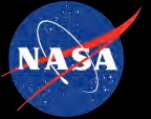
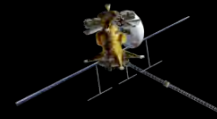
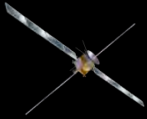


Jupiter Science from the Jupiter Europa Orbiter: An Element of the Europa Jupiter System Mission

Robert Pappalardo

Jet Propulsion Laboratory,
California Institute of Technology

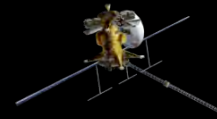
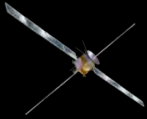
A Joint NASA-ESA Outer Planet Mission Study



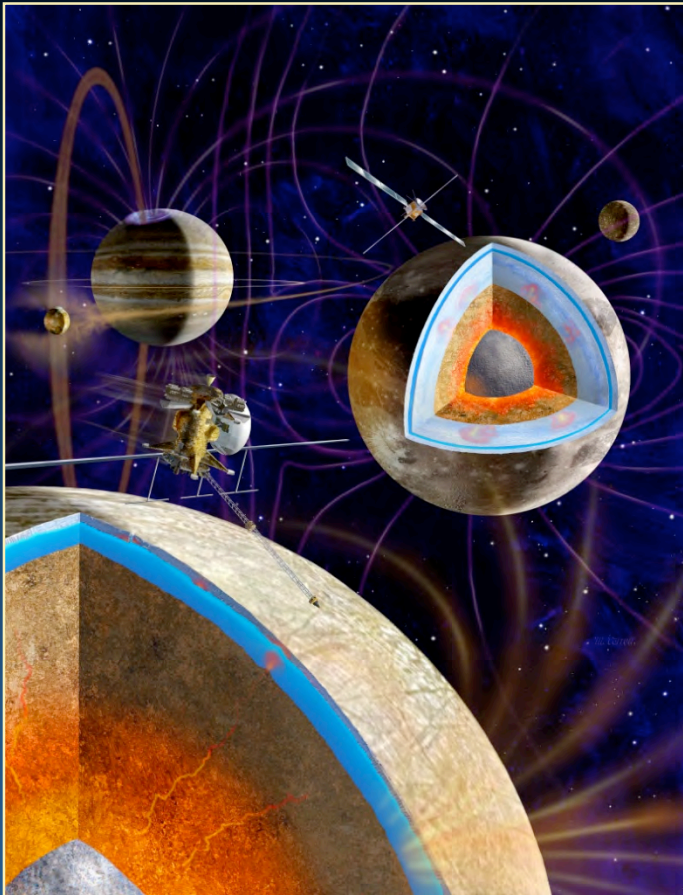
2002 Decadal Survey: Galilean Satellite Science

- Steering Group's "Science Themes" and associated "Fundamental Science Questions" point to Europa:
 - The Origin and Evolution of Habitable Worlds:
 - 7. How do planetary processes give rise to habitable zones and worlds?
 - Processes: How Planetary Systems Work:
 - 11. How do processes that shape planetary bodies operate and interact?
- Large Satellites Panel recommendations:
 - Robust Europa Orbiter with Jupiter system science is strongly recommended
 - Addresses 3 of 4 Large Satellites Panel panel themes and associated key questions
 - Next decade: Ganymede Orbiter, Io Explorer

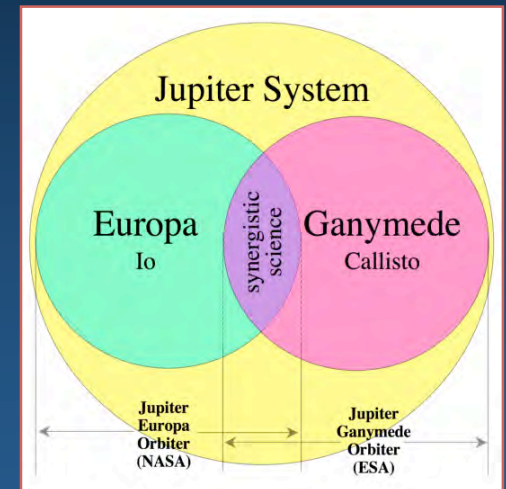
2002 Decadal Survey recommended Europa as top flagship priority



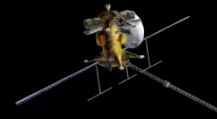
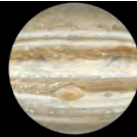
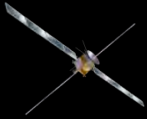
Europa Jupiter Science Mission (EJSM)



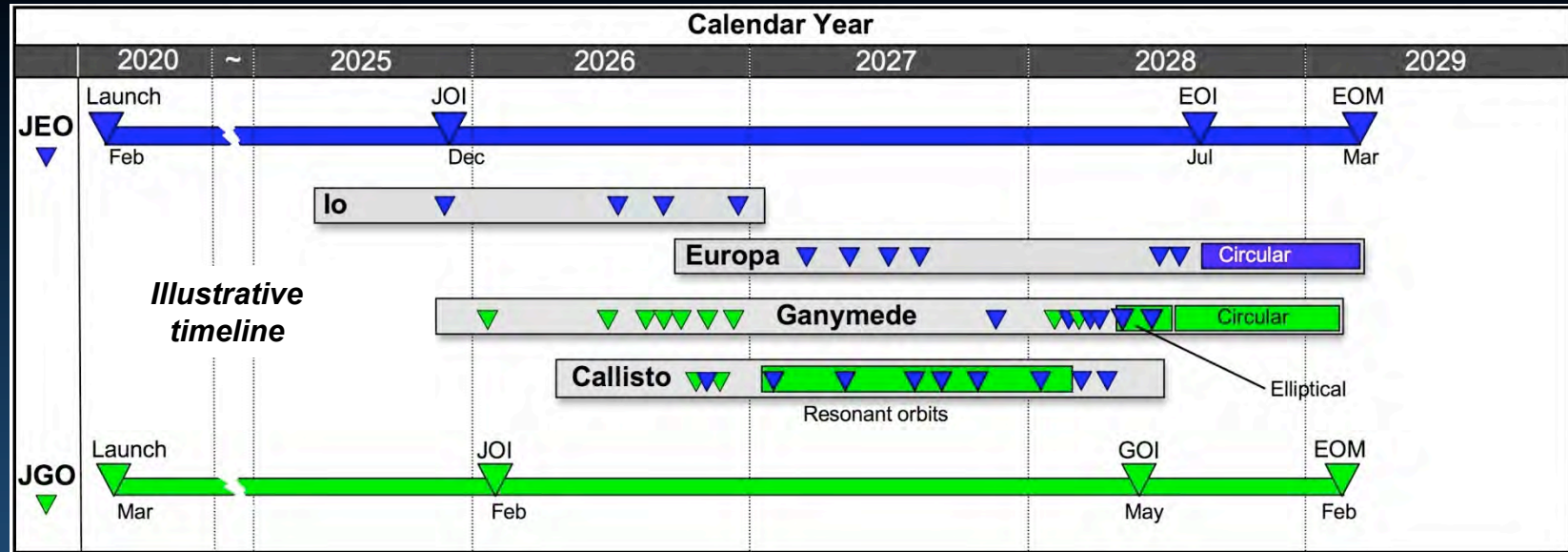
- NASA and ESA: Shared mission leadership
- Independently launched and operated orbiters
 - NASA-led Jupiter Europa Orbiter (JEO)
 - ESA-led Jupiter Ganymede Orbiter (JGO)
- Complementary science and payloads
 - JEO concentrates on Europa and Io
 - JGO concentrates on Ganymede and Callisto
 - Synergistic overlap
 - 11-12 instruments each
- Science goals:
 - Icy world habitability
 - Jupiter system processes



Synergistic science: The sum of JEO + JGO is greater than the parts

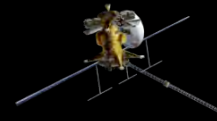
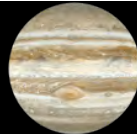
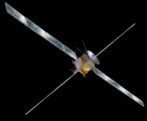


Nominal EJSM Timeline



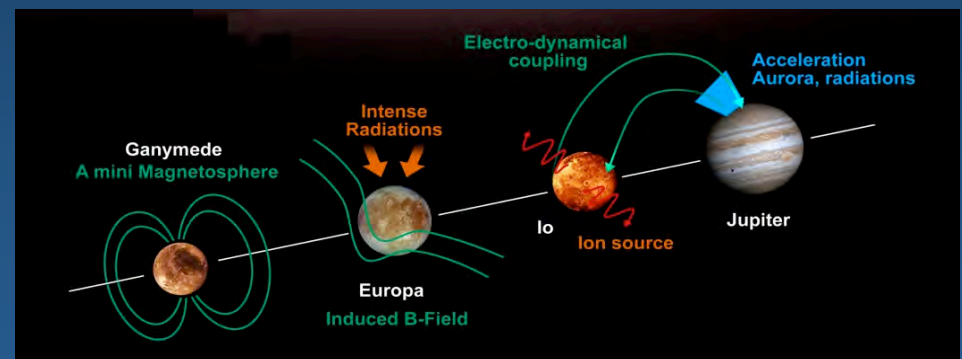
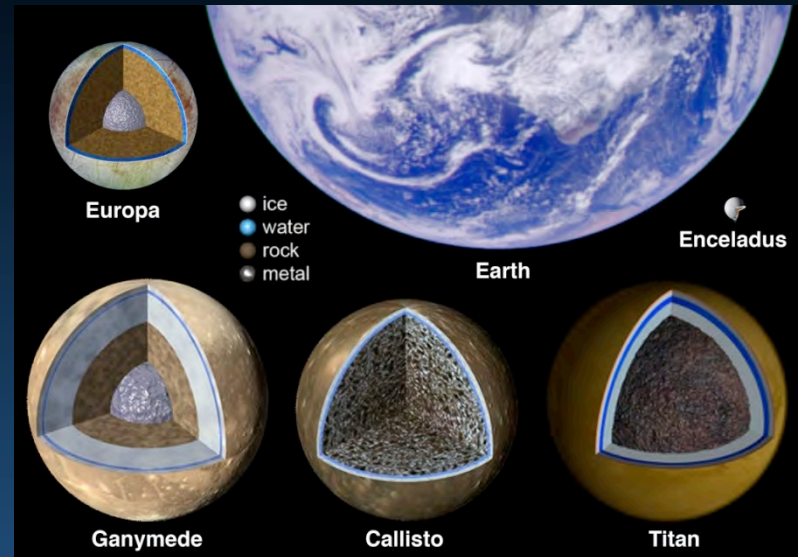
- Launches: 2020
- Jovian system tour phases: 2–3 years
- Moon orbital phases: 6–12 months
- End of Prime Missions: 2029
- Flexibility if either flight element is delayed or advanced

Coordinated timelines ensure synergistic science

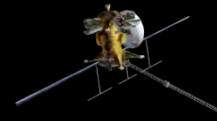
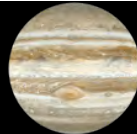
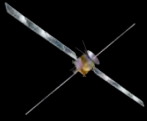


