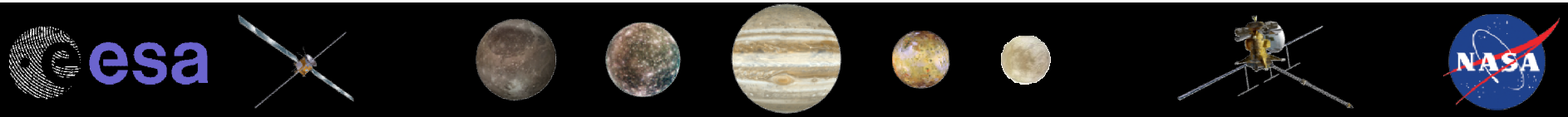
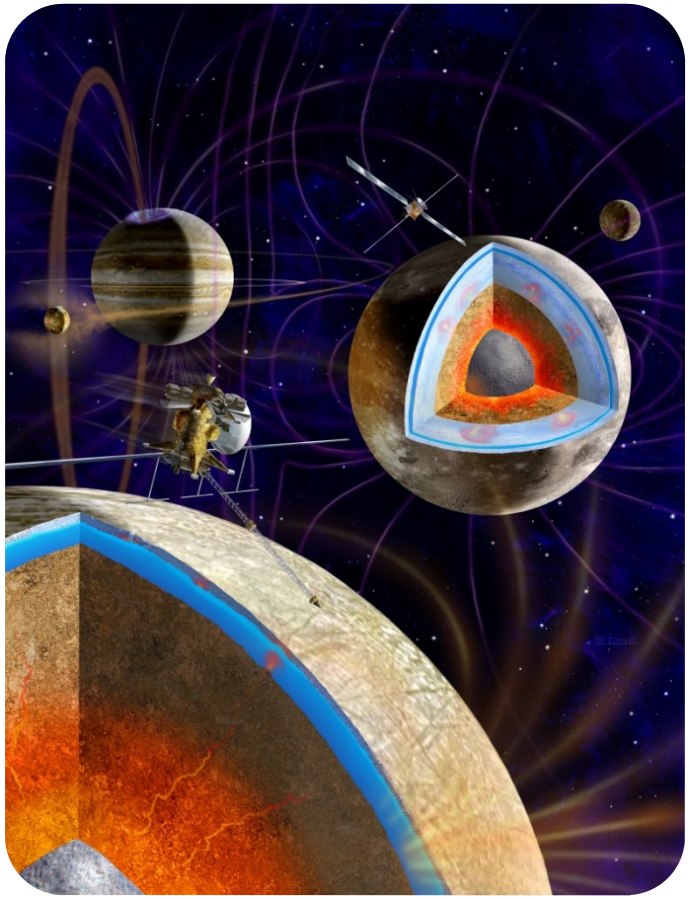


The Europa Jupiter System Mission: A pathfinder for Future Landings in the Jupiter System

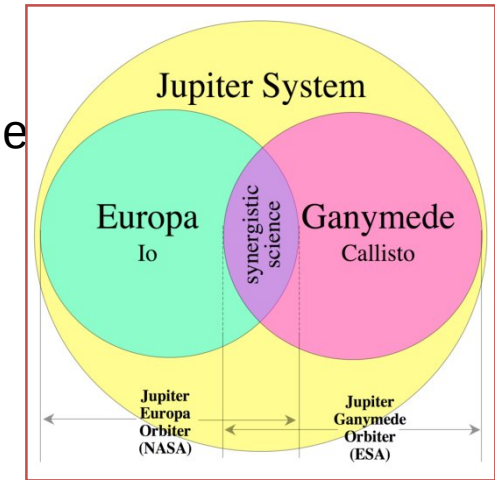
O. Grasset, M. Blanc, E. Bunce, K. Clark, A. Coustenis, M. Dougherty, C. Erd, R. Greeley, J-P. Lebreton, R. Pappalardo, L. Prockter, D. Senske, D. Titov, and the EJSM Joint Science Definition Team

Europa Jupiter System Mission (EJSM-Laplace)

