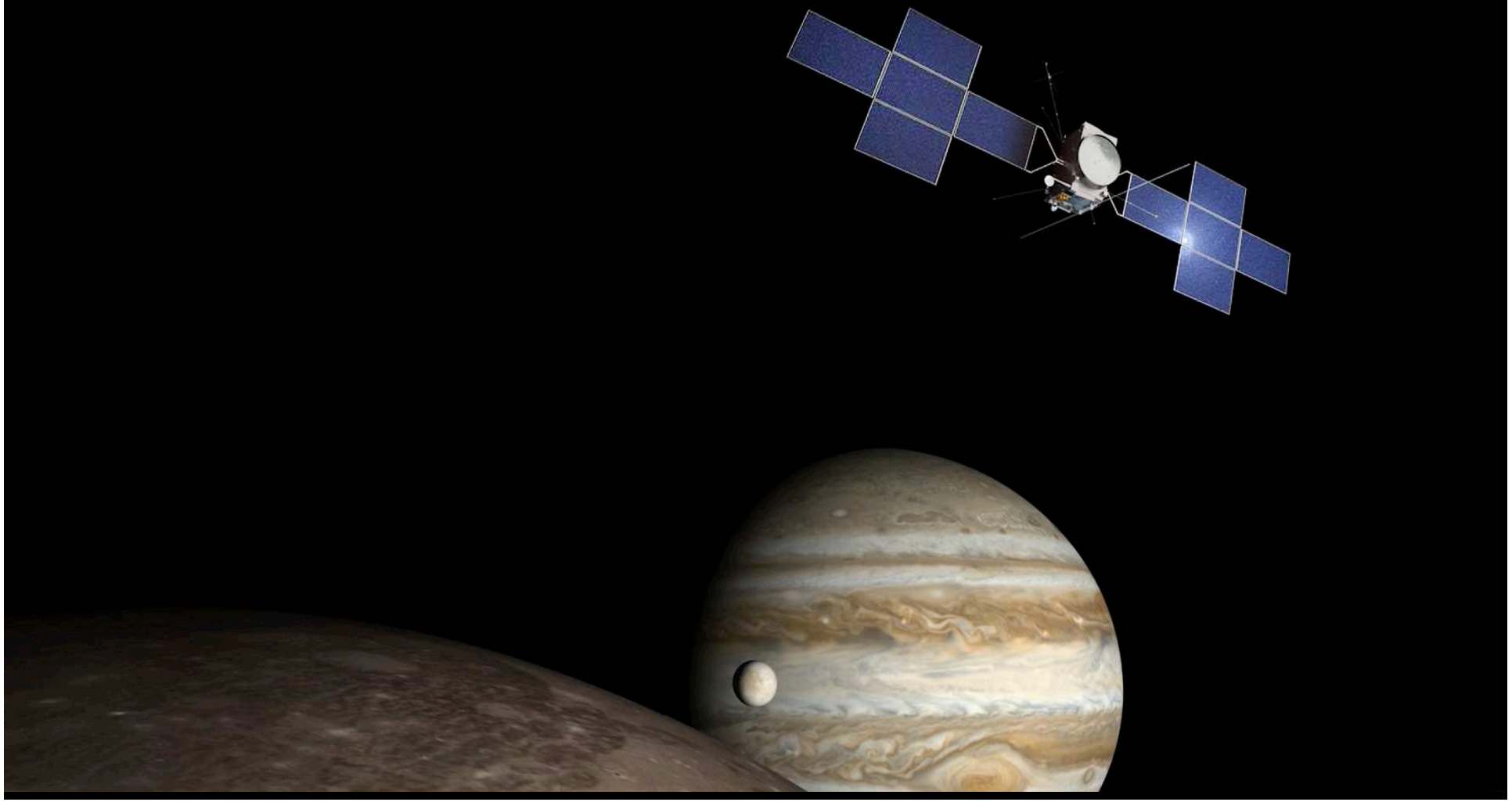
Jupiter system: largest planet, largest storm, fastest rotation, largest magnetic field, largest moon, largest moon system, most active moons

JUICE : Spacecraft, Payload & scenario

Mission contractor

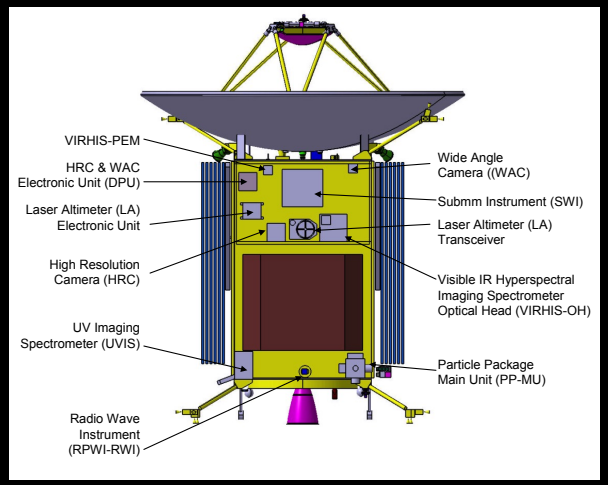
AIRBUS DEFENCE AND SPACE :

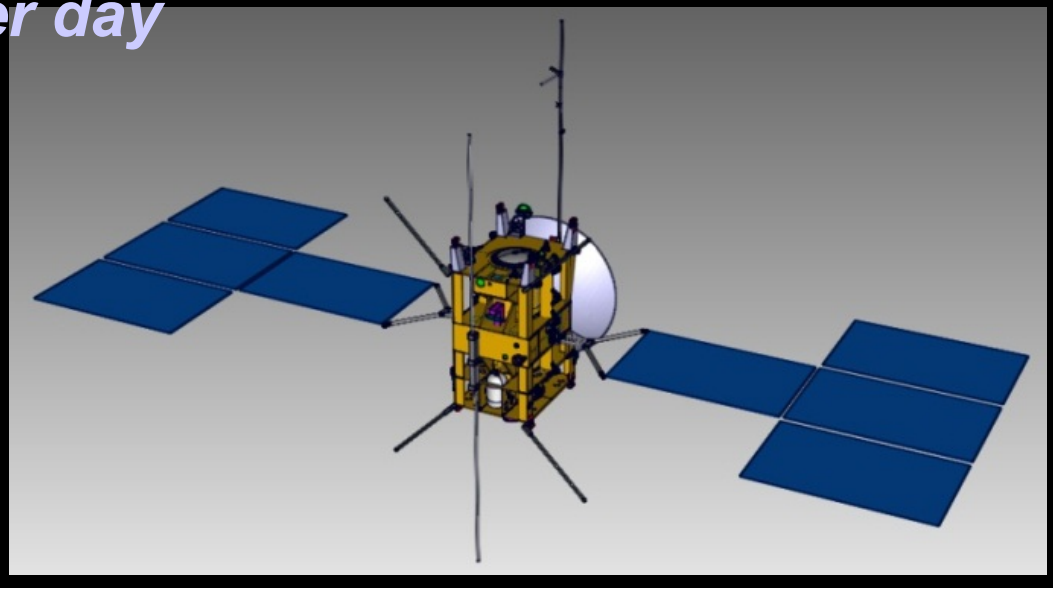
the prime contractor to develop and build the JUICE spacecraft



Main features of the spacecraft design

- *Dry mass ~2000 kg, propellant mass ~3000 kg*
- *Launcher - Ariane 5 ECA (mass : 5-5.5 tons), High Δv required: 2600 m/s*
- *Payload ~110 kg, ~ 150 W*
- *3-axis stabilized s/c*
- *Power: solar array ~ 70 m², ~ 700 W*
- *HGA: ~3 m, fixed to body, X & Ka-band*
- *Data return >1.4 Gb per day*





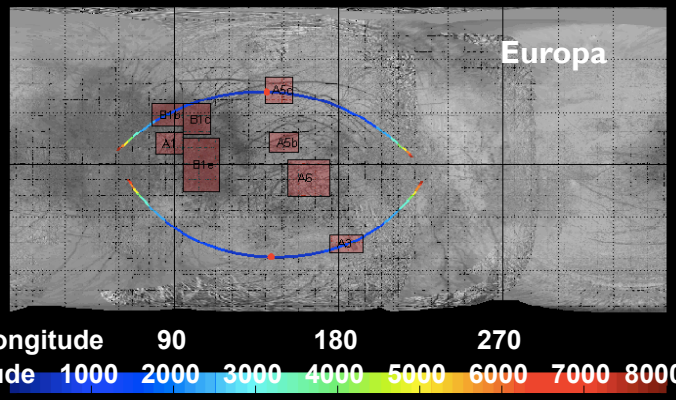
JUICE Payload

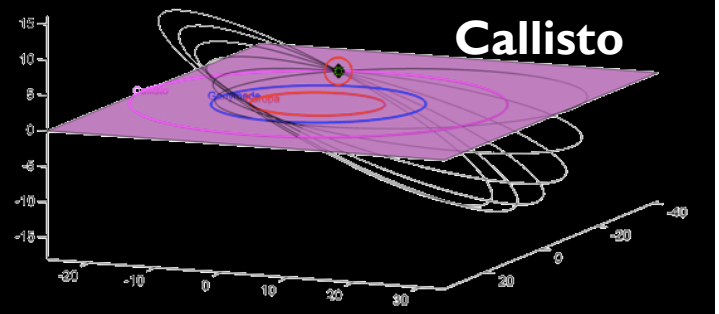
Acronym	PI	LFA	Instrument type
Remote Sensing Suite			
JANUS	P. Palumbo	Italy	Narrow Angle Camera
MAJIS	Y. Langevin G. Piccioni	France Italy	Vis-near-IR imaging spectrometer
UVS	R. Gladstone	USA	UV spectrograph
SWI	P. Hartogh	Germany	Sub-mm wave instrument
Geophysical Experiments			
GALA	H. Hussmann	Germany	Laser Altimeter
RIME	L. Bruzzone	Italy	Ice Penetrating Radar
3GM	L. Iess	Italy	Radio science experiment
PRIDE	L. Gurvits	Netherlands	VLBI experiment
Particles and Fields Investigations			
PEP	S. Barabash	Sweden	Plasma Environmental Package
RPWI	J.-E. Wahlund	Sweden	Radio & plasma Wave Instrument
J-MAG	M. Dougherty	UK	Magnetometer

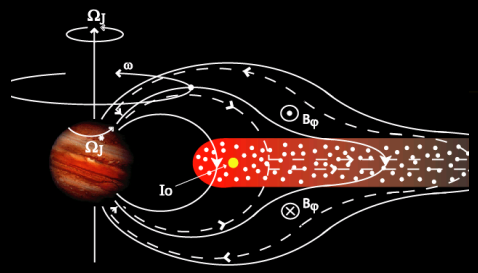
Mission design

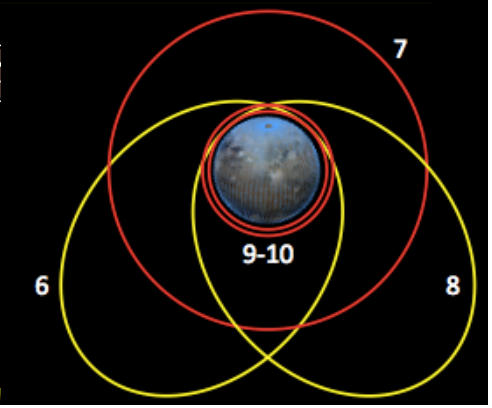
JUICE

Spacecraft Design	Model instruments	Mission phases
Launch	June 2022	
Interplanetary transfer (Earth-Venus-Earth-Earth)	7.6 years (8 years)	
Jupiter orbit insertion and apocentre reduction with Ganymede gravity assists	11 months	
2 Europa flybys	36 days	
Reduction of v_{inf} (Ganymede, Callisto)	60 days	
Increase inclination with 10 Callisto gravity assists	200 days	
Callisto to Ganymede	11 months	
Ganymede (polar) 10,000x200 km & 5000 km 500 km circular 200 km circular	 150 days 102 days 30 days	
Total mission at Jupiter	3 years	