EJSM Theme: The Emergence of Habitable Worlds Around Gas Giants

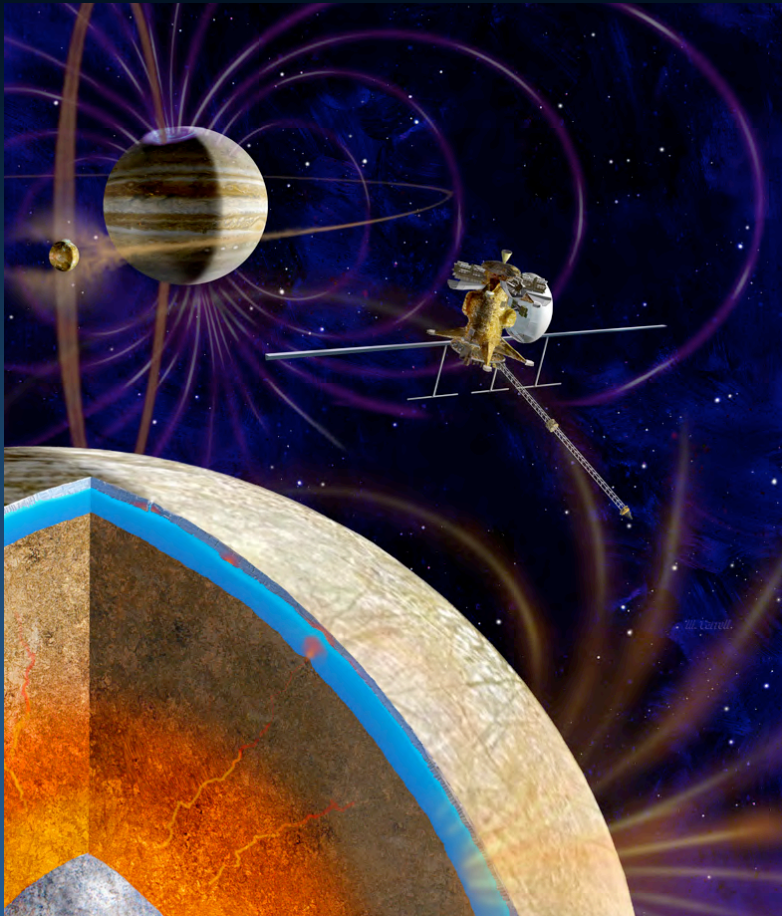
- *Goal 1:* Determine if the Jupiter system harbors habitable worlds
 - Ocean characteristics
 - Ice shells and subsurface water
 - Deep internal structure, and (for Ganymede) intrinsic magnetic field
 - External environments
 - Global surface compositions
 - Surface features and future landing sites
- *Goal 2:* Characterize Jupiter system processes
 - Satellite system
 - Jupiter atmosphere
 - Magnetodisk/magnetosphere
 - Jovian system Interactions
 - Jovian system origin



Emphasis on icy moon habitability and Jupiter system processes



JEO Goal: Explore Europa to Investigate Its Habitability

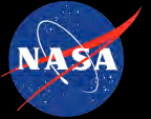
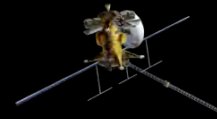
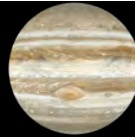
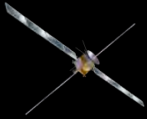


Habitability

Objectives (prioritized):

- Ocean and Interior
- Ice Shell
- Chemistry and Composition
- Geology and Landing Sites
- Jupiter System
 - Satellite surfaces and interiors
 - Satellite atmospheres
 - Plasma and magnetospheres
 - Jupiter atmosphere
 - Rings

Characterizing the archetype of icy world habitability



JEO Traceability: Europa

Goal		Science Objective	Science Investigation
Explore Europa to investigate its habitability.	A. Ocean	Characterize the extent of the ocean and its relation to the deeper interior.	A1. Determine the amplitude and phase of the gravitational tides.
			A2. Characterize the magnetic environment (including plasma) to determine the induction response from the ocean over multiple frequencies.
			A3. Characterize surface motion over the tidal cycle.
			A4. Determine the satellite's dynamical rotation state.
			A5. Investigate the core, rocky mantle, and rock-ocean interface.
	B. Ice	Characterize the ice shell and any subsurface water, including their heterogeneity, and the nature of surface-ice-ocean exchange.	B1. Characterize the distribution of any shallow subsurface water.
			B2. Search for an ice-ocean interface.
			B3. Correlate surface features and subsurface structure to investigate processes governing material exchange among the surface, ice shell, and ocean.
			B4. Characterize regional and global heat flow variations.
	C. Chemistry	Determine global surface compositions and chemistry, especially as related to habitability.	C1. Characterize surface organic and inorganic chemistry, including abundances and distributions of materials, with emphasis on indicators of habitability and potential biosignatures.
			C2. Relate compositions to geological processes, especially material exchange with the interior.
			C3. Characterize the global radiation environment and the effects of radiation on surface composition, atmospheric composition, albedo, sputtering, sublimation, and redox chemistry.
			C4. Characterize the nature of exogenic materials.
	D. Geology	Understand the formation of surface features, including sites of recent or current activity, and identify and characterize candidate sites for future <i>in situ</i> exploration.	D1. Determine the formation history and three-dimensional characteristics of magmatic, tectonic, and impact landforms.
			D2. Determine sites of most recent geological activity, and evaluate future landing sites.
			D3. Investigate processes of erosion and deposition and their effects on the physical properties of the surface debris.

JEO Themes:

Origins

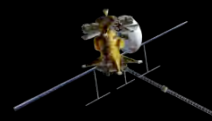
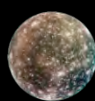
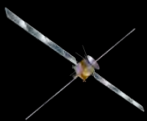
Evolution

Processes

Habitability

Life

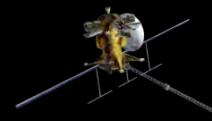
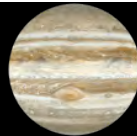
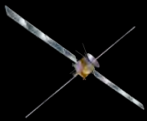
Based on 2002 Decadal's "objectives of solar system exploration"



JEO Traceability: Jupiter System Science

Goal	Science Objective	Science Investigation	
Explore Europa to investigate its habitability.	Understand Europa in the context of the Jupiter system.	Satellite surfaces and interiors	E1. Investigate the nature and magnitude of tidal dissipation and heat loss on the Galilean satellites, particularly Io
			E2. Investigate Io's active volcanism for insight into its geological history and evolution (particularly of its silicate crust)
			E3. Investigate the presence and location of water within Ganymede and Callisto.
			E4. Determine the composition, physical characteristics, distribution and evolution of surface materials on Ganymede.
			E5. Determine the composition, physical characteristics, distribution and evolution of surface materials on Callisto.
			E6. Identify the dynamical processes that cause internal evolution and near-surface tectonics of Ganymede and Callisto.
		Satellite Atmos.	E7. Characterize the composition, variability and dynamics of Europa's atmosphere and ionosphere
			E8. Understand the sources and sinks of Io's crustal volatiles and atmosphere.
			E9. Determine the sources and sinks of the Ganymede and Callisto atmospheres.
		Plasma and magnetospheres	E10. Characterize the neutral atoms and molecules escaping Europa's gravity.
			E11. Characterize the composition of and transport in Io's plasma torus.
			E12. Study the pickup and charge exchange processes in the Jupiter system plasma and neutral tori.
			E13. Study the interactions between Jupiter's magnetosphere and Io, Ganymede and Callisto (incl. characterize Ganymede's magnetic field)
			E14. Understand the structure, composition and stress balance of Jupiter's magnetosphere.
			E15. Determine how plasma and magnetic flux are transported in Jupiter's magnetosphere.
		Jupiter atm.	E16. Characterize the abundance of minor species (especially water and ammonia) in Jupiter's atmosphere to understand the evolution of the Jovian system, including Europa.
			E17. Characterize Jovian atmospheric dynamics and structure.
		Rings	E18. Characterize the properities of the small moons, ring source bodies and dust
			E19. Identify the dynamical processes that define the origin and dynamics of ring dust.

Giant Planets Panel



JEO Model Payload

Ocean

Laser Altimeter

LA

Radio Science

RS

Ice

Ice Penetrating Radar

IPR

Chemistry

Vis-IR Imaging Spectrometer

VIRIS

UV Spectrometer

UVS

Ion and Neutral Mass Spectrometer

INMS

Geology

Thermal Instrument

TI

Narrow Angle Camera

NAC

Wide Angle Camera and Medium Angle Camera

WAC + MAC

Fields and Particles

Magnetometer

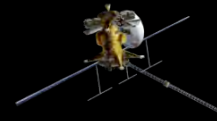
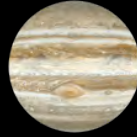
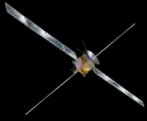
MAG

Particle and Plasma Instrument

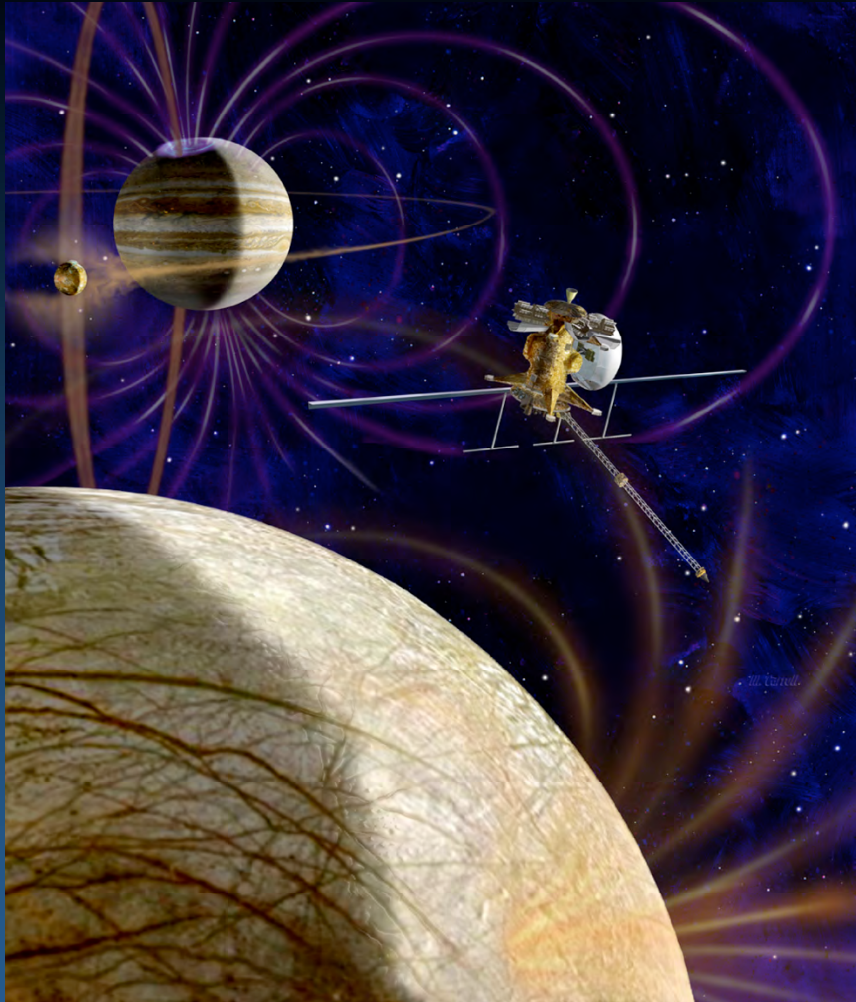
PPI

- Model payload is a proof-of-concept example
 - Other instrument choices may be viable
- Emphasizes accomplishing Europa investigations
- Enables robust Jupiter system science
- The final selected payload would almost certainly be different

Capable model payload with a conservative approach



Jupiter Europa Orbiter Science

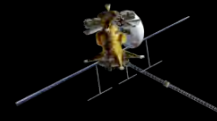
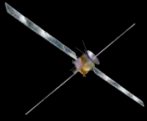


Habitability

Objectives Summary:

- Ocean characterization
- Surface-ice-ocean exchange
- Compositional makeup
- Geological evolution
- Jupiter system science
 - Galilean satellite evolution
 - Sat. atmospheric interactions
 - Magnetospheric physics
 - Jupiter atmospheric dynamics
 - Ring system dynamics