The study of the emergence of habitable worlds around gas giants

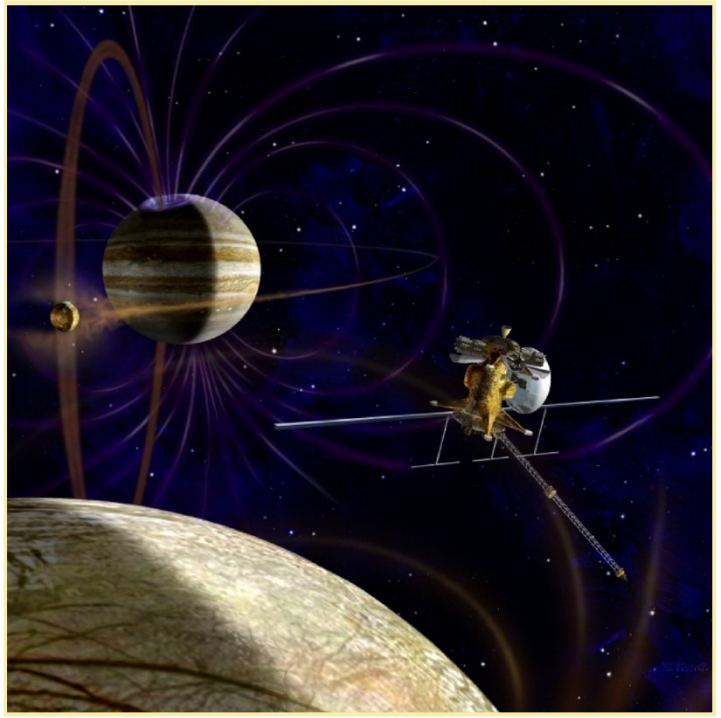


- NASA and ESA: Shared mission leadership
- Independently launched and operated flight systems with complementary payloads
  - NASA-led Jupiter Europa Orbiter (JEO)
  - ESA-led Jupiter Ganymede Orbiter (JGO)
- Complementary science and payloads
  - JEO focuses on Europa and Io
  - JGO focuses on Ganymede and Callisto
  - JGO and JEO addrss Jupite
  - Synergistic overlap
  - 11 instruments on each flight system)



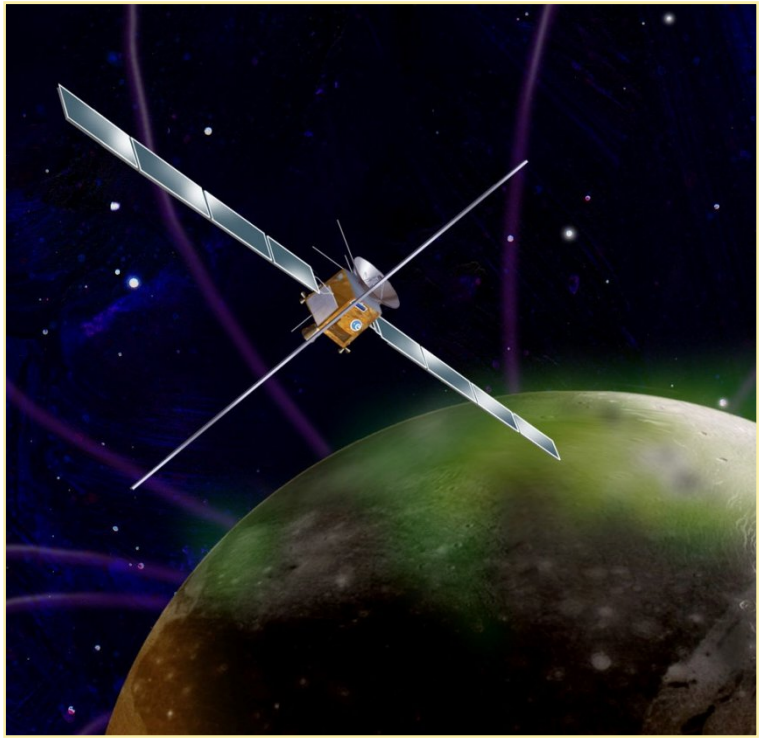
JEO Baseline Mission Overview

- NASA-led portion of EJSM, extensively studied in 2007–2008
- Objectives: Jupiter System, Europa
- Launch vehicle: Atlas V 551
- Power source: 5 MMRTG
- Mission timeline:
  - Launch: 2018 to 2022, nominally 2020
    - 6-year Venus-Earth-Earth gravity assist trajectory
  - Jovian system tour phase: 30 months
    - Multiple satellite flybys: 4 Io, 6 Ganymede, 6 Europa, and 9 Callisto
  - Europa orbital phase: 9 months
  - End of prime mission: 2029
  - Spacecraft final disposition: Europa impact
- 11 Instruments, including radio science
- Radiation dose: 2.9 Mrad (behind 100 mils of Al)
  - Handled using a combination of rad-hard parts and tailored component shielding
  - Key rad-hard parts are available, with the required heritage
  - Team is developing and providing design information and approved parts list for prospective suppliers of components, including instruments



JGO Baseline Mission

- ESA-led portion of EJSM
- Objectives: Jupiter System, Callisto, Ganymede
- Launch vehicle: Ariane 5
- Power source: Solar Arrays
- Mission timeline:
  - Launch: 2020
    - 6-year Venus-Earth-Earth gravity assist trajectory
  - Jovian system tour phase: ~28 months
    - 9 Ganymede flybys
    - 11 Callisto (9 close flybys)
  - Ganymede orbital phase: ~9 months
  - End of prime mission: 2029
  - Spacecraft final disposition: Ganymede impact
- Radiation: ~85 krad behind 320 mils of Al (requirement to keep below 100 krad)