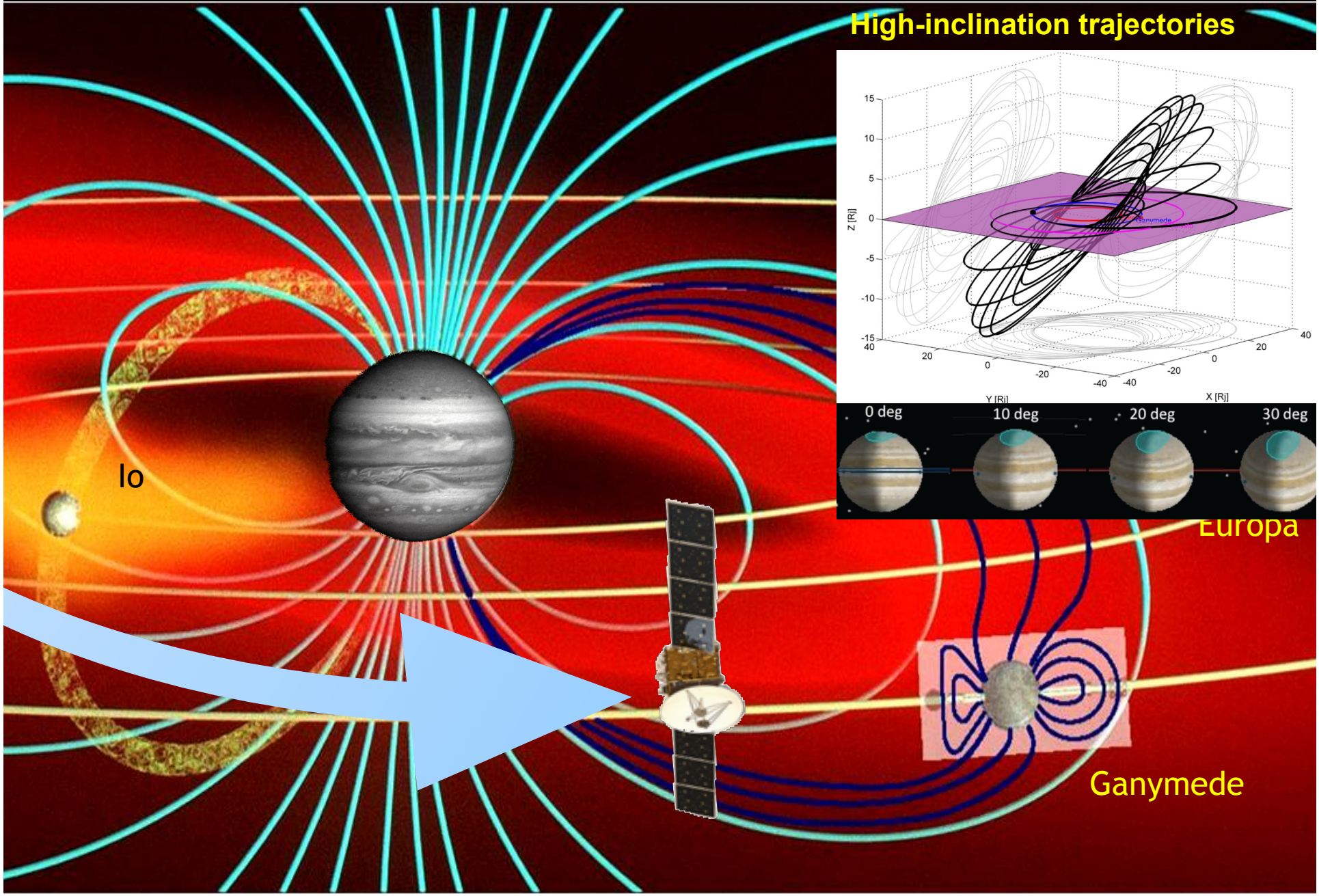




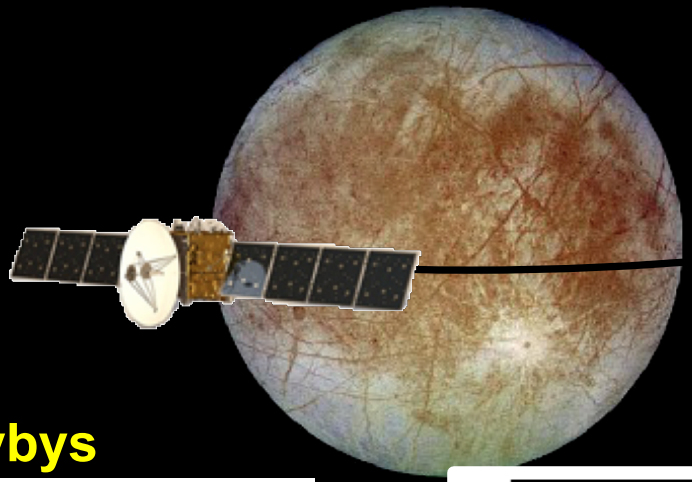




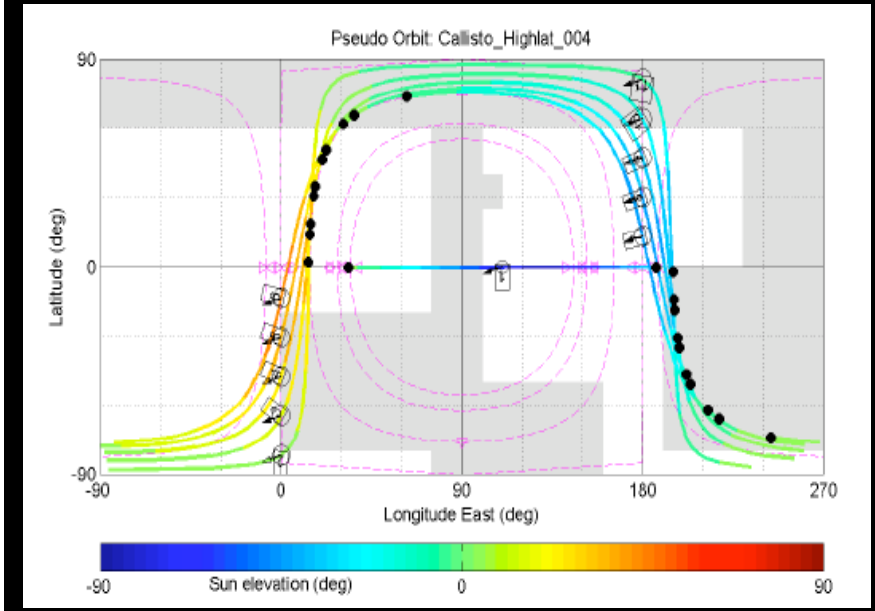
Jupiter Tour



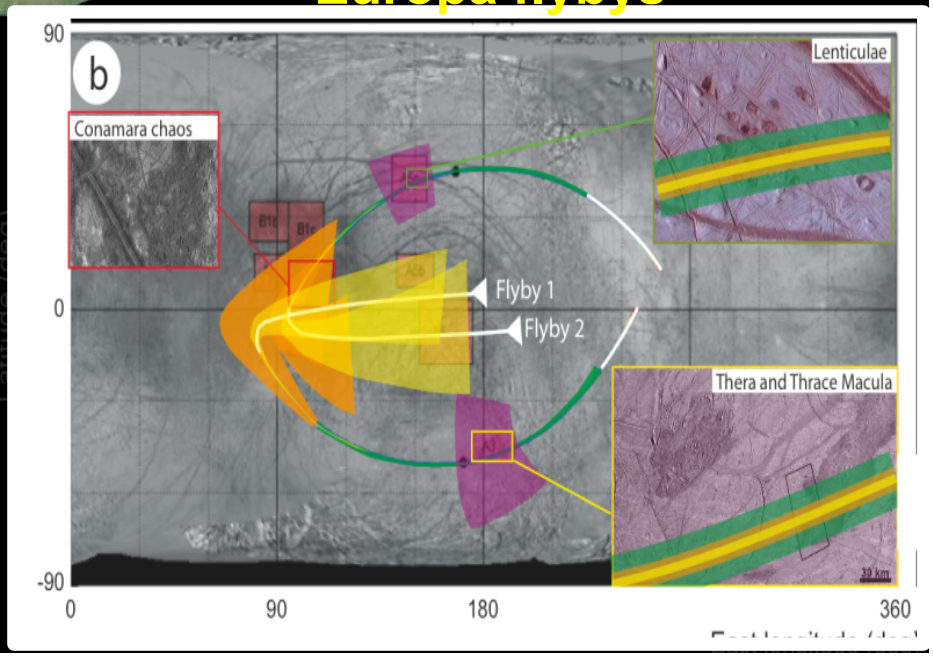
Moons' flybys

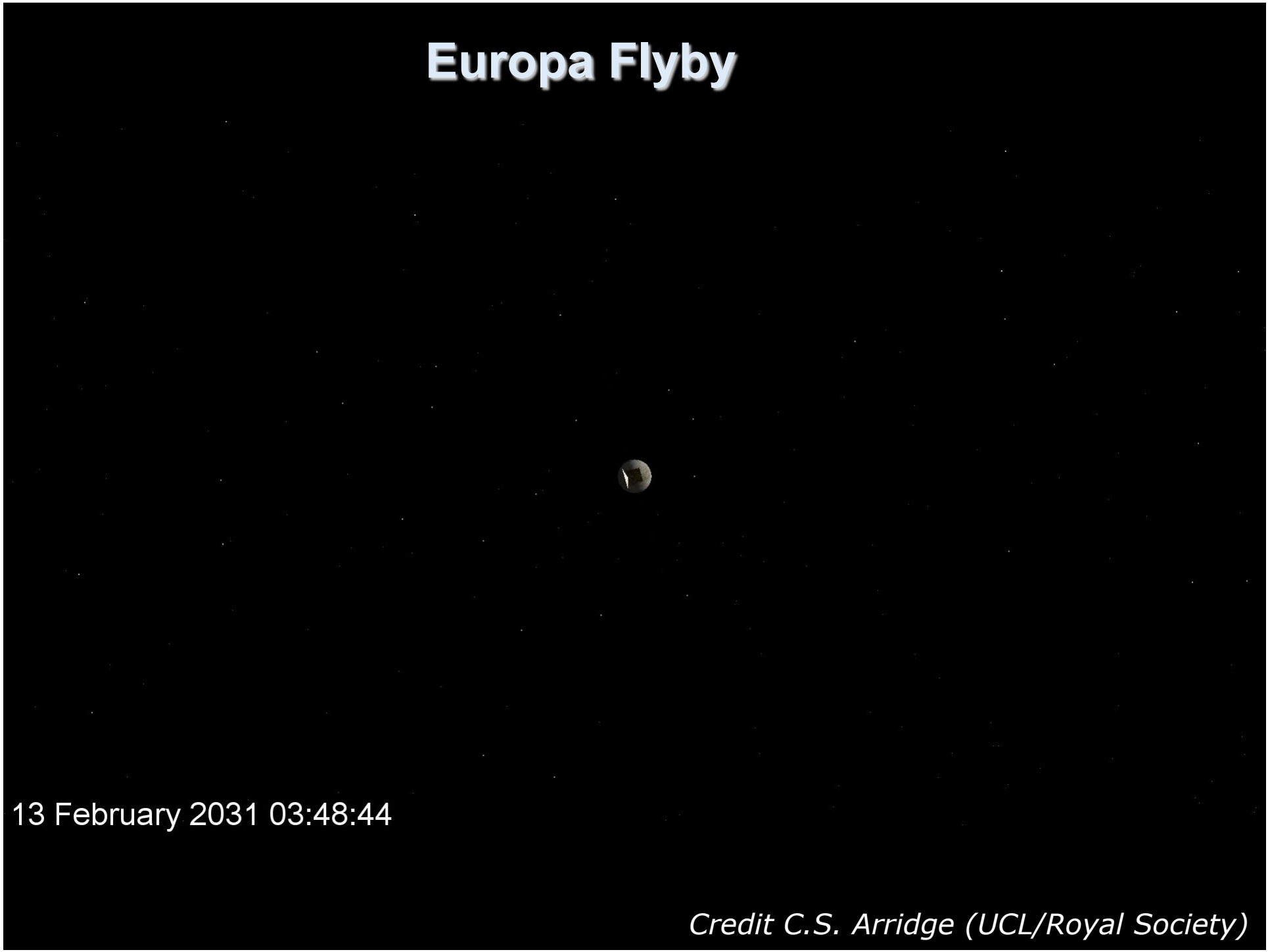


Callisto flybys



Europa flybys

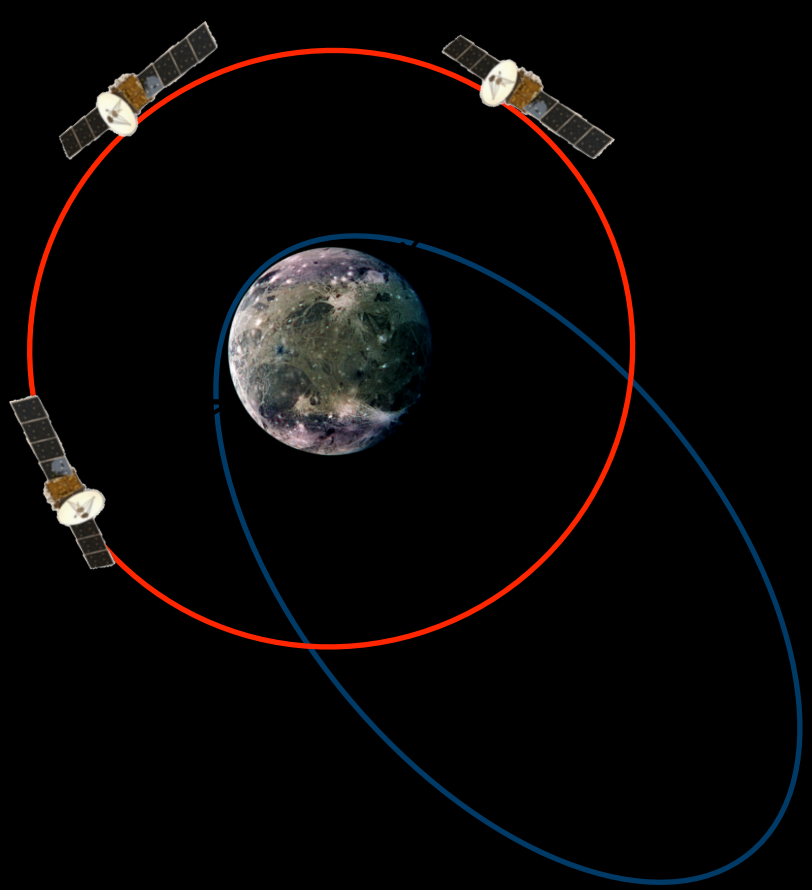


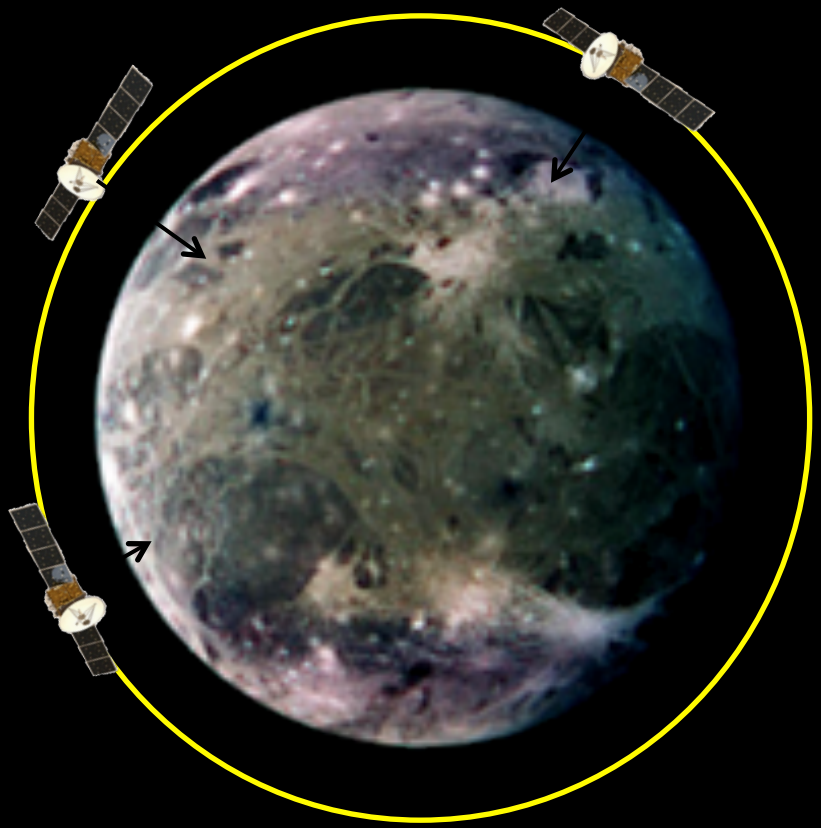

Europa Flyby
13 February 2031 03:48:44