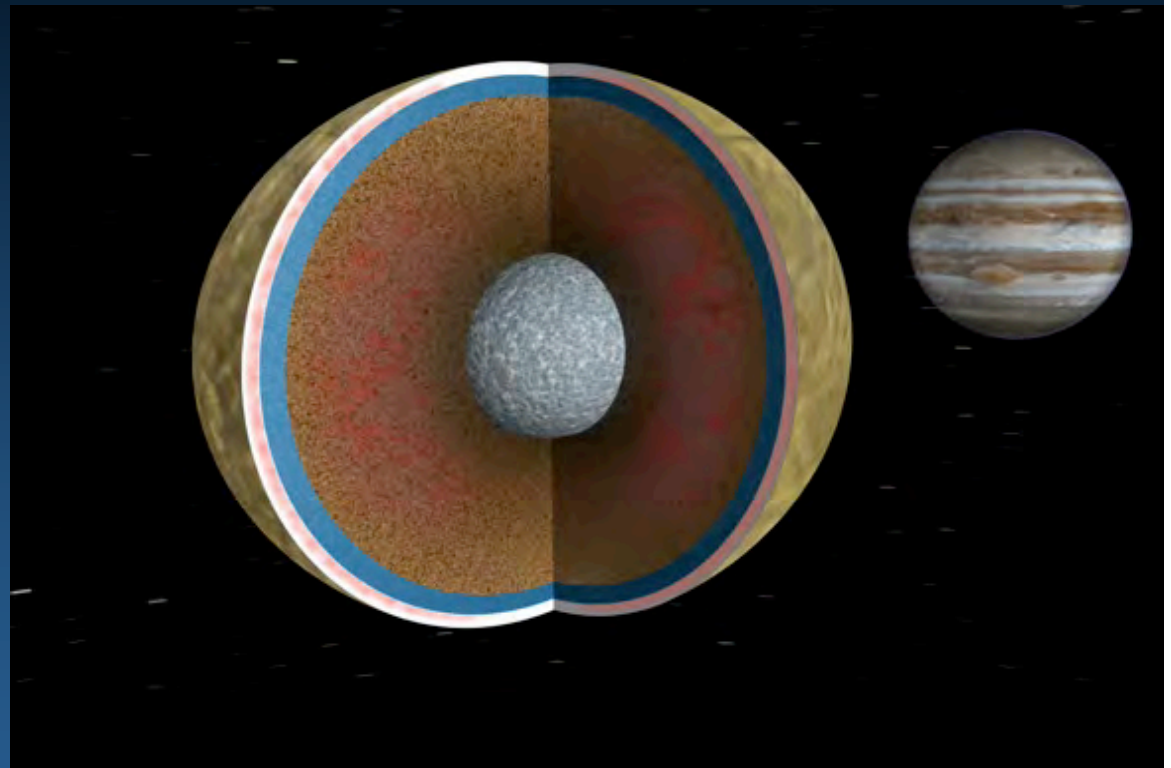
Rich and robust science of Europa and the Jupiter system



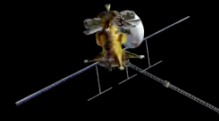
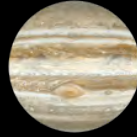
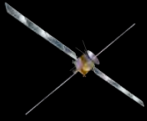
Europa: Ocean • Ice • Chemistry • Geology

A. Ocean & deeper interior:

1. Gravitational tides
2. Magnetic environment (including plasma)
3. Surface motion
4. Dynamical rotation state
5. Core, rocky mantle, & rock-ocean interface



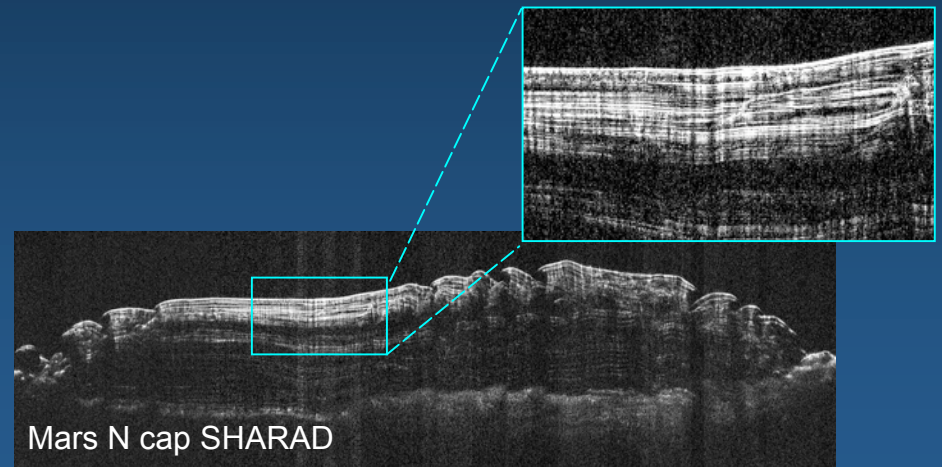
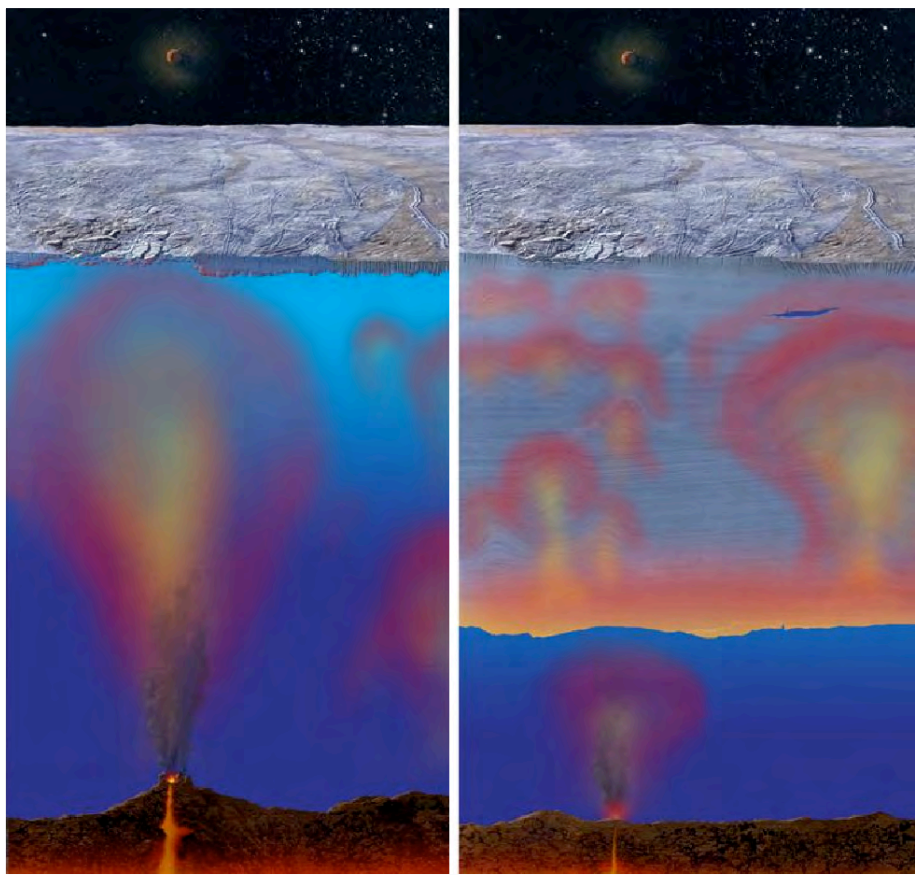
Geophysical techniques reveal the interior



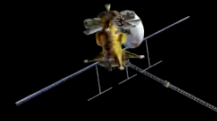
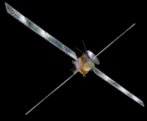
Europa: Ocean • Ice • Chemistry • Geology

B. Ice shell & subsurface water:

- Shallow water
- Ice-ocean interface
- Material exchange
- Heat flow variations



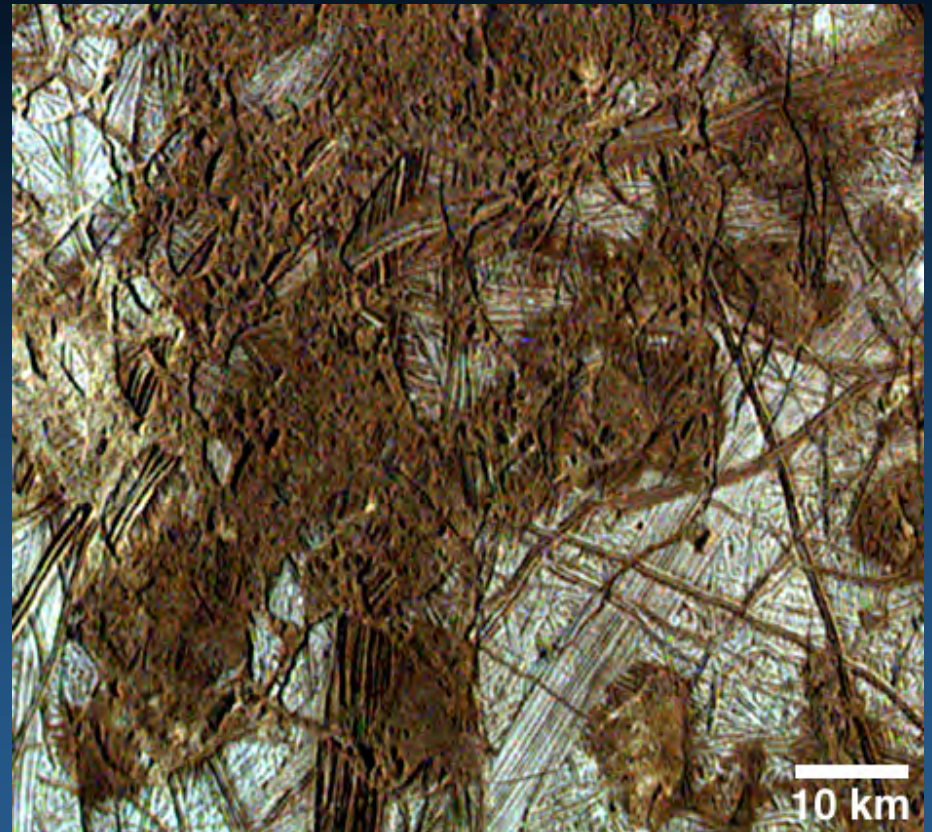
Radar sounding would characterize the ice shell in 3 dimensions



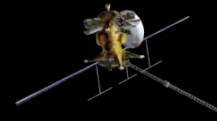
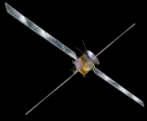
Europa: Ocean • Ice • Chemistry • Geology

C. Global surface composition & chemistry:

1. Organic & inorganic chemistry
2. Relation to geologic processes
3. Radiation effects
4. Exogenic materials



Composition is key to understanding ocean habitability

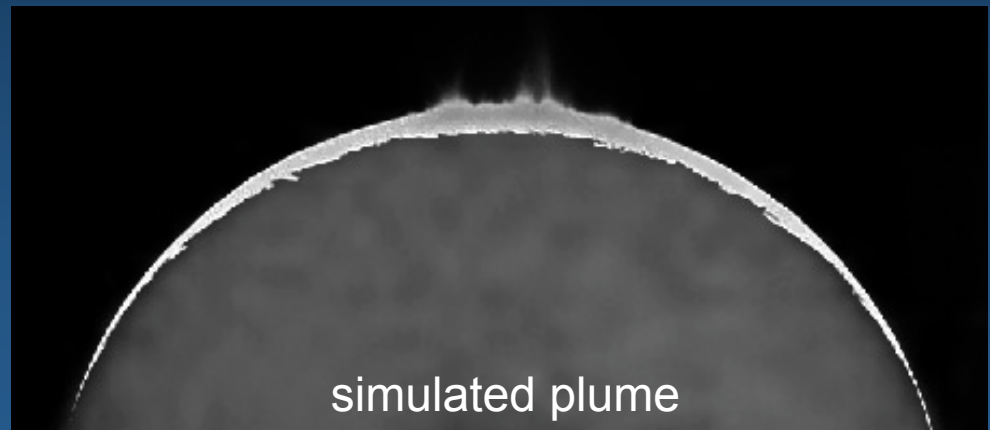


Europa: Ocean • Ice • Chemistry • Geology

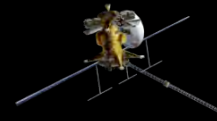
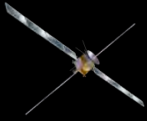


D. Surface features, activity, & landing sites:

1. Formation history & 3-D character
2. Recent activity & future landing sites
3. Erosion & deposition

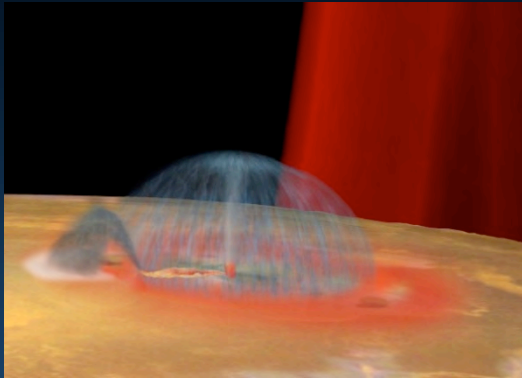


JEO would decipher Europa's varied and complex geology

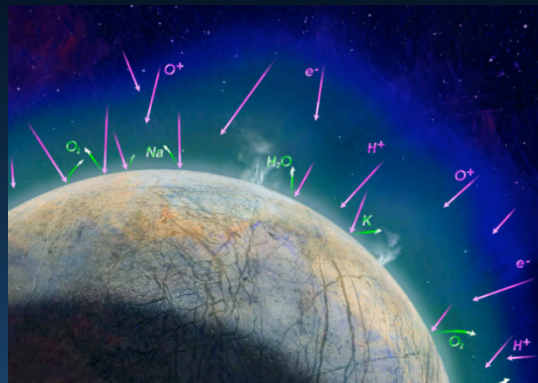


Jupiter System: Sats • Atm • Mag • Jupiter • Rings

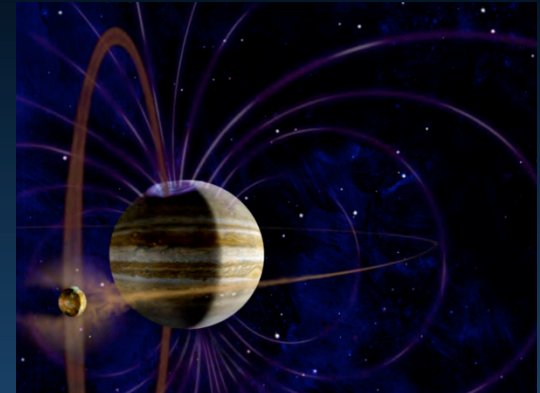
E. Understand Europa in the context of the Jupiter system