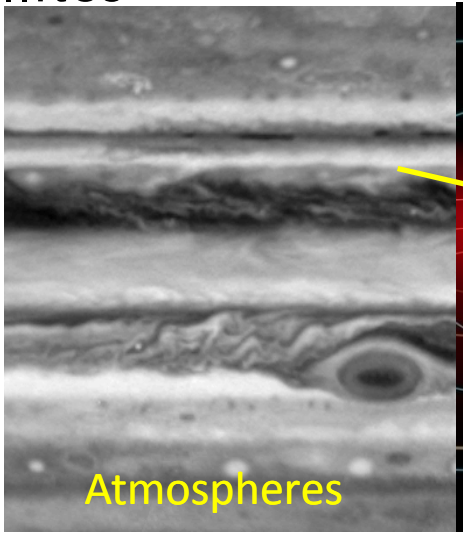


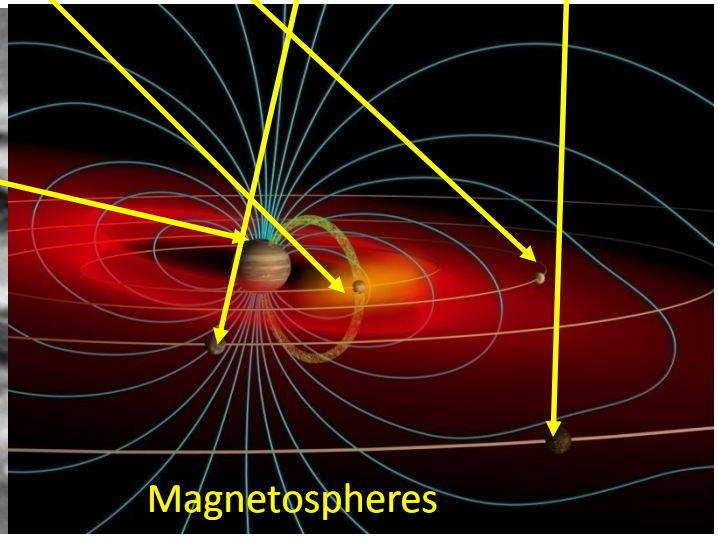
Europa Jupiter System Mission – JEO and JGO Science

- Characterize Europa and Ganymede as planetary objects and potential habitats

- Study Europa, Ganymede, Callisto and Io in broader context of the system of Galilean satellites

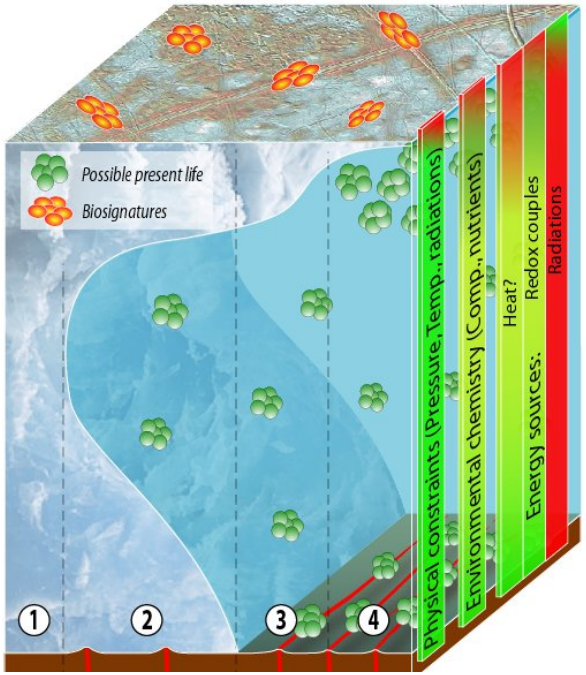
- Jupiter science:
  - the planet
  - it's atmosphere
  - the magnetosphere
  - the coupled system