Credit C.S. Arridge (UCL/Royal Society)

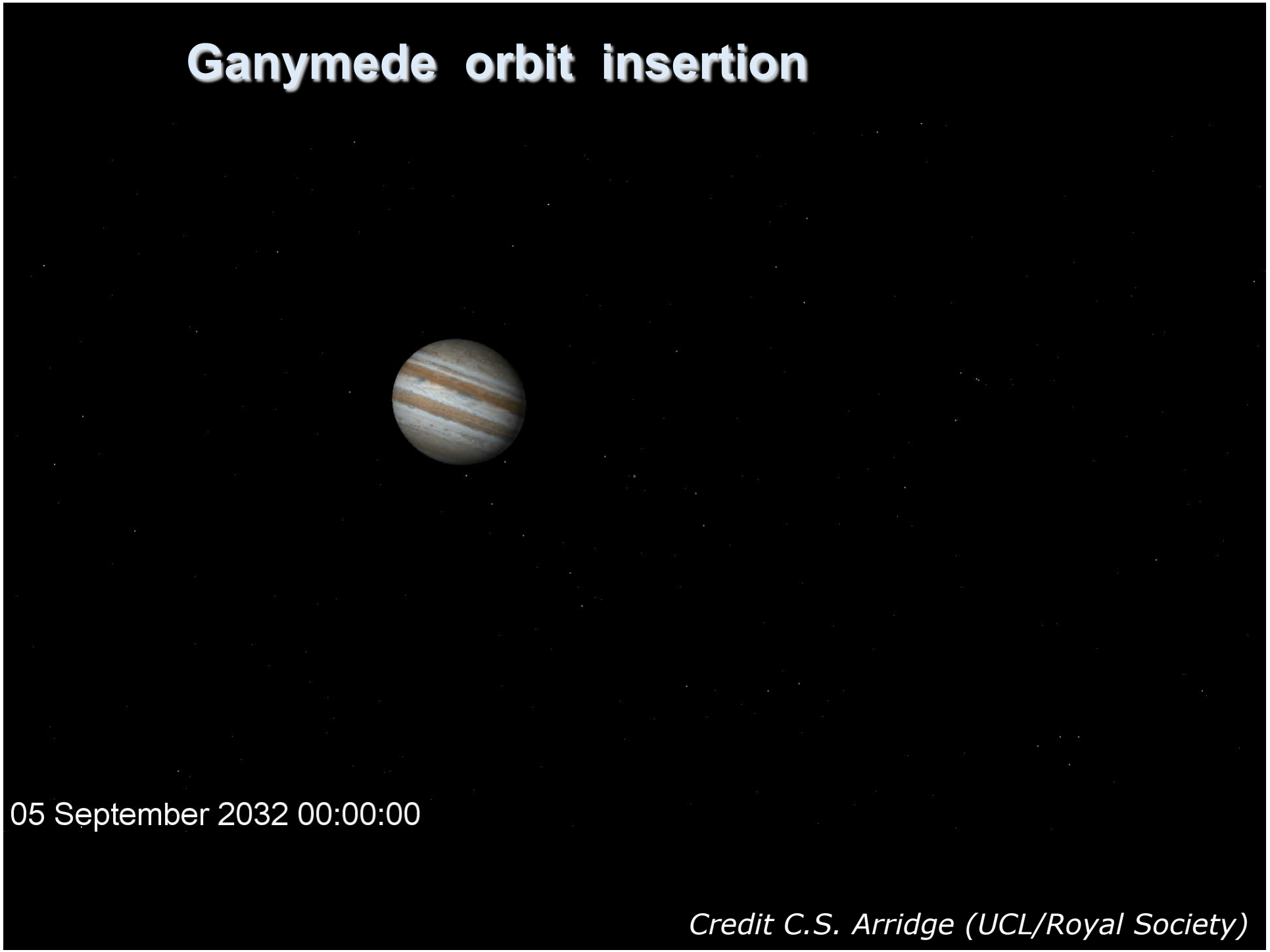
Ganymede Tour

GCO-5000 & GEO

GCO-500



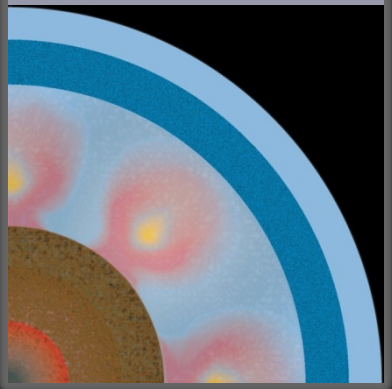



Ganymede orbit insertion
05 September 2032 00:00:00
Credit C.S. Arridge (UCL/Royal Society)

JUICE : Science investigations

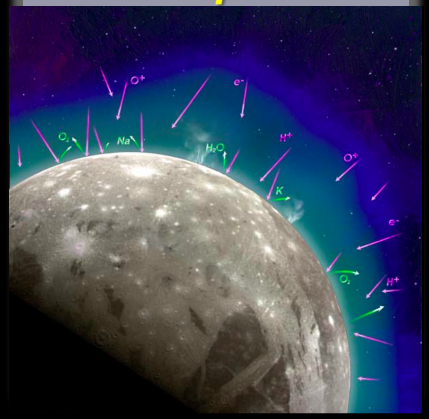
Ganymede: planetary object and potential habitat