Satellite surfaces & interiors



Satellite atmospheres



Plasma & magnetospheres

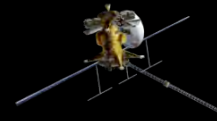
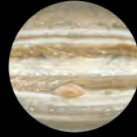
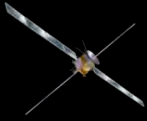


Jupiter atmosphere



Rings

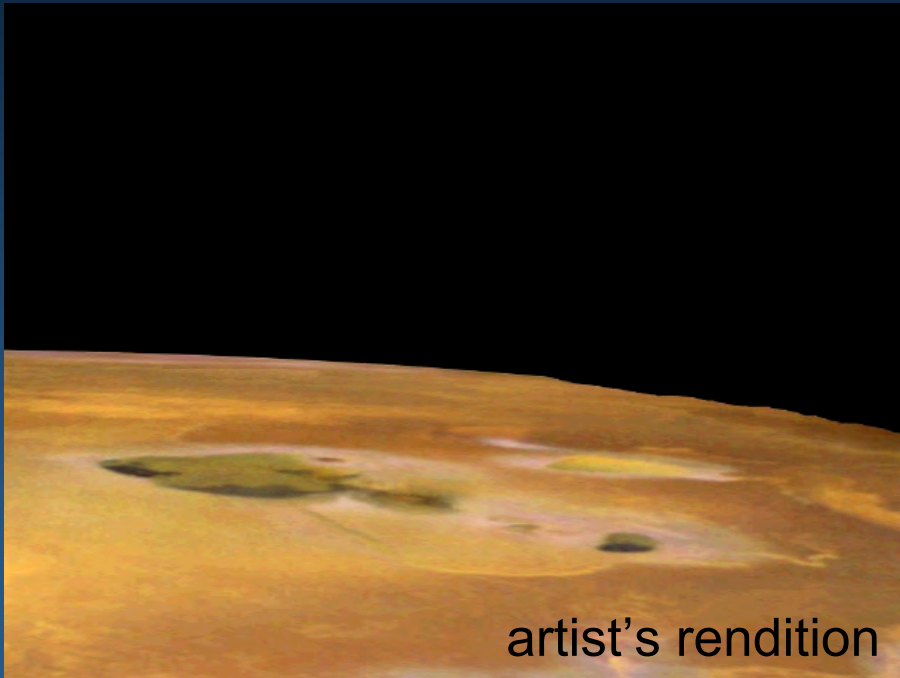
The Jupiter system is rich in dynamic and coupled processes



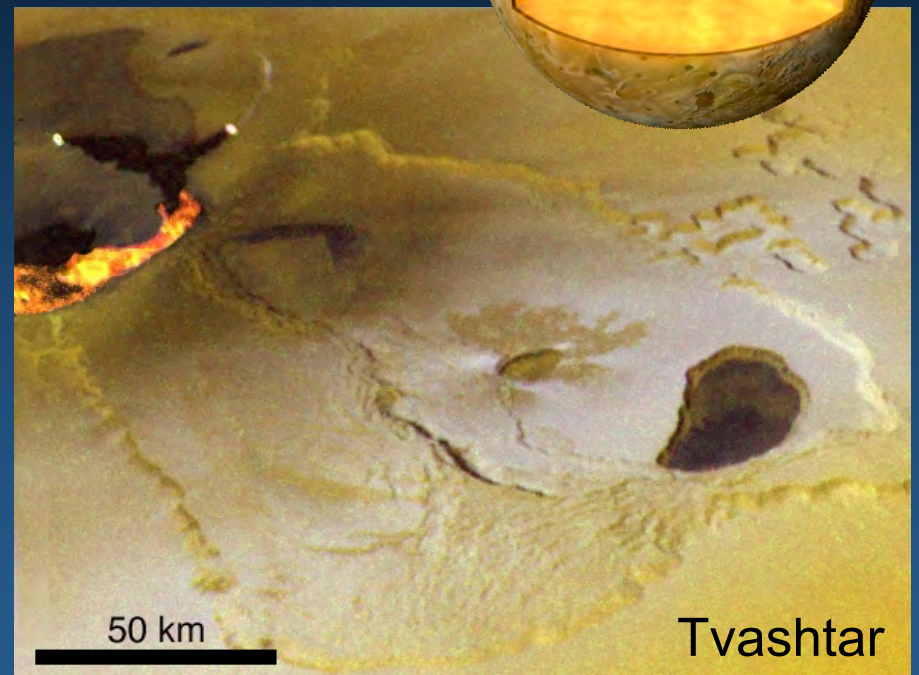
Jupiter System: Sats • Atm • Mag • Jupiter • Rings

Satellite surfaces & interiors:

1. Io's tidal heating & heat loss
2. Io's active volcanism



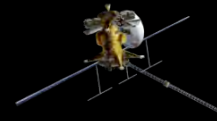
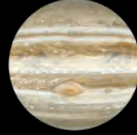
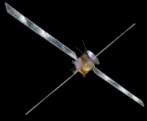
artist's rendition



50 km

Tvashtar

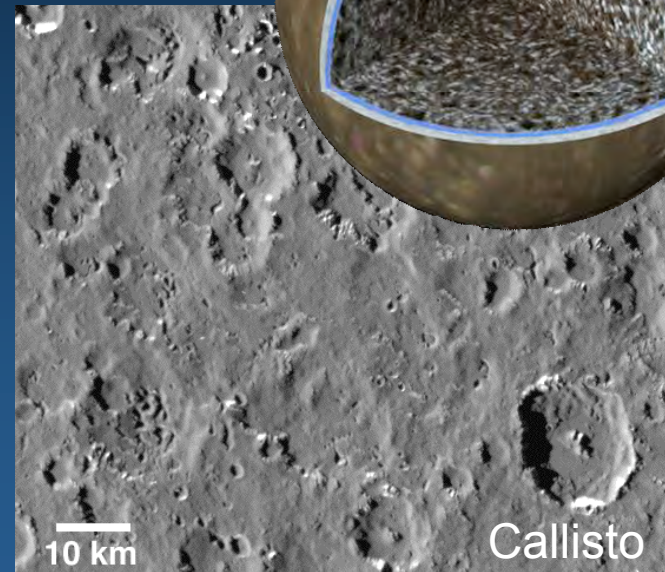
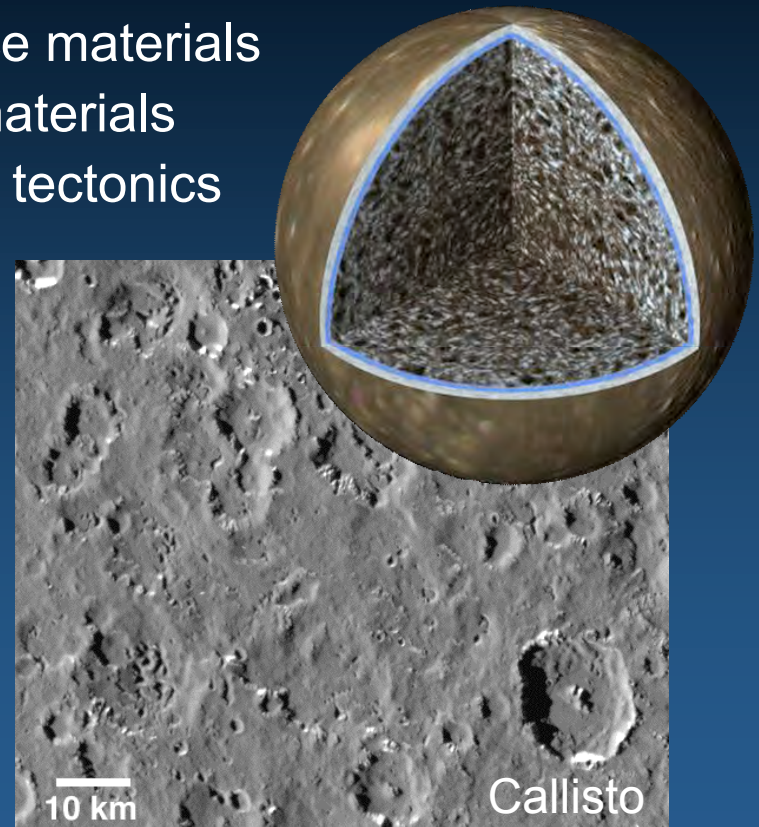
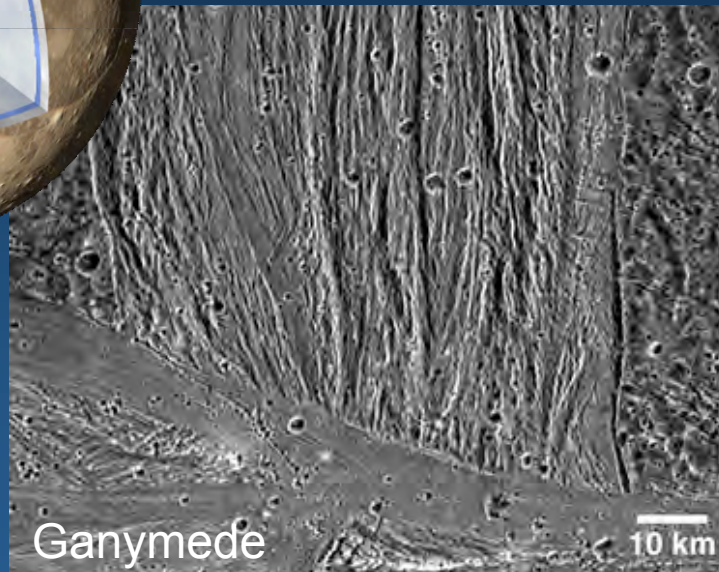
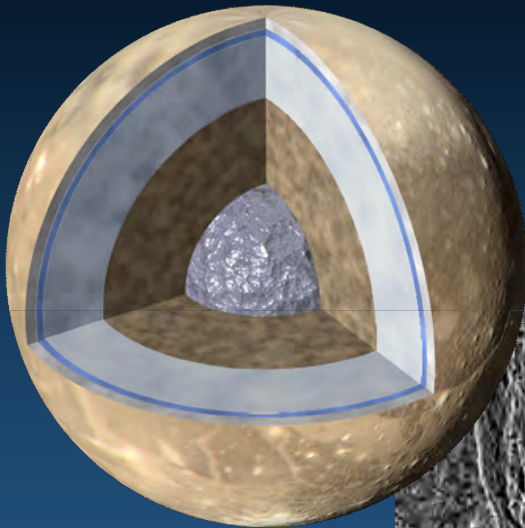
Io is the tidal engine of the Laplace resonance



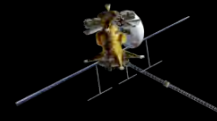
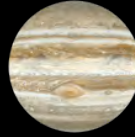
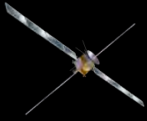
Jupiter System: Sats • Atm • Mag • Jupiter • Rings

Satellite surfaces & interiors (cont.):

3. Water in Ganymede & Callisto
4. Ganymede's surface materials
5. Callisto's surface materials
6. Internal evolution & tectonics