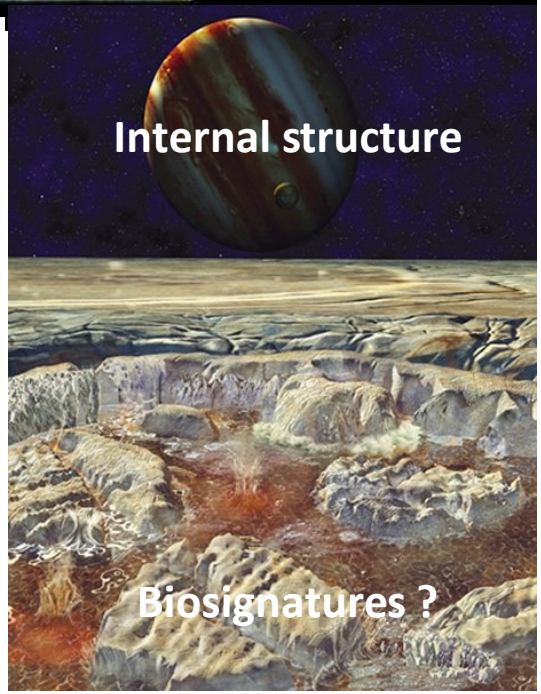


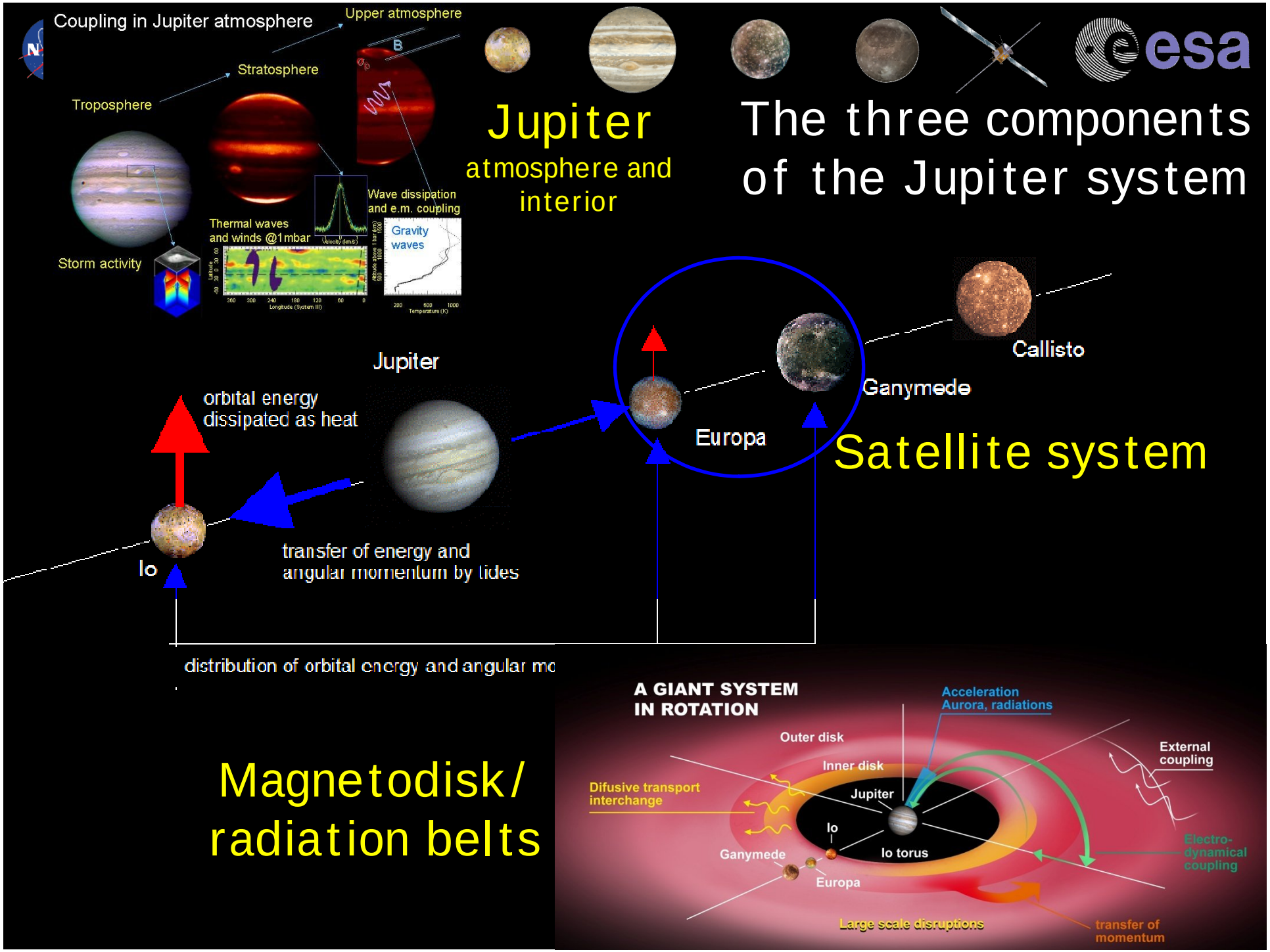


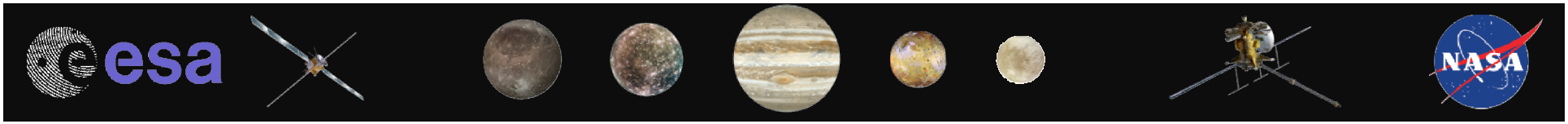
Are Europa and Ganymede Habitable?

1. Ocean beneath active icy crust
2. Ocean in contact with its silicate mantle?
3. Conditions close to those on sea floor
4. JEO will investigate conditions for habitability; characterise surface material; originates in ocean?
5. JGO will investigate depth of Ganymede ocean, link to silicate mantle?