Ice shell, ocean, deeper interiors

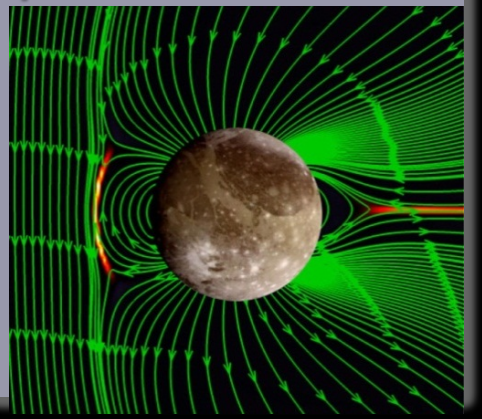


Geology, surface composition

Atmosphere, ionosphere

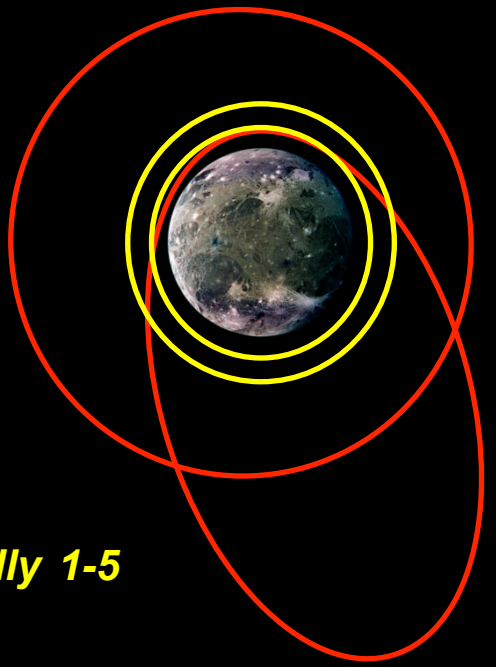


Magnetosphere, plasma environment



Main investigations

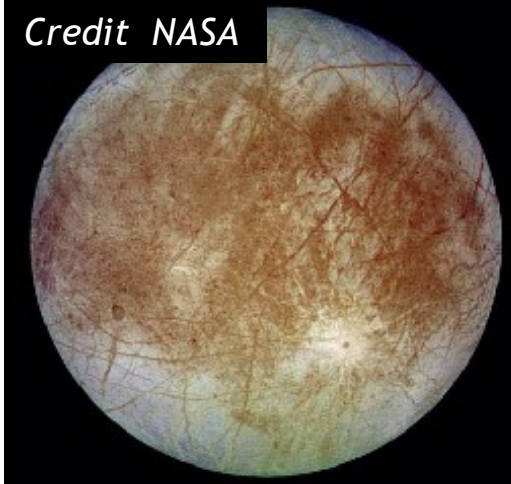
- *Elliptical (1000x10000 km) & high (~5000 km) circular orbit*
- *Medium (500 km) circular orbits*
- *Favorable illumination conditions (β-angle 30°-70°)*
- *Dedicated pointing modes*
- *Sub-surface sounding down to ~9 km depth*
- *Imaging: global ~400 m/px, selected targets ~3 m/px*
- *Mineralogical mapping (especially of non-ice materials): globally 1-5 km/px , selected targets ~25 m/px*

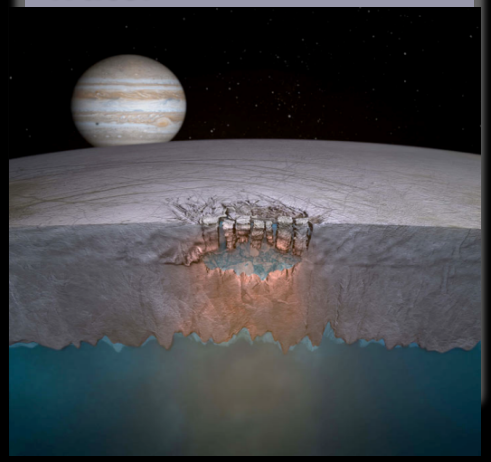


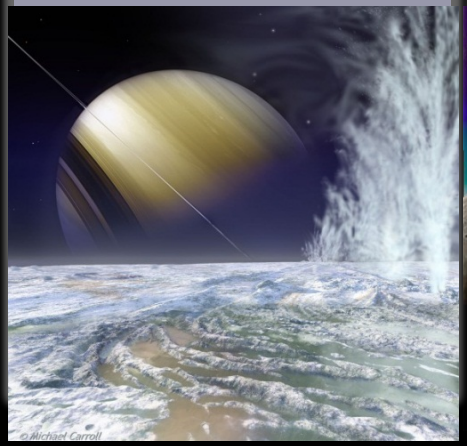
Credit NASA

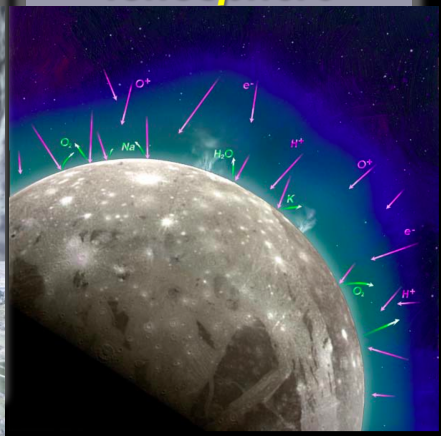
Europa: study of recently active regions

Composition of non-ice material	Liquid sub-surface water	Active processes	Atmosphere, ionosphere





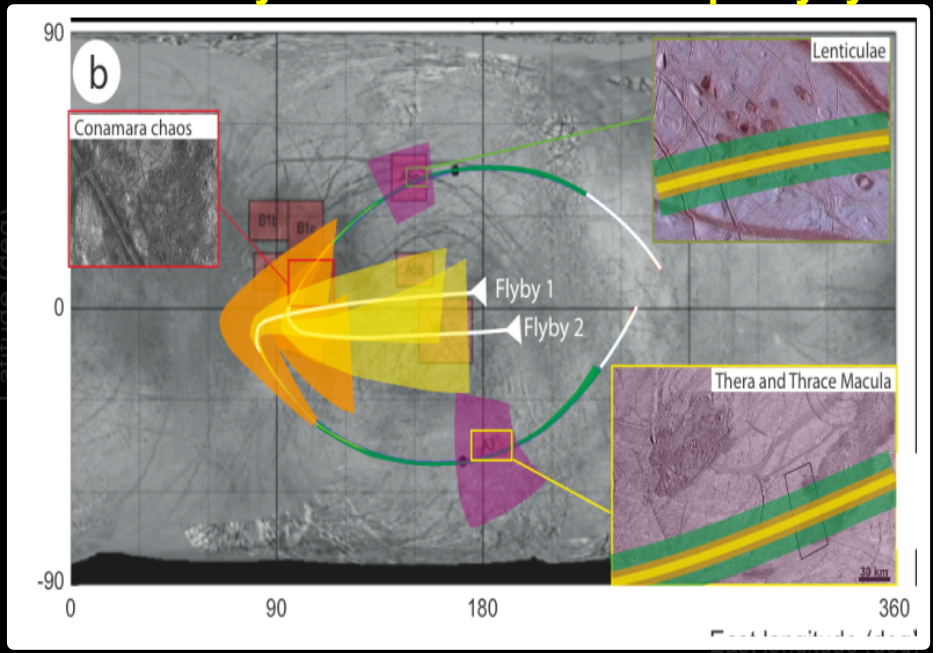




Main investigations

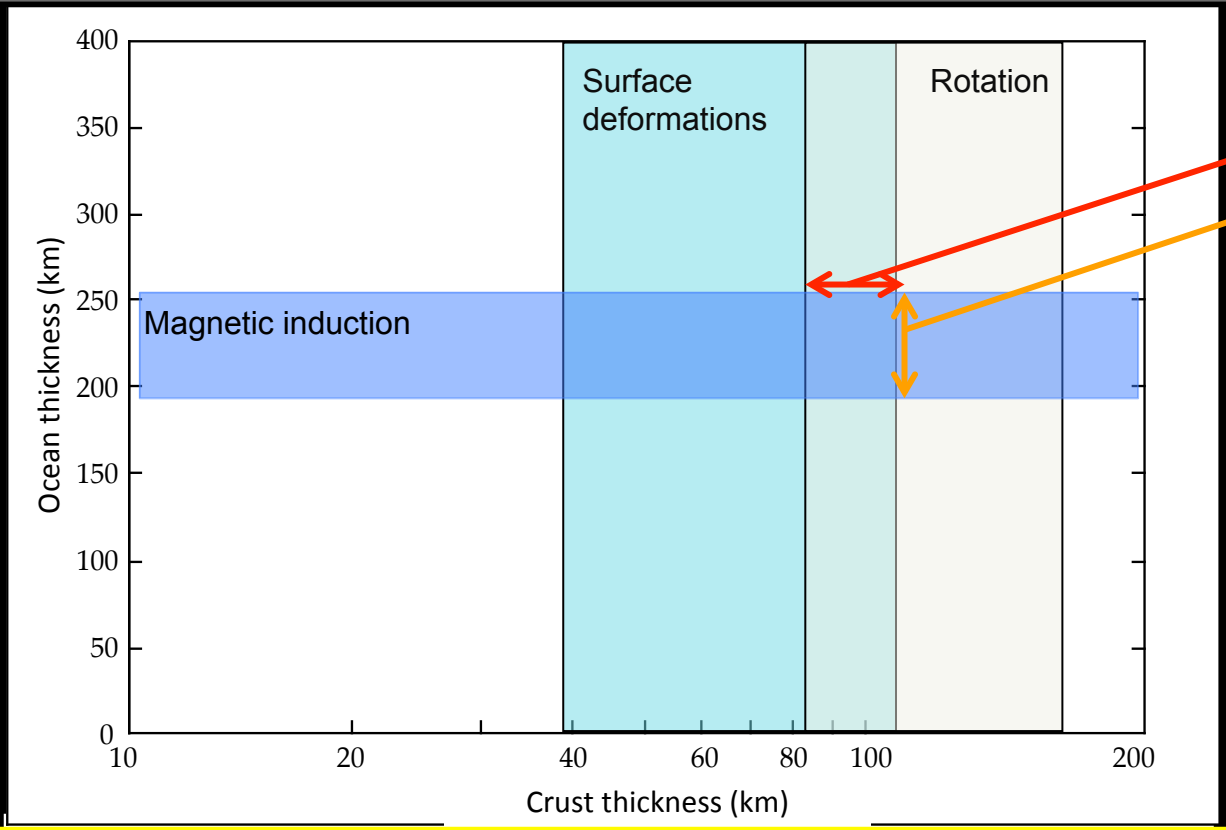
- ***At least 1 Europa flyby with CA ~400 km over the most active regions***
- ***Favorable illumination conditions at CA***
- ***Anti-Jovian side at CA***
- ***Simultaneous operations of all experiments (including 3GM as a goal)***
- ***Non-ice materials in selected sites mapped at regional (>5 km/px) and local (<500 m/px) scales & processes in active sites***

Geometry of two baseline Europa flybys

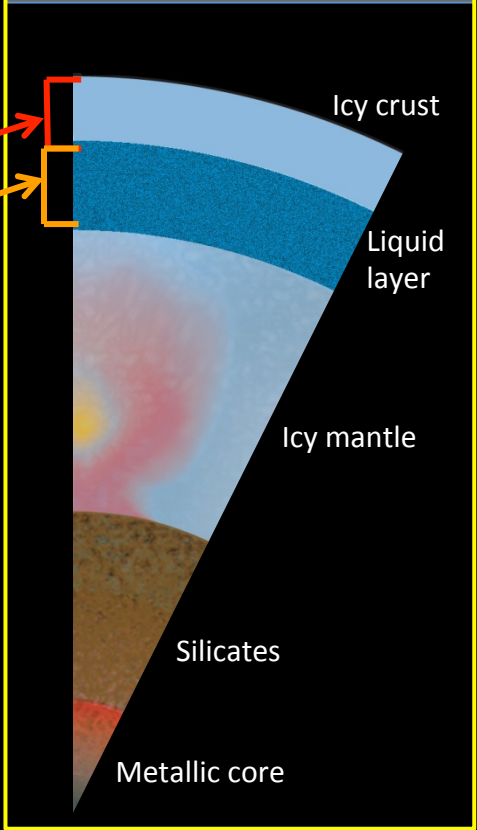


Characterise Ganymede as a planetary object and possible habitat

1. Extent of the ocean and its relation to the deeper interior



Internal structure



JUICE measurements

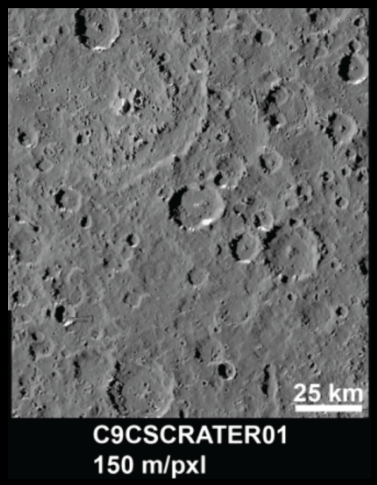
- Eccentric orbit ->Surface deformations
- Periodic variations in the rotation (librations)
- Magnetic induction from the field vector