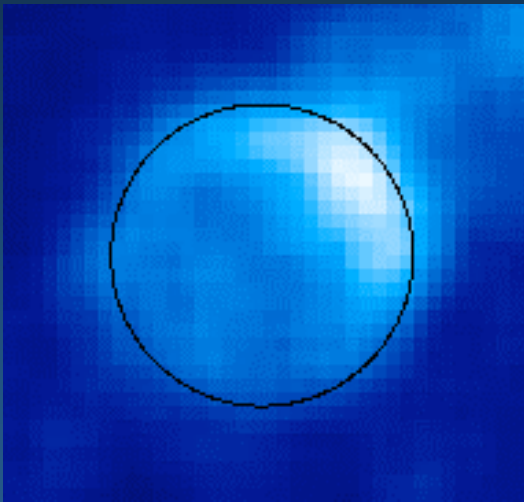
The icy Galilean satellites provide context for Europa



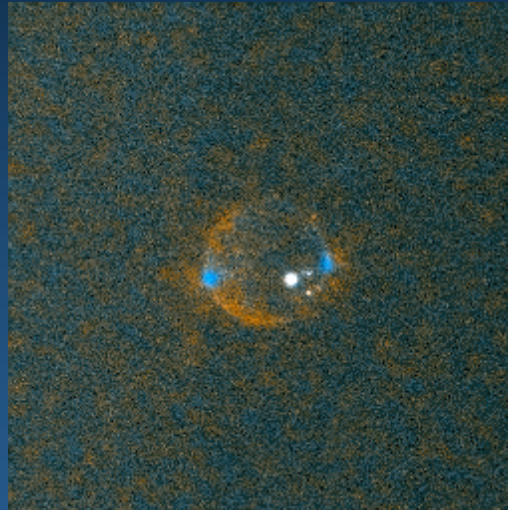
Jupiter System: Sats • Atm • Mag • Jupiter • Rings

Satellite atmospheres:

7. Europa: Composition, variability, and dynamics
8. Io: Composition, sources, and evolution
9. Ganymede and Callisto: Sources and sinks



Europa atm. (HST O 1356Å)

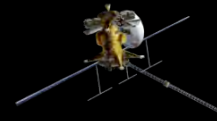
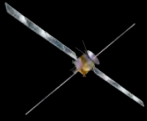


Io atm. & aurora (Cassini)

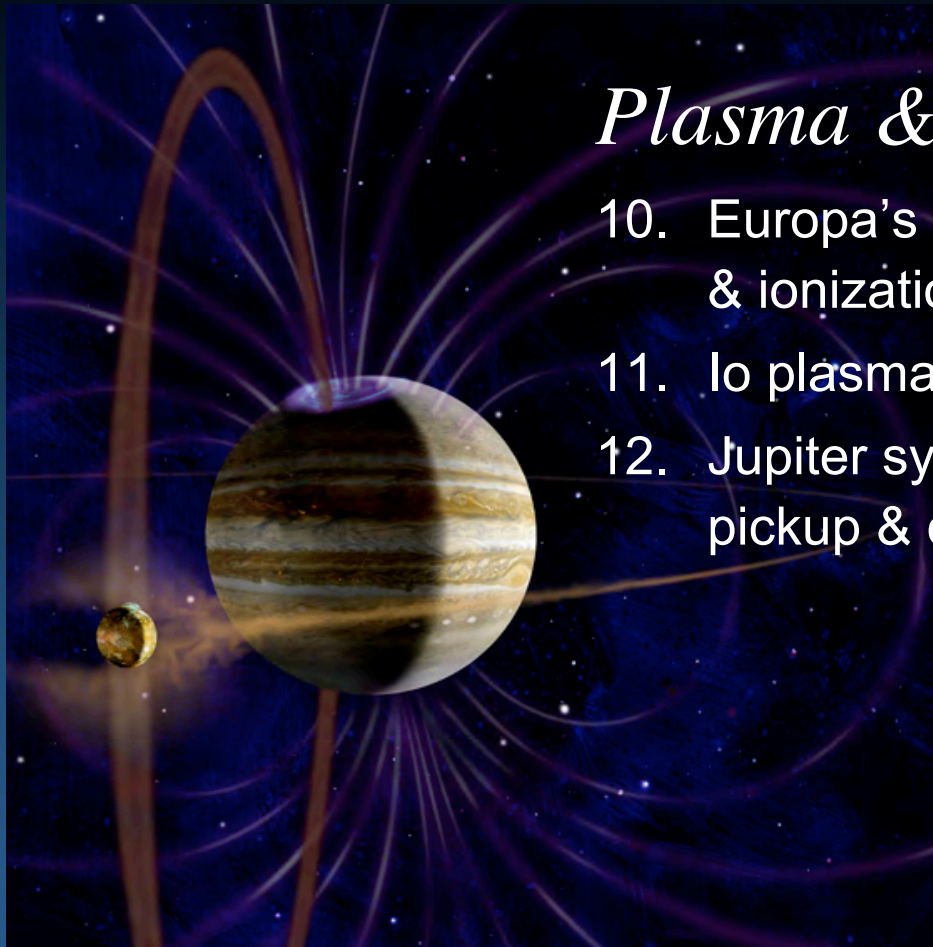


Ganymede aurora (HST)

Understanding atmospheric interactions and processes



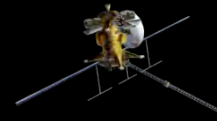
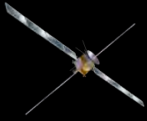
Jupiter System: Sats • Atm • Mag • Jupiter • Rings



Plasma & magnetospheres:

- 10. Europa's escaping neutrals: escape, pickup, & ionization
- 11. Io plasma torus: composition and transport
- 12. Jupiter system plasma and neutral tori: pickup & charge exchange

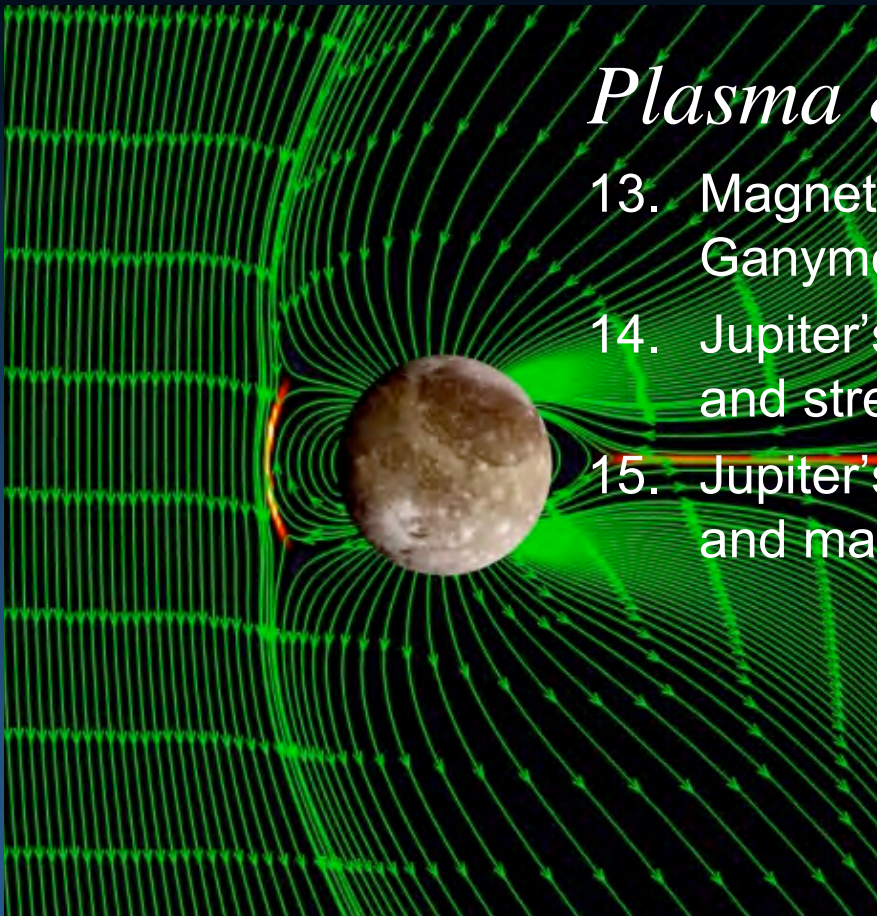
Probing the Solar System's largest magnetosphere



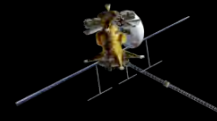
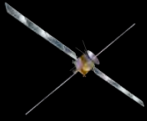
Jupiter System: Sats • Atm • Mag • Jupiter • Rings

Plasma & magnetospheres (cont):

13. Magnetosphere-satellite interactions, including Ganymede's field
14. Jupiter's magnetosphere: structure, composition, and stress balance
15. Jupiter's magnetosphere: transport of plasma and magnetic flux



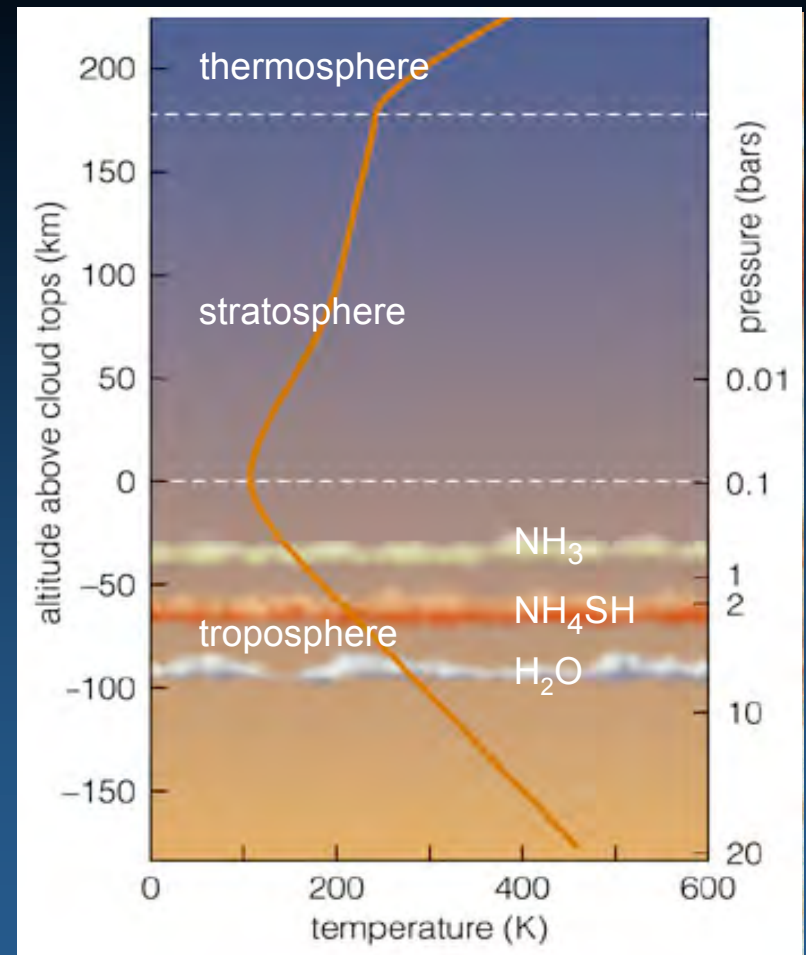
Observing unique satellite-magnetosphere interactions



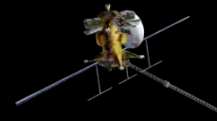
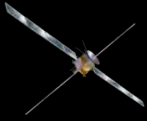
Jupiter System: Sats • Atm • Mag • Jupiter • Rings

E. Jupiter atmosphere:

16. Minor species abundances, esp. H_2O and NH_3
 - a. Global distribution of H_2O vapor humidity (2-8 bar)
 - b. Global distribution of gaseous NH_3 (0.1-0.4 bar & 2-8 bar)
 - c. Vertical distribution of stratospheric water (1-300 mbar)
 - d. Global distribution of gaseous H_2O & NH_3 (10-100 bar)
 - e. 3-D distribution of disequilibrium species (0.1-4 bar)
 - f. 3-D distribution, properties, and variability of aerosols