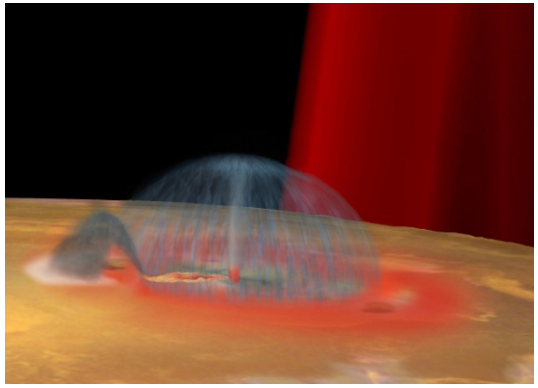




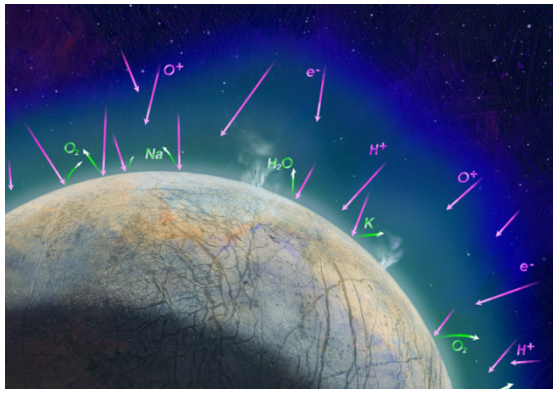

Coupling in Jupiter atmosphere
Upper atmosphere
Stratosphere
Troposphere
B
Storm activity
Thermal waves
and winds @1mbar
Wave dissipation
and e.m. coupling
Gravity
waves
Jupiter
atmosphere and
interior
The three components
of the Jupiter system
esa
Jupiter
orbital energy
dissipated as heat
Io
transfer of energy and
angular momentum by tides
distribution of orbital energy and angular mo
Europa
Ganymede
Callisto
Satellite system
Magnetodisk/
radiation belts
A GIANT SYSTEM
IN ROTATION
Acceleration
Aurora, radiations
Outer disk
Inner disk
Difusive transport
interchange
Jupiter
Io
Ganymede
Io torus
Europa
External
coupling
Electro-
dynamical
coupling
Large scale disruptions
transfer of
momentum