Instrument Packages

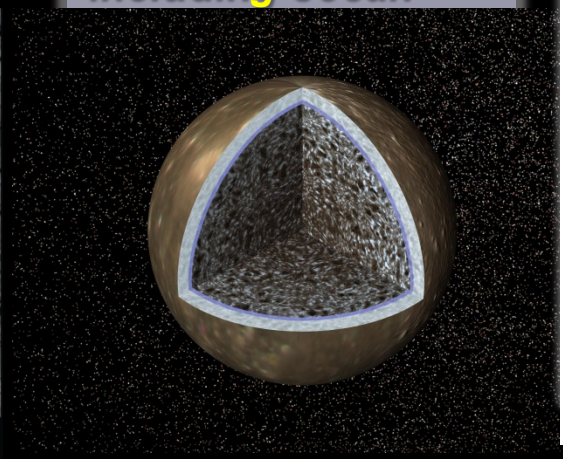
- In situ Fields and Particles
- Imaging
- Sounders and Radio Science

Callisto: a witness of the early Solar System

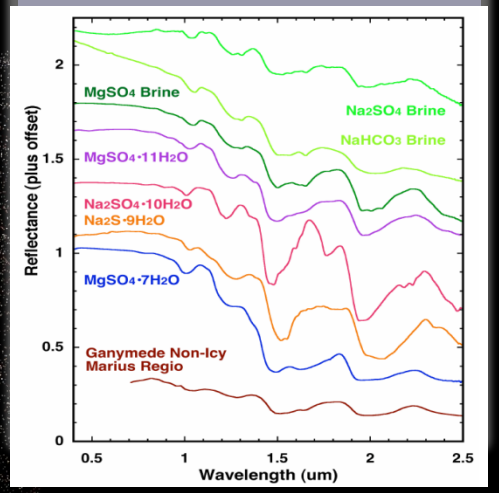
Geological history and past activity



Outer shell including ocean



Non-ice material

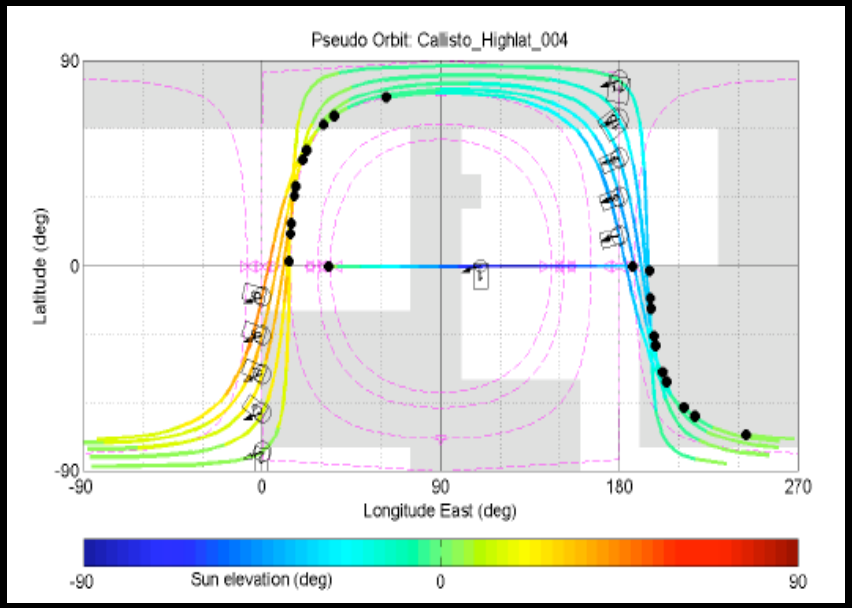


Credit NASA

Main investigations

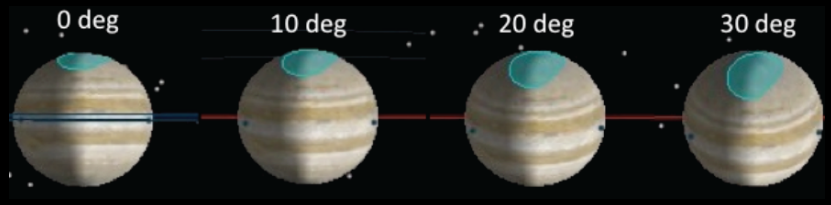
- *At least 9 Callisto flybys with CA<1000 km*
- *Several flybys with CA<500 km and good illumination conditions*
- *Flyby trajectory inclined by at least 50° to the moon's equator*
- *Medium resolution imaging (<400 m/px)*
- *Regional mineralogical mapping (~5km/px)*
- *Subsurface down to few km*

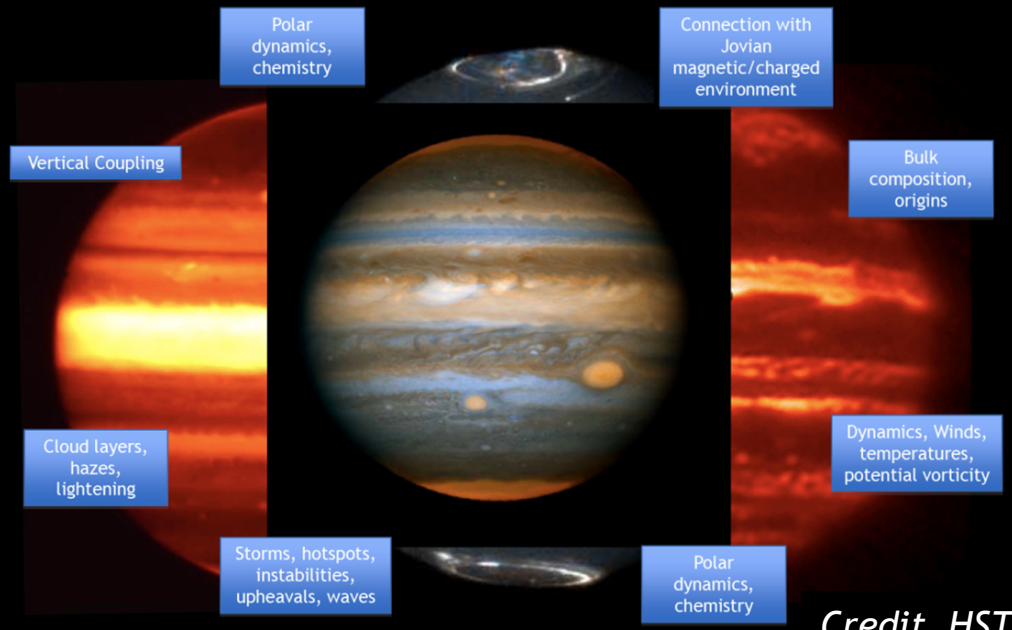
Geometry of the baseline Callisto flybys



Jupiter atmosphere

- ***Atmospheric structure, composition and dynamics***
- ***Coupling between troposphere, stratosphere and thermosphere***



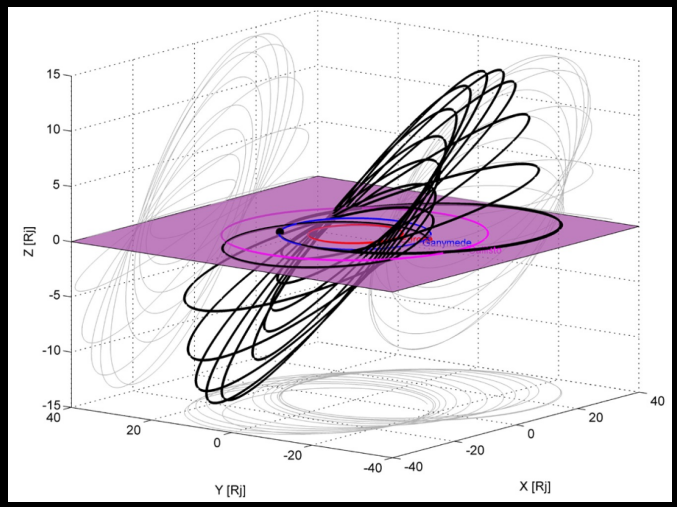


Credit HST

Main investigations

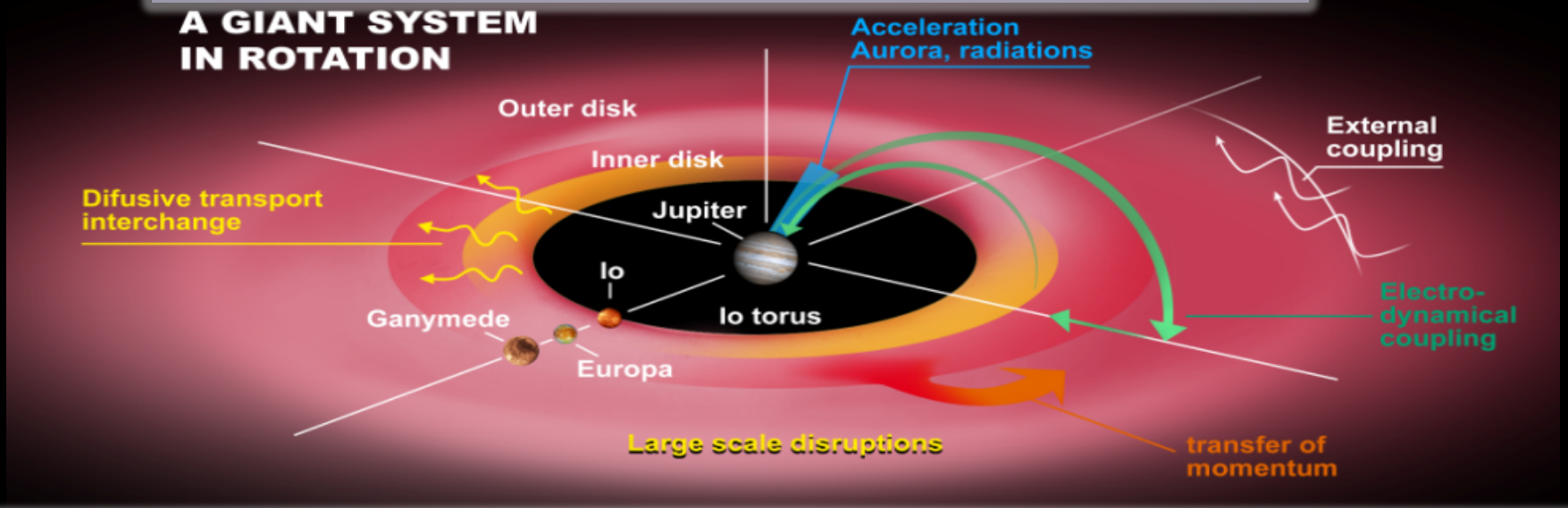
- ***Multi-wavelength observations from UV to sub-mm***
- ***Imaging ~15 km/px, spectro-imaging 100-200 km/px***
- ***Complete latitude, phase angle, local time coverage***
- ***Repeated observations with time scales from hours to months***
- ***Extended period of time (3 years in total)***

High-inclination trajectories



Jupiter magnetosphere

- *Magnetosphere as a fast rotator*
- *Magnetosphere as a giant particle accelerator*
- *Interaction of the Jovian magnetosphere with the moons*
- *Moons as sources and sinks of magnetospheric plasma*