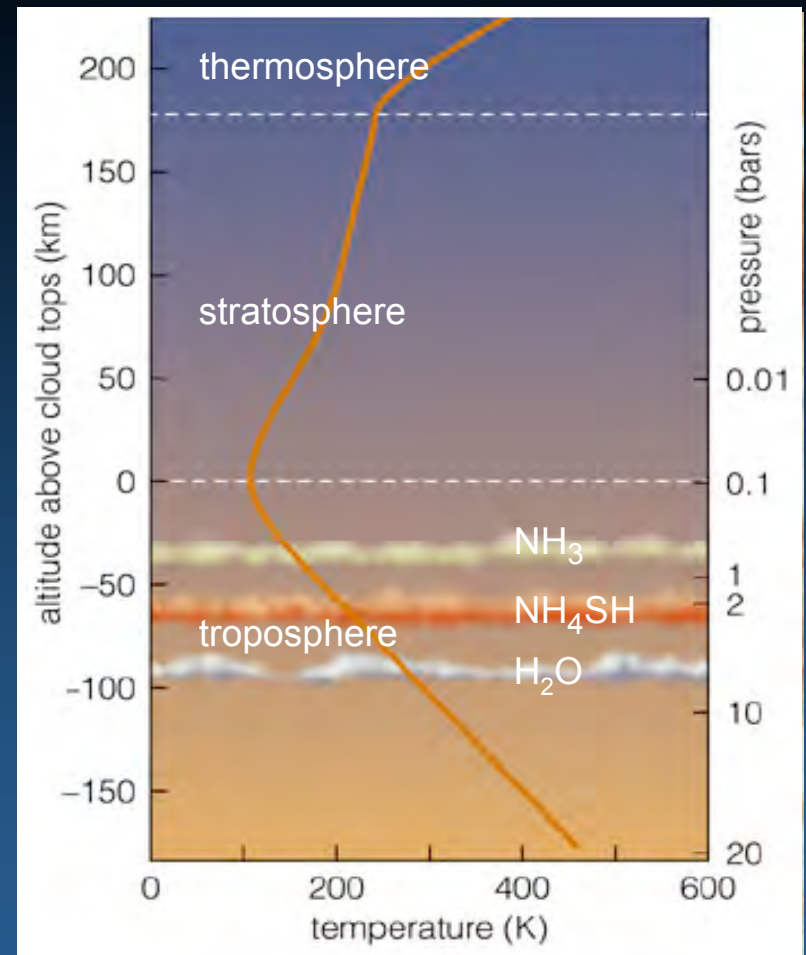
Opportunity for long-term monitoring from 70 nm to 40 mm



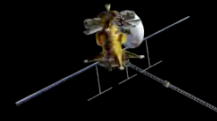
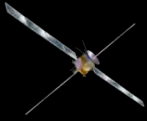
Jupiter System: Sats • Atm • Mag • Jupiter • Rings

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Jupiter System: Sats • Atm • Mag • Jupiter • Rings

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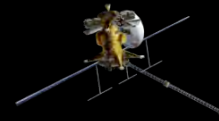
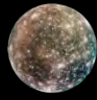
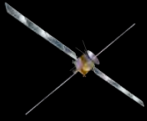
17. Dynamics & structure

- a. Global dynamics and winds, over day to year timescales
- b. Vertical temperature structure & horizontal gradients for deriving thermal wind shears (1-500 mbar)
- c. Ionospheric variability, and wave propagation in stratosphere & upper troposphere, through radio occultations
- d. Temperature structure & composition in upper stratosphere through stellar and solar occultations
- e. Global 3-D distribution of stratospheric species
- f. Observe aurora, over minute to day timescales



Voyager 1, 1979

Addresses unanswered questions and complements Juno



Jupiter System: Sats • Atm • Mag • Jupiter • Rings

E. Jupiter atmosphere:

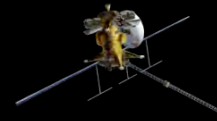
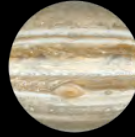
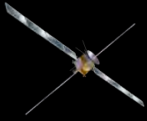
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Voyager 1, 1979

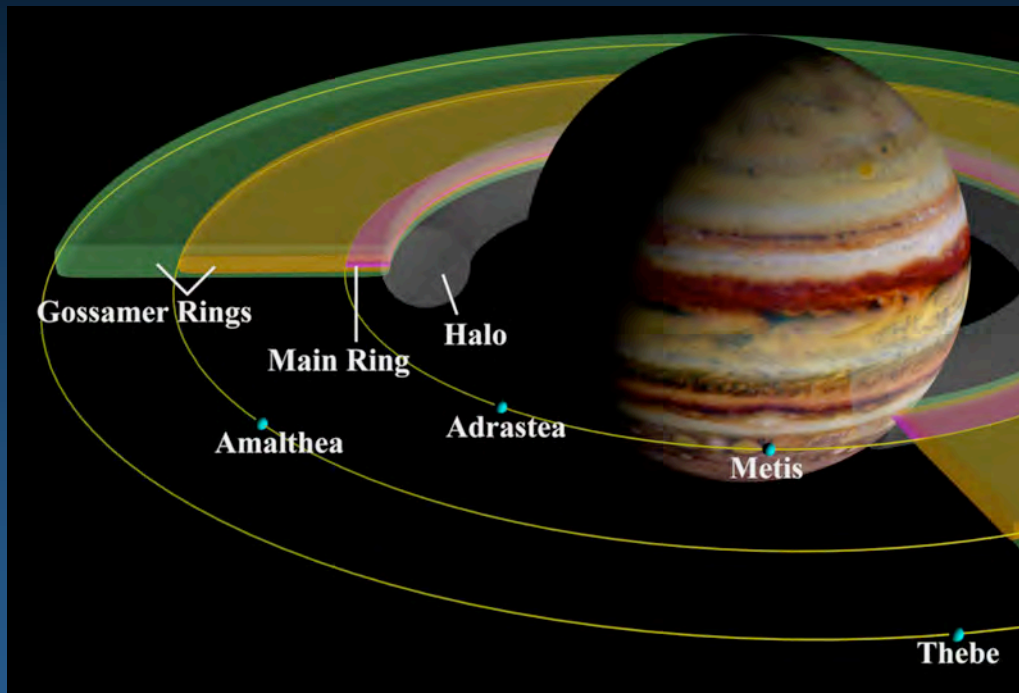
Addresses unanswered questions and complements Juno



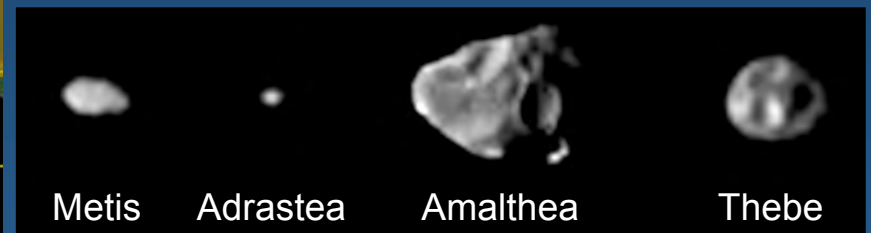
Jupiter System: Sats • Atm • Mag • Jupiter • Rings

Rings:

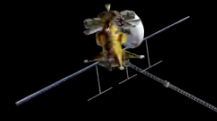
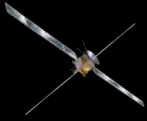
18. Properties of small moons, ring source bodies, & dust



- Search for embedded moons within rings
- Search for small moons
- Search for dust belts
- Radial structure of rings
- Ring and inner moon compositions



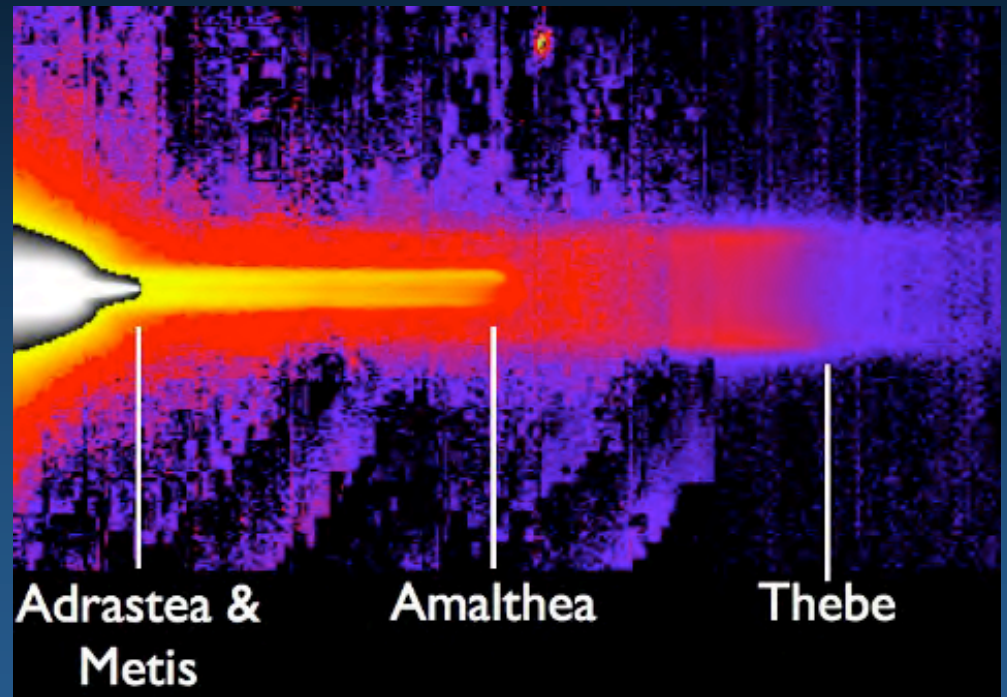
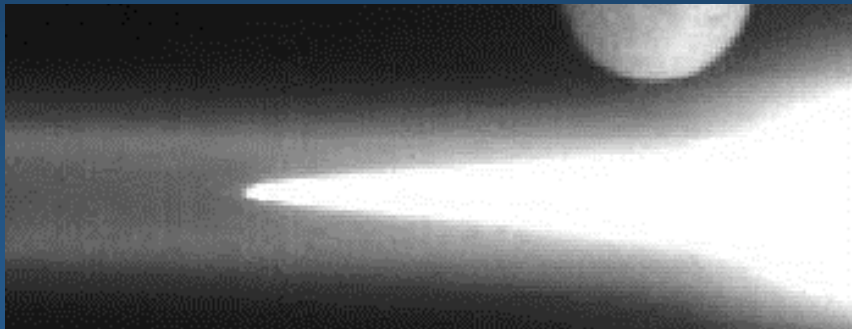
Many questions remain about the source bodies and ring dust



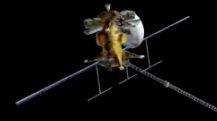
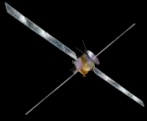
Jupiter System: Sats • Atm • Mag • Jupiter • Rings

Rings (cont):

19. Dynamical processes that define the origin and dynamics of ring dust
 - a. Rings' 3-D structure
 - b. Time-variable phenomena, including clump evolution
 - c. Warps and asymmetries



Enabling comparative studies of ring dynamics and evolution



Jupiter Science Drivers for Instrumentation

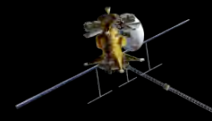
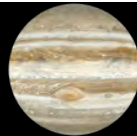
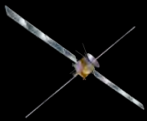
- JEO would permit regular temporal monitoring of Jupiter's dynamic atmosphere across a broad wavelength range
- JEO model instruments were defined by striking a balance among all five JEO science objectives
- Simple instrument enhancements provide substantial potential for Jupiter science

Example 1: NAC Color Filters

INVESTIGATION E17a: Global dynamics and winds, over day to year timescales

REQUIREMENT: High-resolution imaging at multiple visible wavelengths, repeated on hourly/daily/weekly timescales.

ACCOMMODATION: Include ≥ 4 narrow-band filters to sound CH_4 absorption and continuum. 7 km resolution from $9.5 R_J$, ~ 3000 images per opportunity, movies.



Jupiter Science Drivers for Instrumentation (cont.)

Example 2: Thermal Instrument

INVESTIGATION E17b:

Vertical temperature structure & horizontal gradients for deriving thermal wind shears

REQUIREMENT: Global temperature maps through spectroscopy of H_2 -He absorption in thermal-IR.

ACCOMMODATION: 4 filters (17.2, 21.0, 28.2, 40.0 μm) to probe 100-500 mbar; 1700 km/pixel from 9.5 R_J .

NB: Filtered imaging rather than full spectra.

Example 3: VIS-IR Spectrometer

INVESTIGATIONS E16a,b:

Global H_2O vapor humidity, and gaseous NH_3 (2-8 bar).

REQUIREMENT: IR spectroscopy to 5.2 μm with 10 nm spectral resolution.