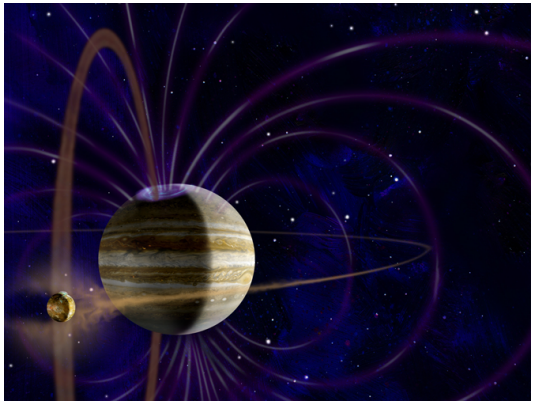
Jupiter's Coupled System



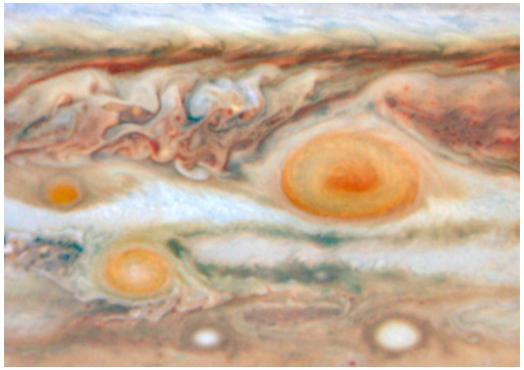
Satellite geology



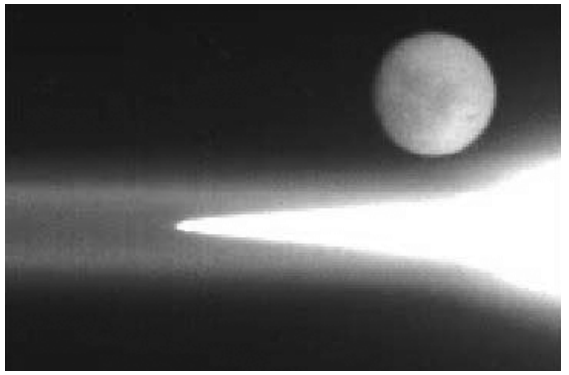
Satellite atmospheres



Plasma & magnetospheres

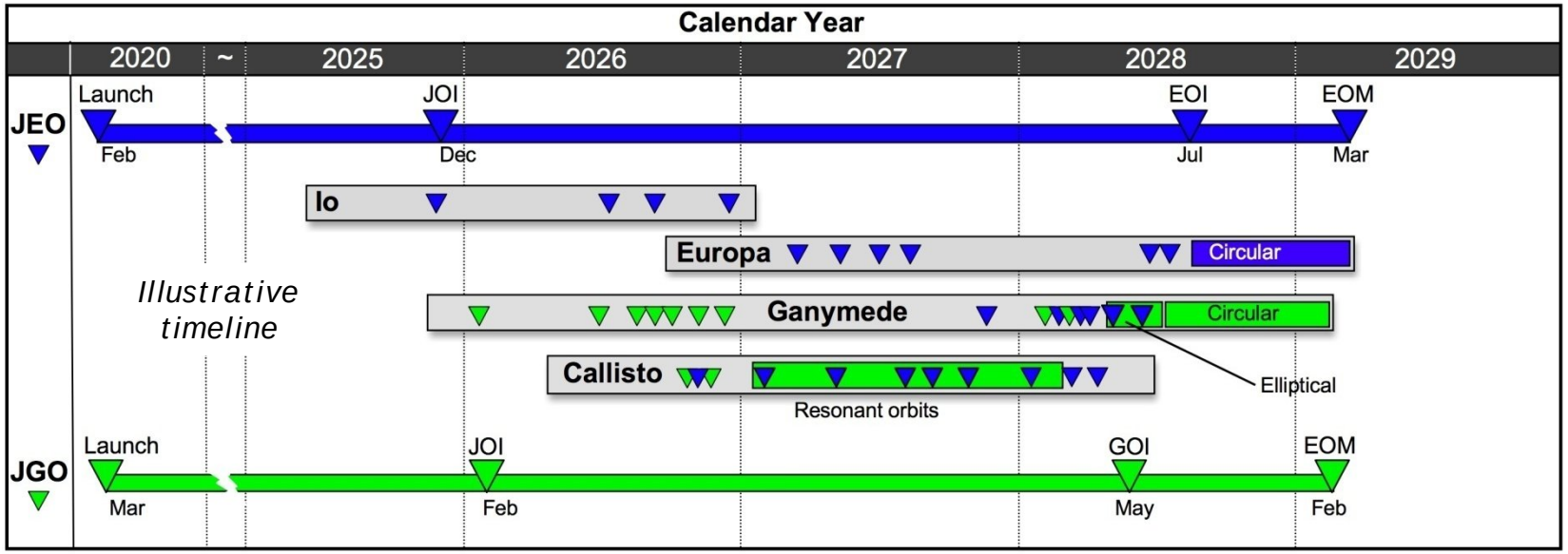


Jupiter atmosphere

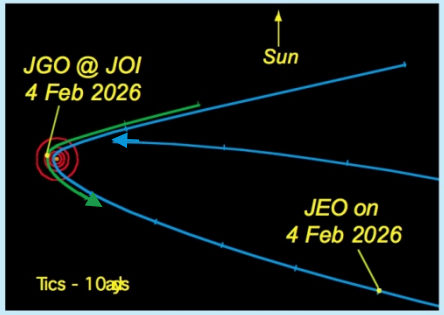