JUICE features

- *Equatorial magnetosphere at R ~ 10 - 30 R_J and out to at least 100 R_J*
- *High-inclination orbit (up to at least 22°)*
- *Simultaneous remote sensing and in-situ observations*

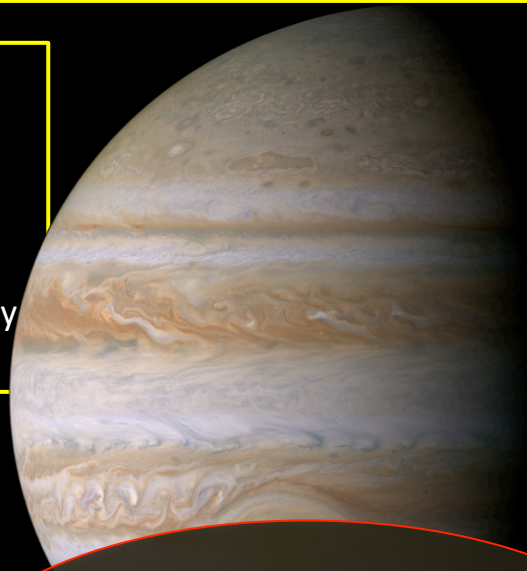
Exploration of the Jupiter system

JUICE

The biggest planet, the biggest magnetosphere, and a mini solar system

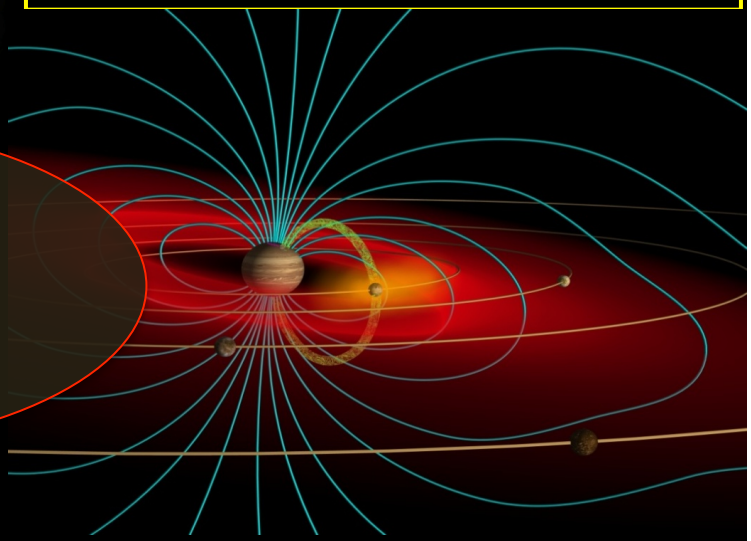
Jupiter

- Archetype for giant planets
- Natural planetary-scale laboratory for fundamental fluid dynamics, chemistry, meteorology,...
- Window into the formational history of our planetary system



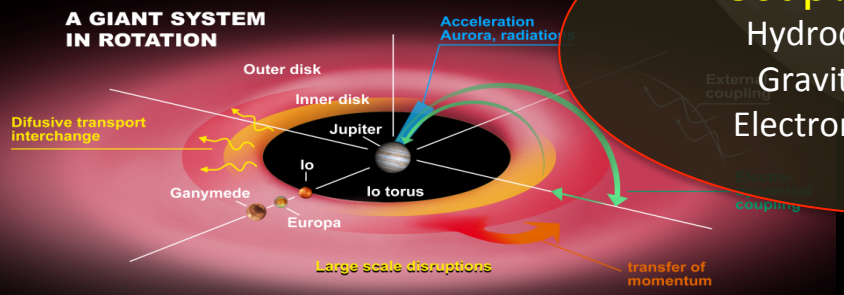
Magnetosphere

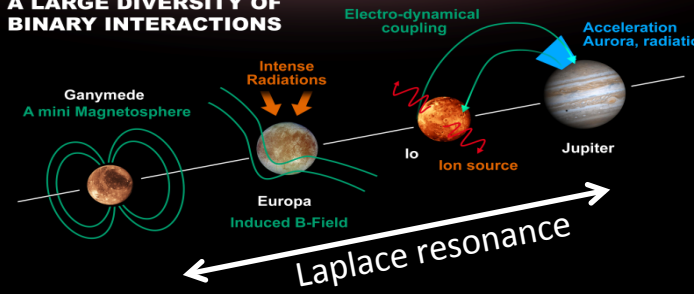
- Largest object in our Solar System
- Biggest particle accelerator in the Solar System
- Unveil global dynamics of an astrophysical object



Coupling processes

Hydrodynamic coupling
Gravitational coupling
Electromagnetic coupling

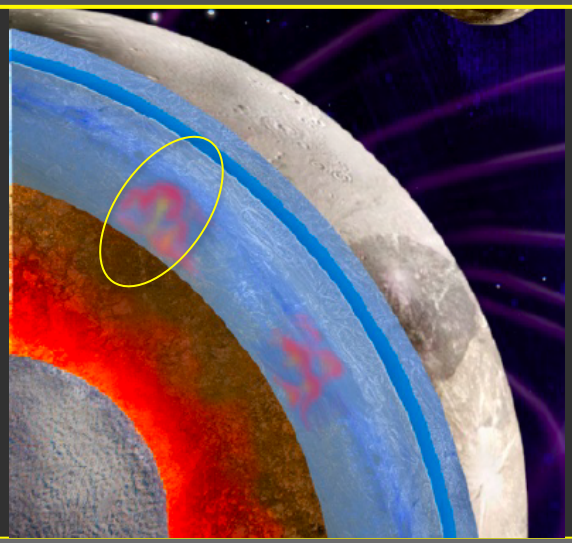




Satellite system

- Tidal forces: Laplace resonance
- Electromagnetic interactions to magnetosphere and upper atmosphere of Jupiter

Waterworlds: If habitable, the liquid layers are trapped between two icy layers

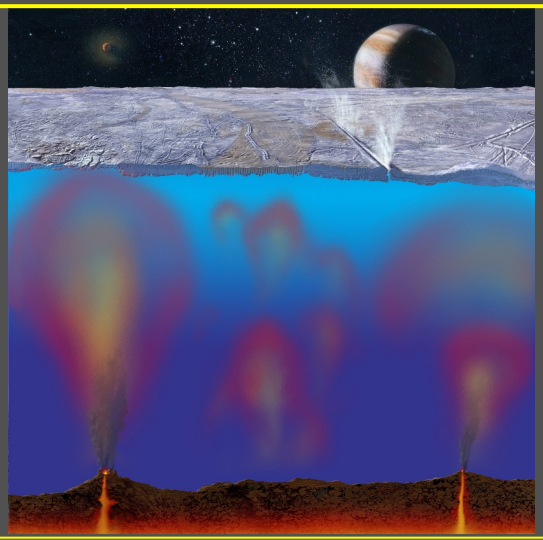


Occurrence:
Largest moons, hot ice giants, ocean-planets…
Most common habitat in the universe ?

Key question:
Are these waterworlds habitable ?

What JUICE will do:
Via characterisation of Ganymede, will constrain the likelihood of habitability in the universe

Europa-like: If habitable, the liquid layers may be in contact with silicates as on Earth



Occurrence:
Europa, Enceladus
Only possible for very small bodies

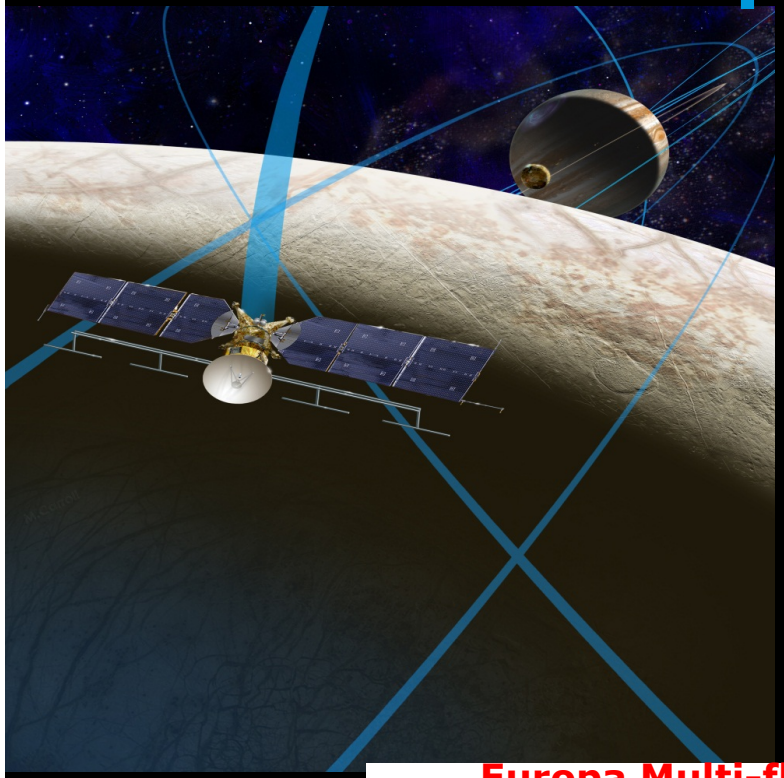
Key question:
How are the surface active areas related to potential deep habitats?

What JUICE will do:
Pave the way for future landing on Europa
Better understand the likelihood of deep local habitats

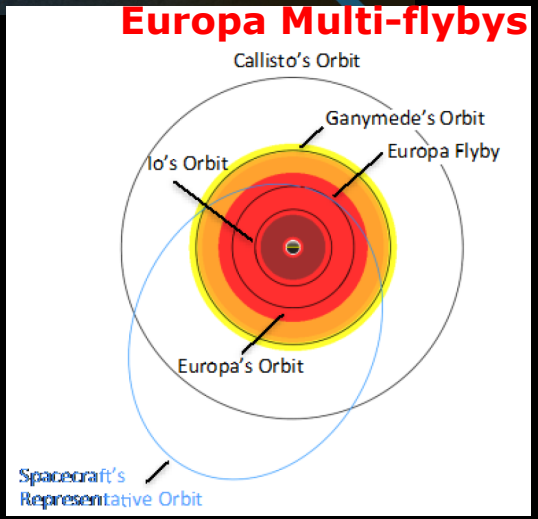
In summary, JUICE is

- **Highly capable spacecraft with synergistic and multi-disciplinary payload**
- **Detailed study of two classes of planetary objects**
  - *a gas giant*
  - *several icy moons with focus on Ganymede*
- **Comparative study of the icy moons family**
- **Investigations of two classes of planetary atmospheres**
  - *well developed atmosphere of the gas giant*
  - *tenuous exospheres of the icy moons*
- **Magnetosphere and plasma environment of the gas giant and its interaction with its moons**
- **Couplings within the Jovian system**
- **Conjunction with ground-based support**
- **Precursor for future missions**

NASA Europa "Clipper" mission



- Spacecraft in orbit around Jupiter
- Science goal: Europa's habitability
- Multiple (45) flybys of Europa
  - Altitudes: 25 – 2700 km
- 9 instruments selected: cameras, magnetometers, radar, dust analyser, spectrometers, plasma + mass spectrometer
- Schedule
  - Start formulation phase in Oct. 2016
  - Launch 2020-2025
  - Cruise: 2 or 7 years
  - Nominal mission: 3-4 years