ACCOMMODATION: Extend IR range from 5.0 to 5.2 μm ; 170 km res. from 9.5 R_J ; 4 image cubes for full hemispherical map; movies.

Example 4: Radio Science

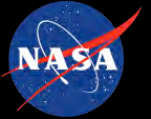
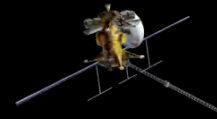
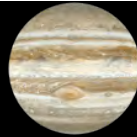
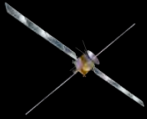
INVESTIGATION E17c:

Ionospheric variability, and wave propagation in stratosphere & upper troposphere.

REQUIREMENT: Radio occultations for refractivity profiles, with sub-scale height resolution.

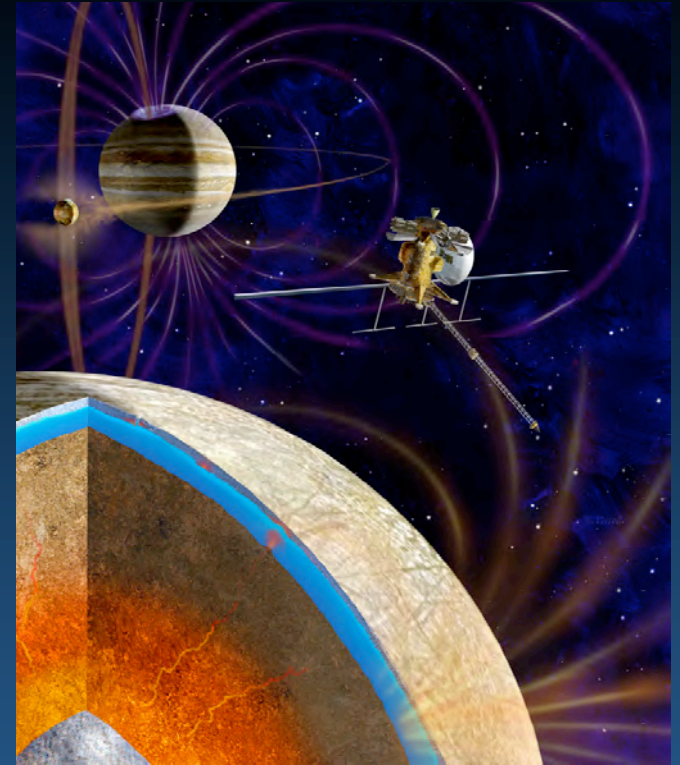
ACCOMMODATION: Dual X/Ka band to separate ionized and neutral media; stable USO for frequency and phase; height resolution 1-2 km at Ka, 3-4 km at X; possible dual-s/c communications.

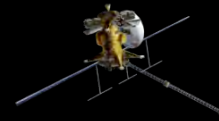
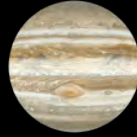
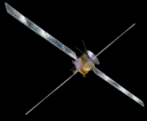
Simple instrument enhancements would enable Jupiter science



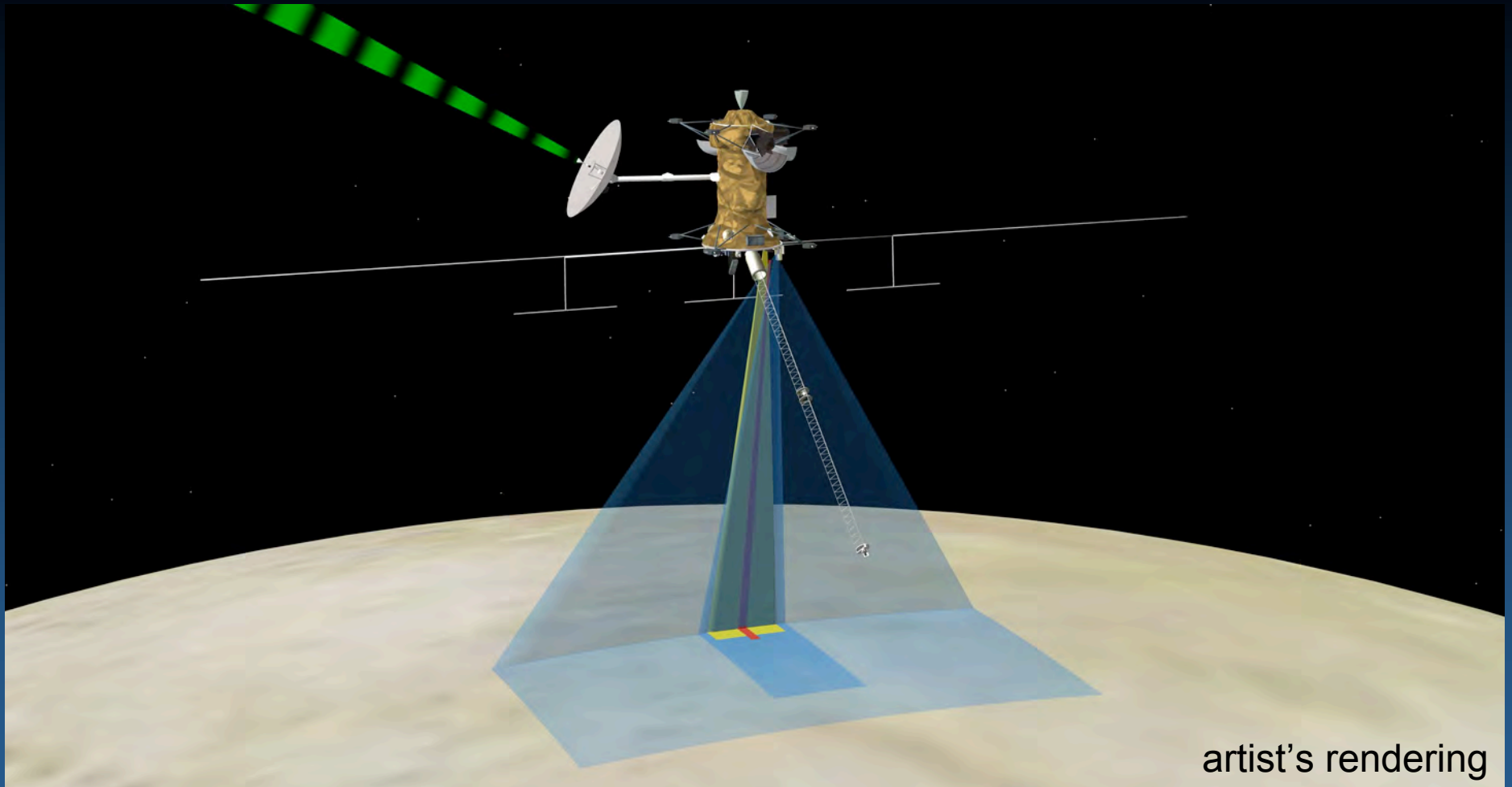
JEO Baseline Mission Overview

- Launch vehicle: Atlas V 551
- Power source: 5 MMRTG or 5 ASRG
- Mission timeline:
 - Launch: 2020
 - Jovian system tour phase: 30 mo.
 - Europa orbital phase: 9 mo.
 - End of prime mission: 2029
 - Spacecraft final disposition is Europa impact
- Radiation dose: 2.9 Mrad (behind 100 mils 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



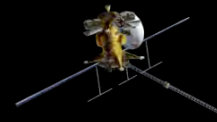
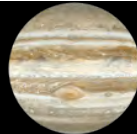
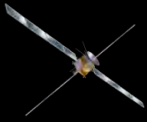


Orbital Operability

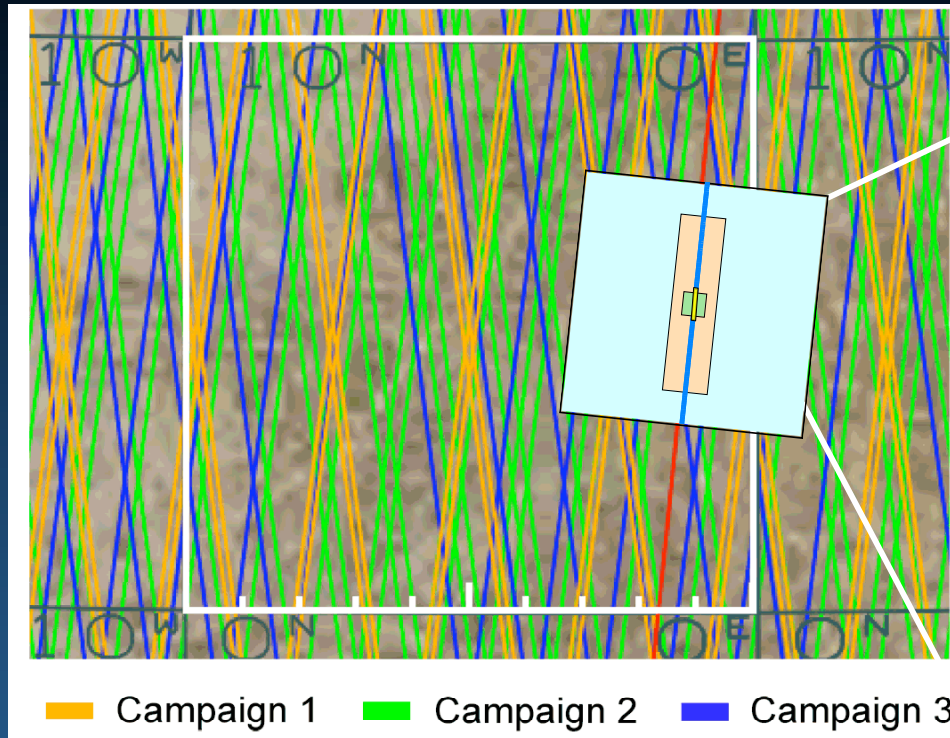


artist's rendering

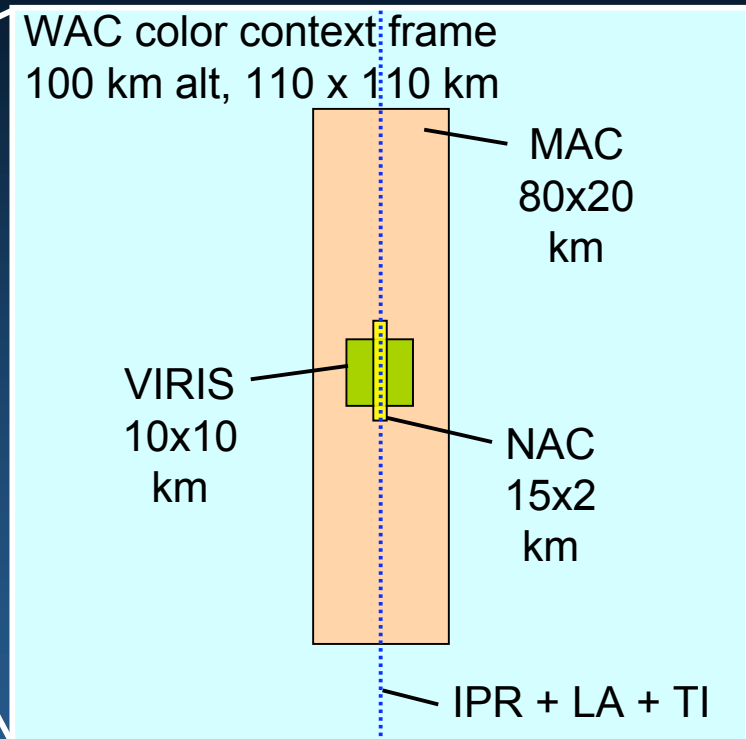
Articulated antenna would permit simultaneous observations and downlink



Europa Science Campaigns: Profiling and Targeted Observations

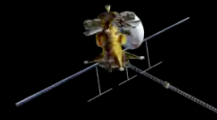
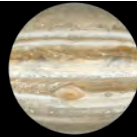
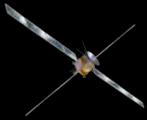