Rings

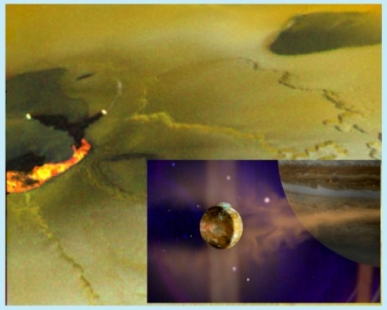
EJSM Synergistic Science



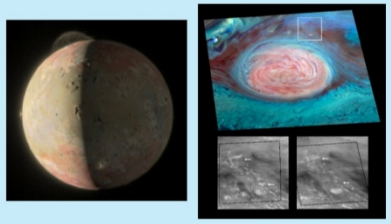
Jupiter Magnetosphere Studies



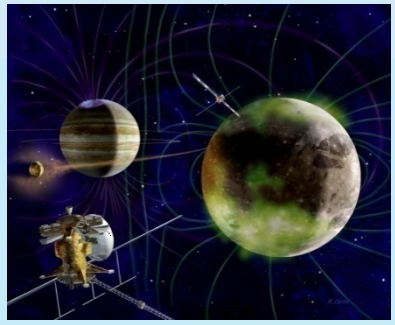
Io Volcanism & Io Torus Dynamics



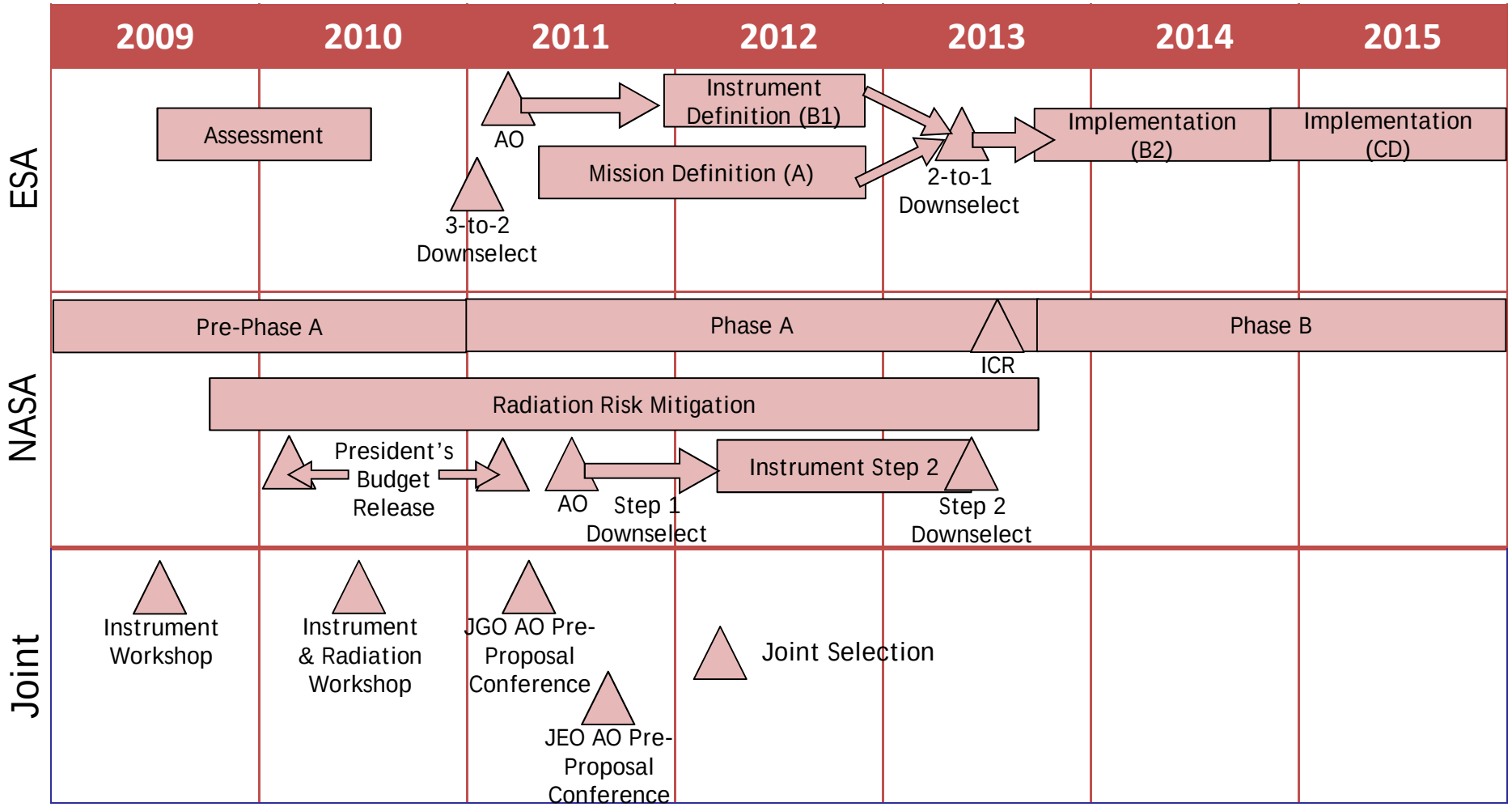
Satellite/Jupiter Monitoring and Radio Occultation Science