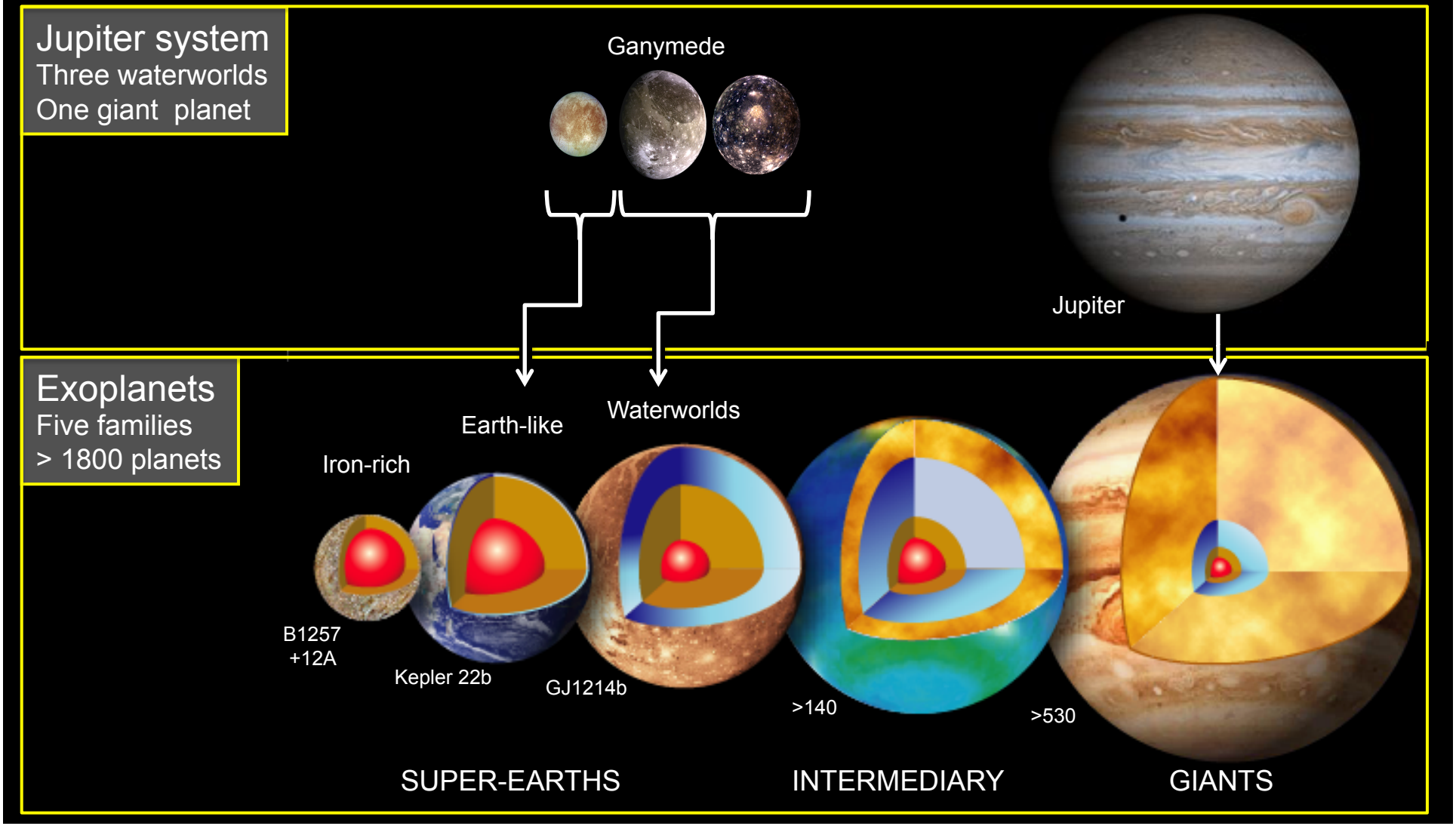


Possible extra probe, penetrator or lander provided by ESA is being discussed

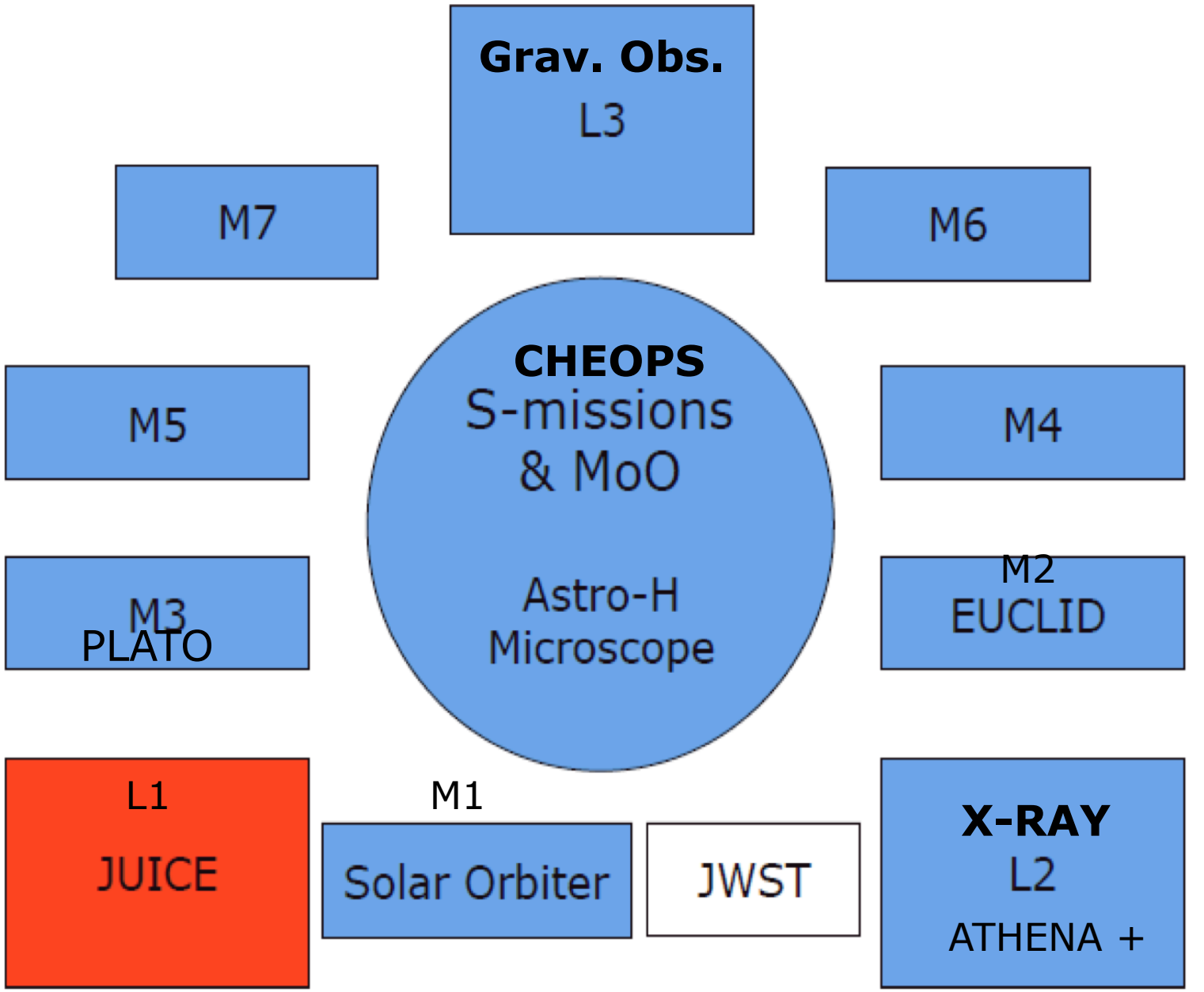
From the Jovian system to extrasolar planetary systems

Waterworlds and giant planets | Habitable worlds | Astrophysics Connection

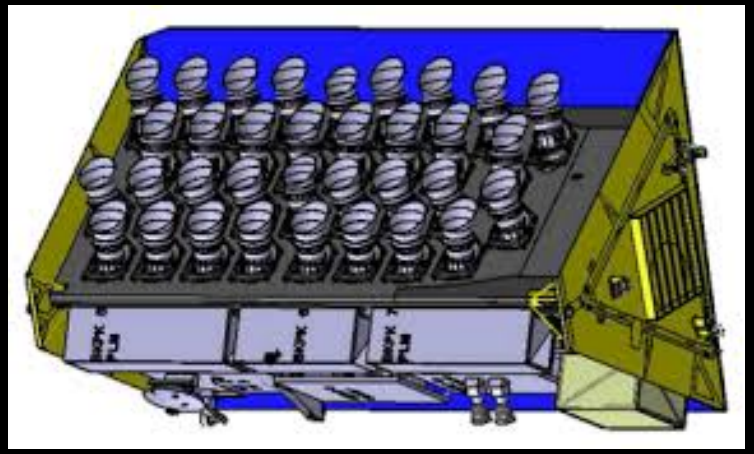
By studying Ganymede, we can characterise an entire family of exoplanets: the waterworlds.



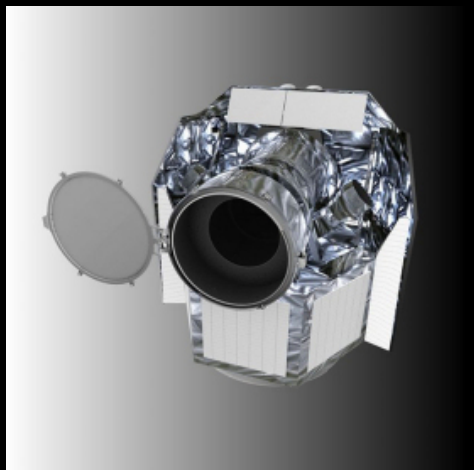
COSMIC VISION (2015-2035)



Ideas/studies for exoplanet exploration

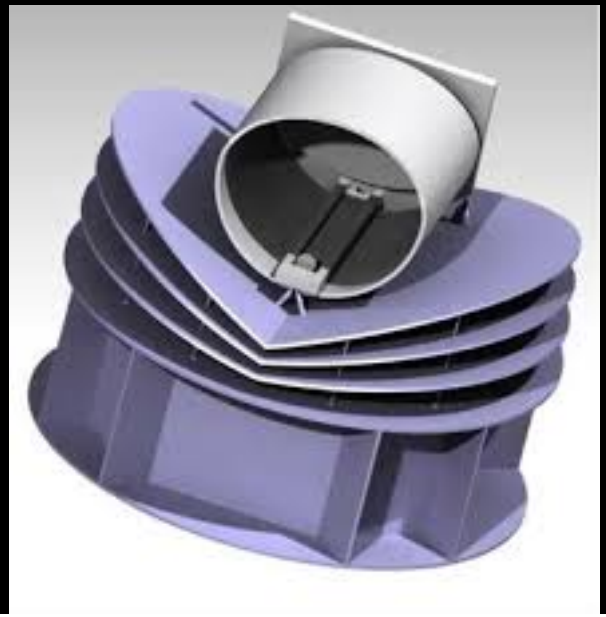


PLATO

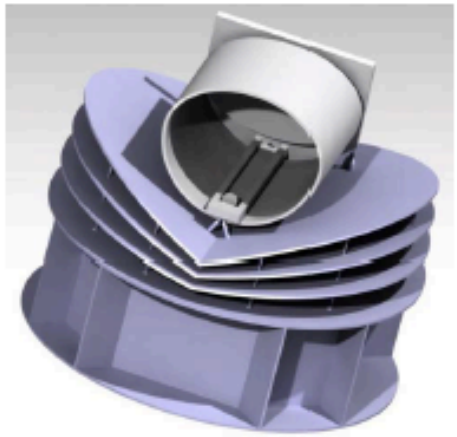


CHEOPS

ARIEL

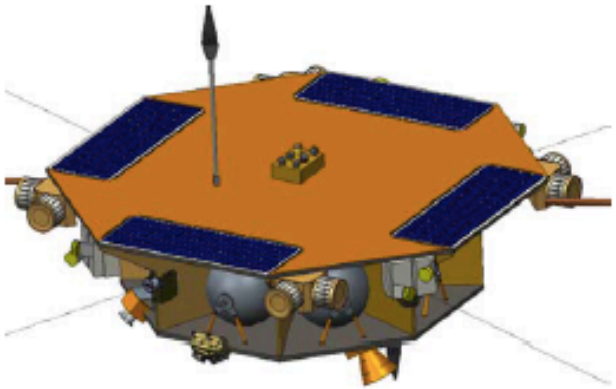


M4 candidates



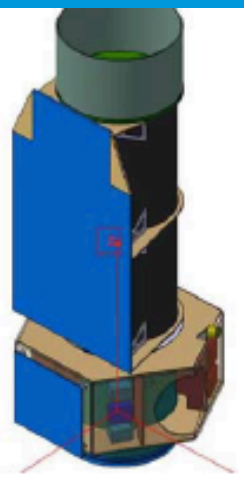
ARIEL

Exoplanet atmosphere spectroscopy in the IR (λ = 2-8 μm) for hot transiting planets. L2 orbit.