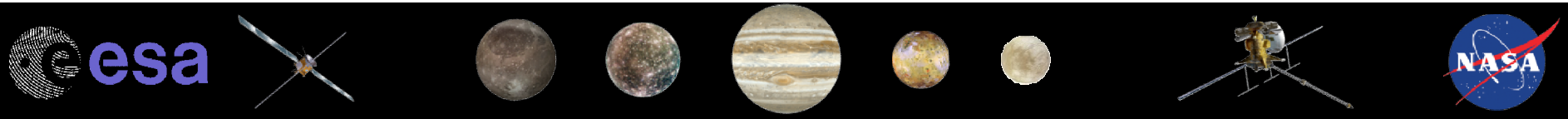
Ganymede Magnetosphere Studies



NASA and ESA Schedules



NB Continued discussions on schedule & AO coordination

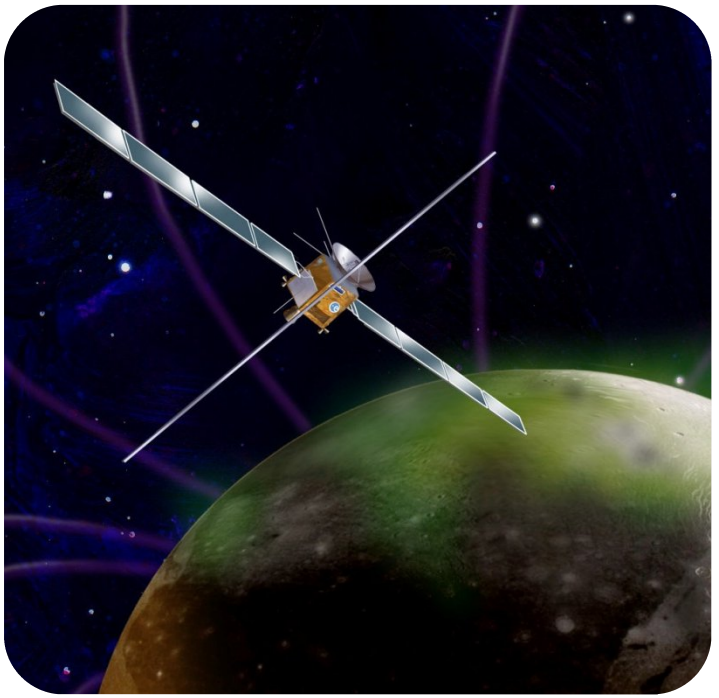


JGO Baseline Planning Milestones

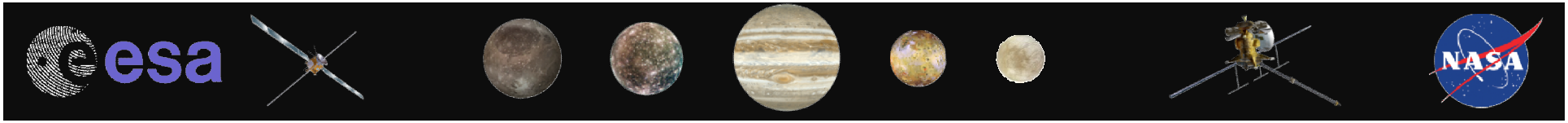
July 2009 – June 2010	Spacecraft Phase 0/A (3 parallel studies) – 12 months
Mid 2009 – mid 2010	Instrument Phase A (12 months) – DOI Studies
17 – 19 May 2010	EJSM Science Workshop (ESTEC)
Mid 2010	Preparations of study report (*Yellow Book*)
26 – 29 July 2010	4th EJSM Instrumentation Workshop (Pasadena)
31 August 2010	DOI Studies Report due
End 2010/mid- 2011	Review & Down-selection (3 → 2)
Early-mid 2011	Instrument AO
Mid 2011 – end 2012	Spacecraft Phase A/B1 (2 parallel studies) – 18 months
End 2011 – end 2012	Instrument Phase B1 (12 months)
End 2012	Preparations of study report
Early 2013	Review & Mission adoption (2 → 1) **TRL ≥ 5**
Mid 2013	Start of implementation Phase (B2/C/D)

JGO Study Model Payload

PDD Model Instrument Name	Acronym
Wide Angle Camera	WAC
Magnetometer	MAG
Radio Science Transponder and USO	JRST+USO
Visible InfraRed Hyperspectral Imaging Spectrometer	VIRHIS
Plasma Package & Ion and Neutral Mass Spectrometer	PLP/INMS
Sub-mm Instrument	SWI
Radio and Plasma Wave Instrument	RPWI
Narrow Angle Camera	HRC
Sub-Surface Radar	SSR
Laser Altimeter	LA
UV Imaging Spectrometer	UVIS



This study model payload is currently being studied by three industrial contractors



JEO Model Payload

Interdisciplinary Science, including Astrobiology		
Ocean Team		
	Laser Altimeter	**LA**
	Radio Science	**RS**
Ice Team		
	Ice Penetrating Radar	**IPR**
Chemistry Team		
	Vis-IR Imaging Spectrometer	**VIRIS**
	UV Spectrometer	**UVS**
	Ion and Neutral Mass Spectrometer	**INMS**
Geology Team		
	Thermal Instrument	**TI**
	Narrow Angle Camera	**NAC**
	Wide Angle Camera and Medium Angle Camera	**WAC + MAC**
Fields and Particles Team		
	Magnetometer	**MAG**
	Particle and Plasma Instrument	**PPI**

- Model payload is a proof-of-concept example
  - Other instruments may be viable
- 11 model payload instruments (including radio science)
- Emphasizes Europa investigations
- Enables robust Jupiter system science

Potentiel Surface Elements For Ganymede and/or Europa

- JGO Ganymede Penetrator studied by UK consortium under ESA special contract
  - Low-resource allocated (< 100 kg)
  - Strong/competing science case not achieved
  - Ganymede penetrator not included in baseline JGO configuration
- Penetrator study re-focused on Europa for consideration as of the potentiel JEO Europa Surface Element under study by ESEWG (on-going)

Main conclusions of the first face to face meeting of the SEWG (London June 2010)

Science Objectives

- Both in-situ **astrobiological** and **geophysical** measurements offer high science value that cannot be obtained from orbit.
- **No prioritization** of one theme over the other, because of the uncertainty of the environment (neither the presence/type of chemical species of astrobiological interest, nor the level of seismic activity, are known).
- **Context data** assumed to be provided by the lander system (temperature, penetration depth [if applicable], radiation, light level.)

Choice of the Surface Element

Most of the discussion have been oriented towards a penetrator, but the group did not make a recommendation at this stage

Localization

Geophysics: tidal forcing strongest at the Sub- and Anti-Jovian points, likely leading to higher seismic activity, but any location acceptable.

Astro/composition: investigations favor fresh non-ice material.

Engineering: maximizing the probability of a survivable landing (e.g. slopes < 30°) and maximizing the volume of data returned should be considered of **higher priority** than the scientific considerations

Main conclusions of the first face to face meeting of the WG

List of instruments that should be considered - Floor mission

1. Chemistry/Astrobiology (e.g. Mass Spec, Raman/UV/IR Spectrometer, etc.)
   Tens of mins- Hours Lifetime.
1. Geophysics (Geophone/Seismometer)
   1.0 Europa Day Lifetime*
1. Engineering Data (Temperature, Accelerometer, Light Level, Radiation)

Additional instruments

2. Camera (landing site panorama for lander / microscope for penetrator)
3. Enhancement to chemistry/astrobiology
4. Enhancement to Geophysics (e.g. Magnetometer, Tracking Beacon, tiltmeter, broader band seismometer, etc.)
5. Enhancement of Lifetime to 2 Europa days or more
6. Descent Camera

RSA Europa Lander Study

Slide Extracted from presentation given at EJSM science workshop, 17-19 May, ESTEC Noordwjk, Courtesy L. Zelnyi, O. Korablev

Main stages of mission

- Proton/Breeze-M launch (target date **2021**, as in the project of Federal Space Programme)
- Electric propulsion transport module (separation in the vicinity of Jupiter)
- Using Earth, Jupiter and Galilean satellites gravity assist maneuvers
- Multiple fly-bys of Ganimede, Callisto and Europa;
- Final circular orbit around Europa with a height of 100 km;
- Separation of the Landing module and landing. Europa orbiter and supports telecommunication. Optional TM relay via NASA JEO or directly to Earth via VLBI.