THOR

Understanding turbulent fluctuations in plasmas. Spinning S/C, in High Elliptic Orbit.



XIPE

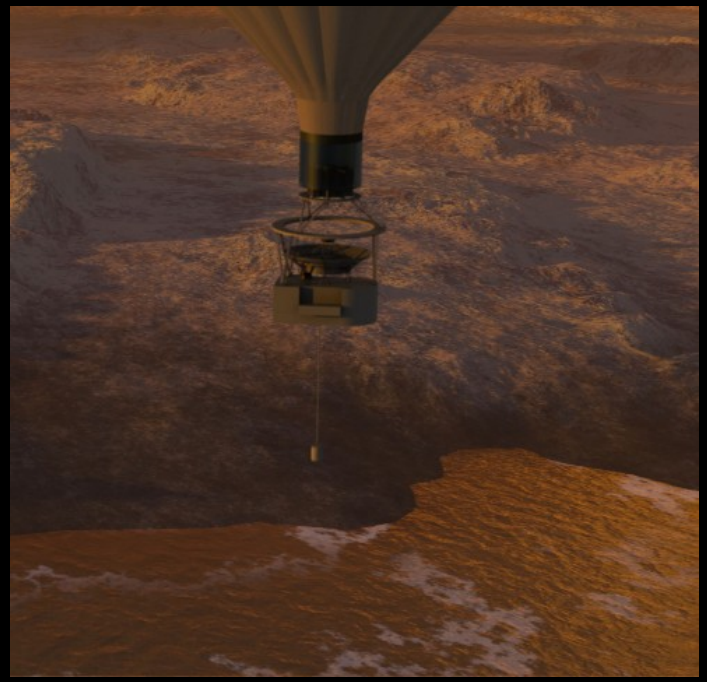
Observatory for measuring the polarization of X-ray sources. LEO equatorial orbit 550 km

Outer solar system investigations
M5 concepts…

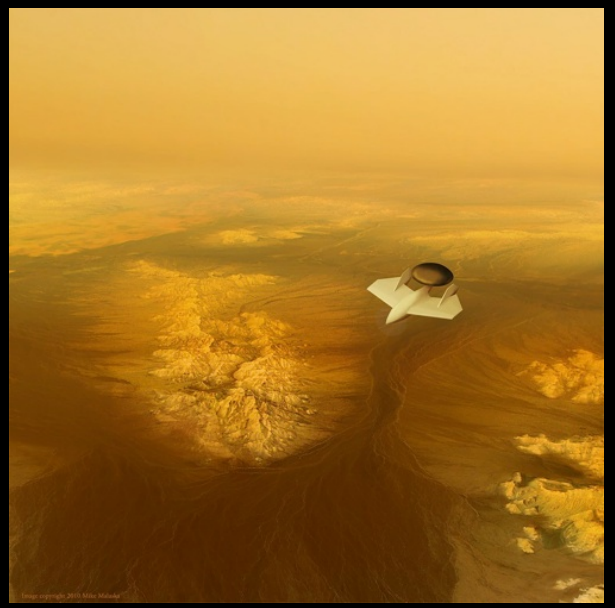
Study of ocean worlds with an eye to habitability

- Because no congressional directives or Decadals (but ministerial support for mandatory program) we can accommodate all kinds of responses to CV calls – ESSC has requested and will support exo-oceans studies
- In Europe, in response to the M-class CV calls, there have been several proposals for concepts to Saturn, Titan and Enceladus.
  - TSSM (joint NASA-ESA study : 2008-2010),
  - HERA (Saturn probe),
  - More Enceladus and Titan (launch 2029-2030 with solar arrays, several flybys of Enceladus and Titan, arrival 2037 or so, when the sun will start to illuminate the polar seas on Titan (full visibility in 2039-2040). The illumination of the Northern polar region in 2037 is equivalent to the illuminatio nin 2008: SOI, Enceladus exploration phase, Transfer to Titan, Titan exploration phase (in the 2040s)).
  - Responses to M3, M4 and this year to M5 CV calls…
- Advocating international collaboration as per the example set by Cassini

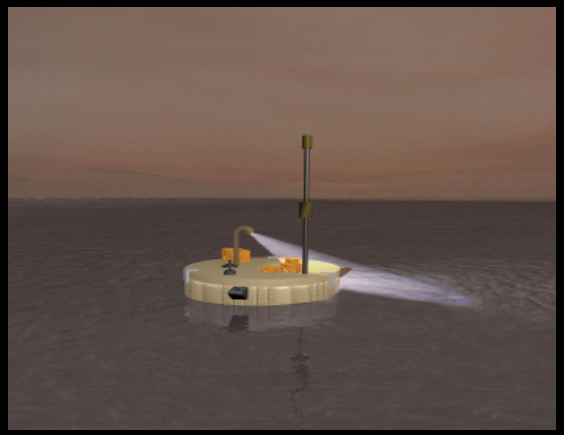
Ideas/studies for returning to Titan



TSSM: Balloon,
lander & orbiter
(Coustenis et al. 2009)

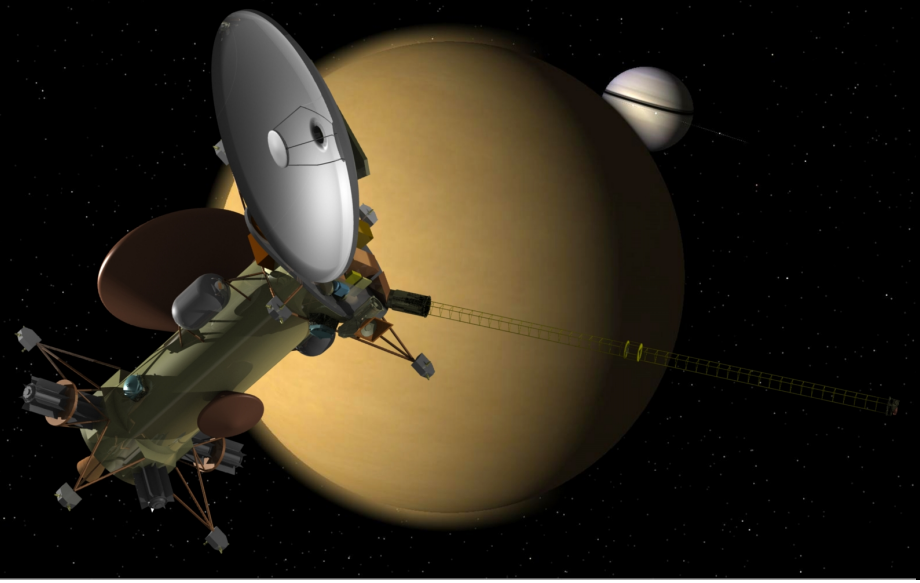


AVIATR /PLANE
(Barnes et al. 2010)



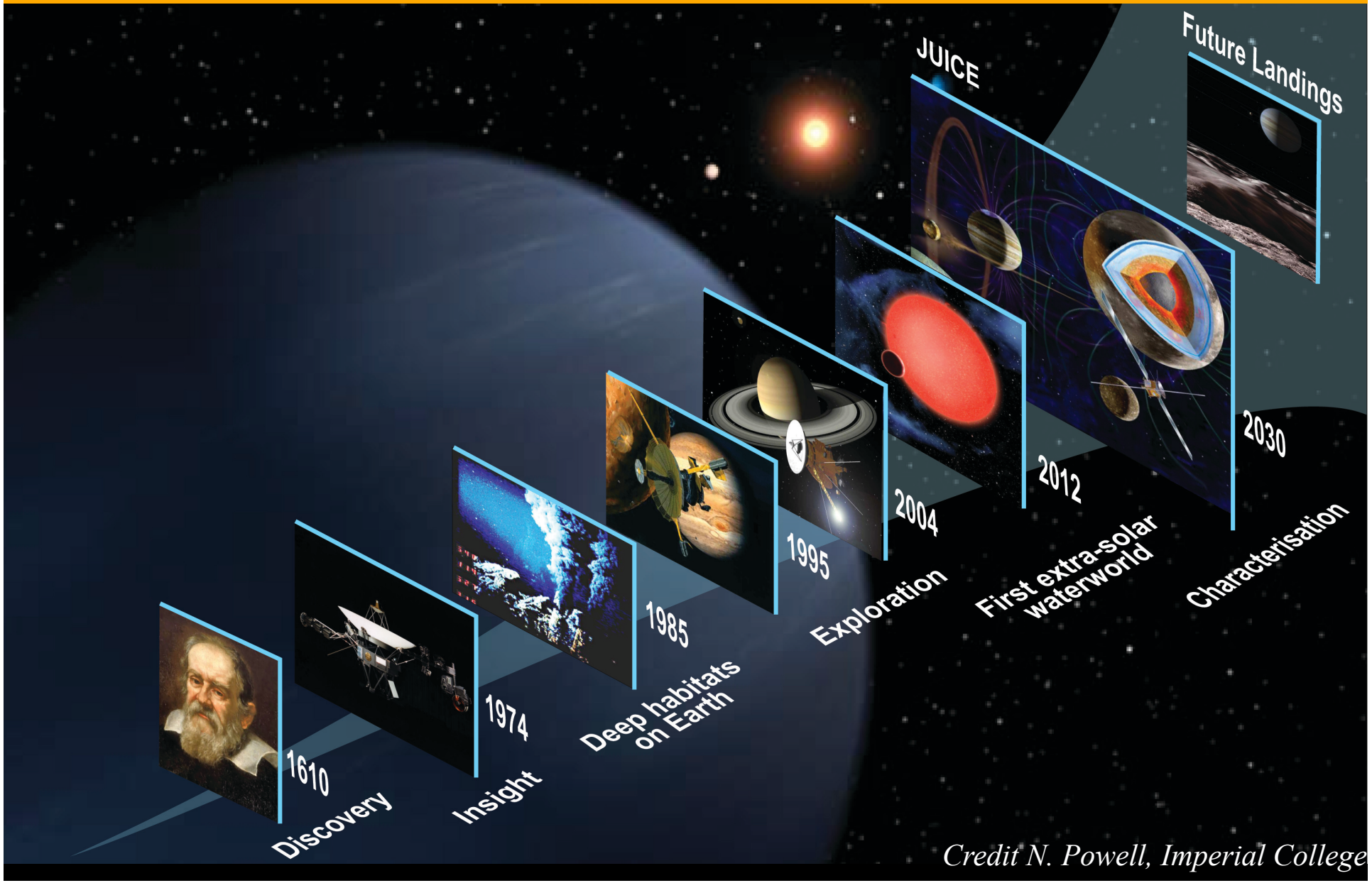
TIME: Lake lander
(Stofan et al. 2013)

Future Saturnian system exploration



THE FUTURE OF EXPLORATION

Rich future for exploration of habitable worlds in the outer solar system with JUICE as L1 and more : missions to Europa, Titan, Enceladus, and exoplanets



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