≤18 km groundtrack separation after 100 dy

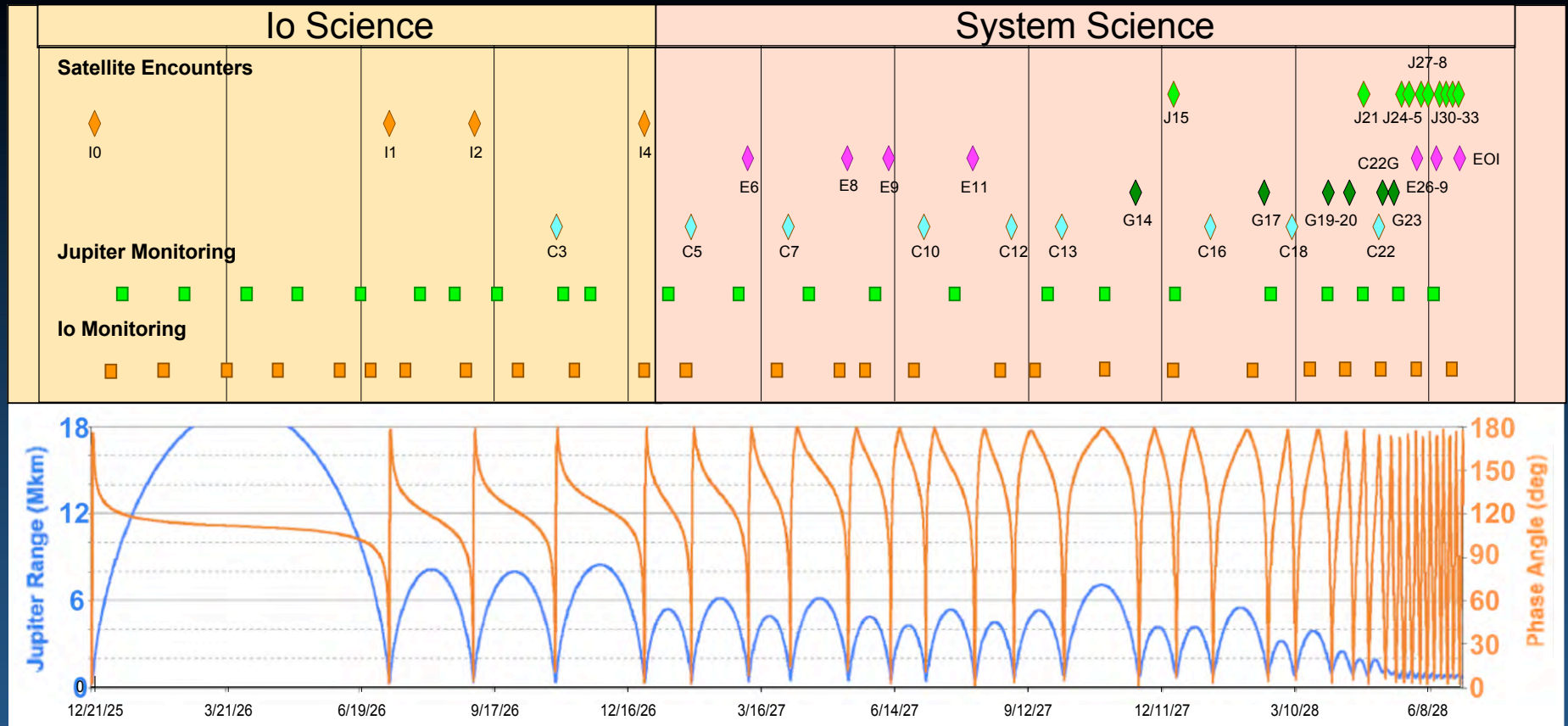


Coordinated targets (290 Mb)

~1700 coordinated targeted observations obtained after 9 mo.

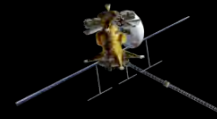
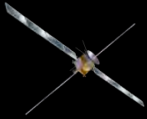


Jovian Tour Example



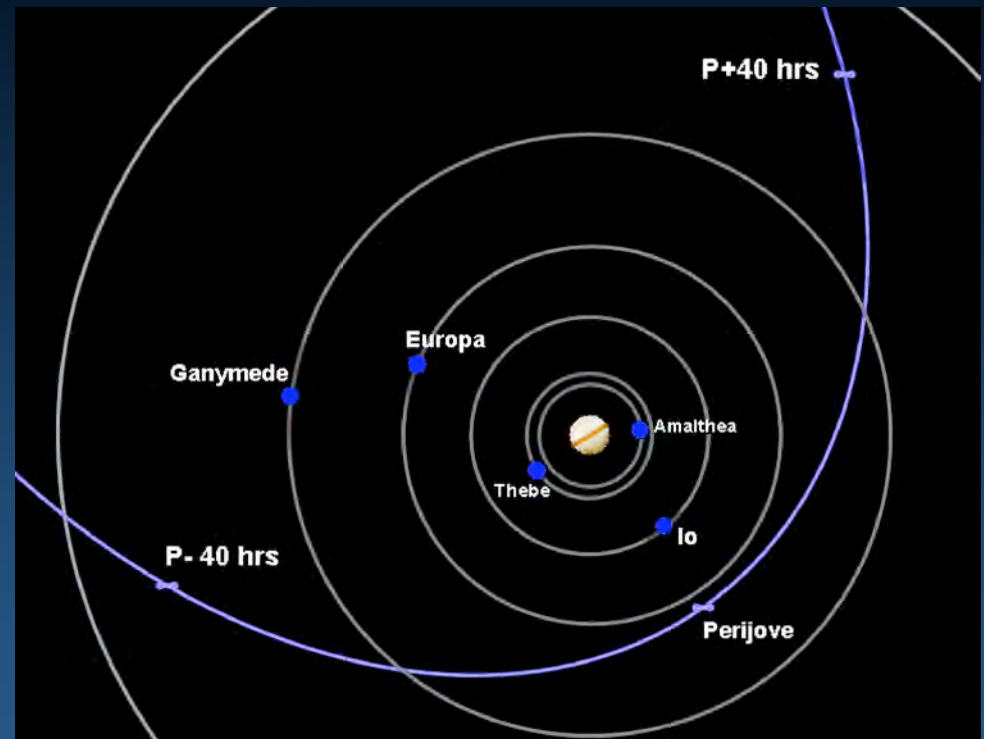
- 33 perijoves during Jovian Tour
 - 23 with satellite flybys
 - 22 permit JEO-Earth radio occultations

Rich opportunities to acquire Jupiter System Science

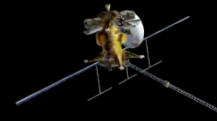
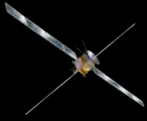


Jupiter System Science: Data Volume

- 16 Gb “hybrid” SSR
- ~3 days within 1.5 Mkm per perijove, with ~25 Gb collected
- 100s of NAC images plus contextual remote sensing every day
- ~3.2 Tb available throughout 2.5 yr Jovian tour
- ~1000x Galileo data return

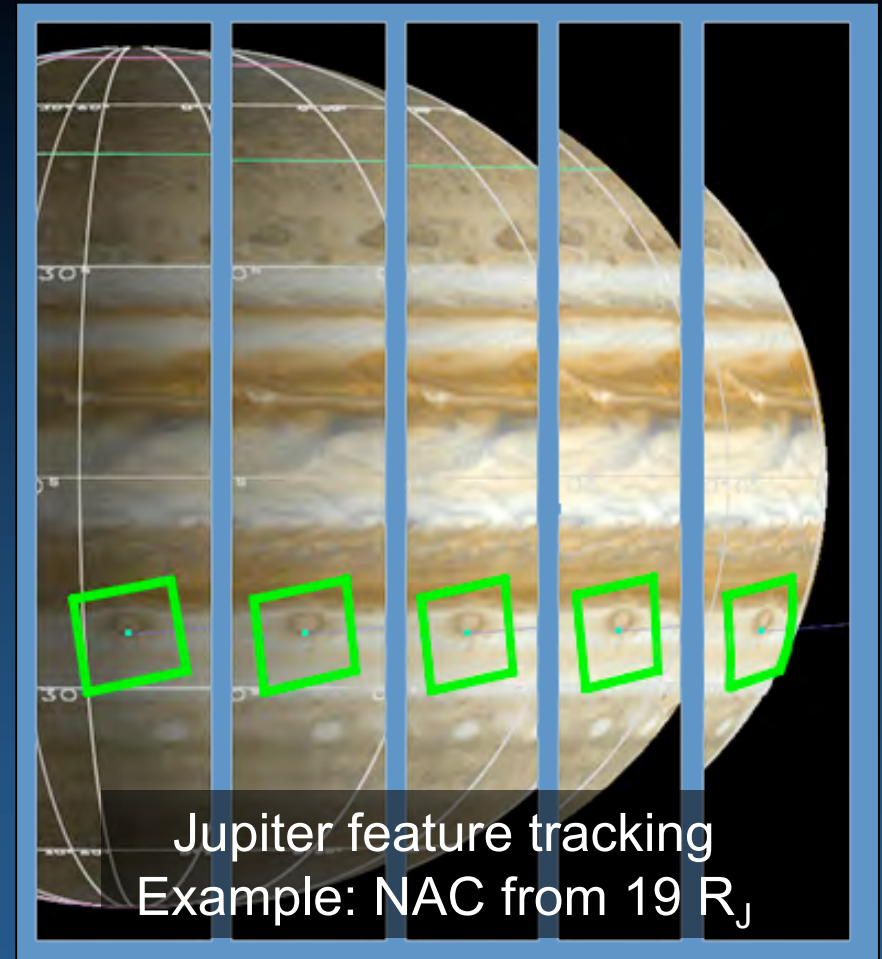


Jovian Tour would enable in-depth Jupiter system exploration

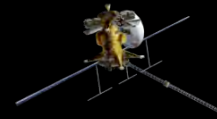
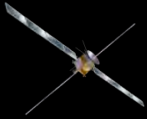


Jupiter Best Spatial Resolution

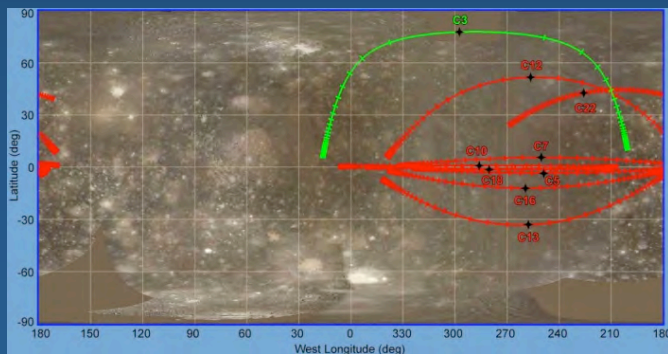
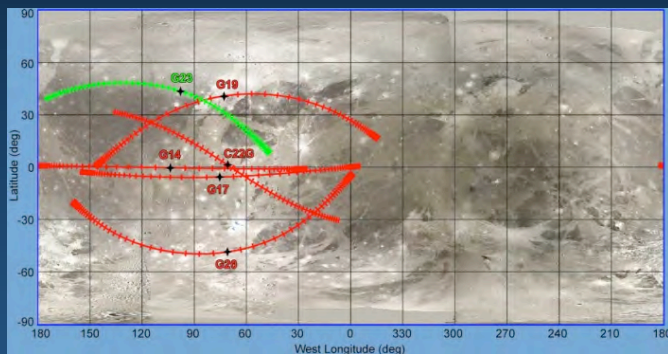
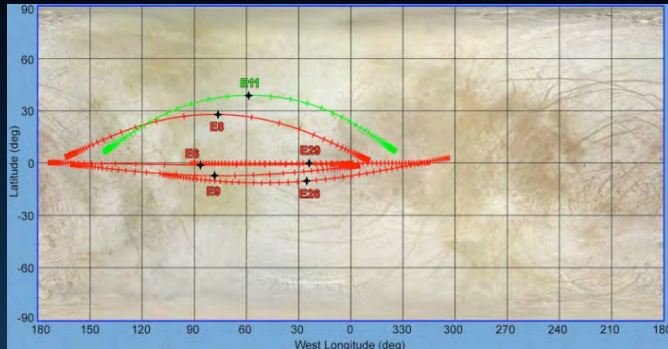
- Best resolution surpasses Voyager, Galileo, New Horizons
- Spatial resolutions (per pixel) from $9.5 R_J$:
 - Thermal Instrument: 1700 km
 - Wide-angle camera & UV spectrometer: 700 km
 - IR Spectrometer: 170 km
 - Medium-angle camera: 70 km
 - Narrow-angle camera: 7 km



Perijove would permit high spatial resolution remote sensing

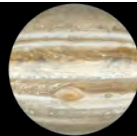
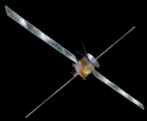


Jovian Tour Satellite Science



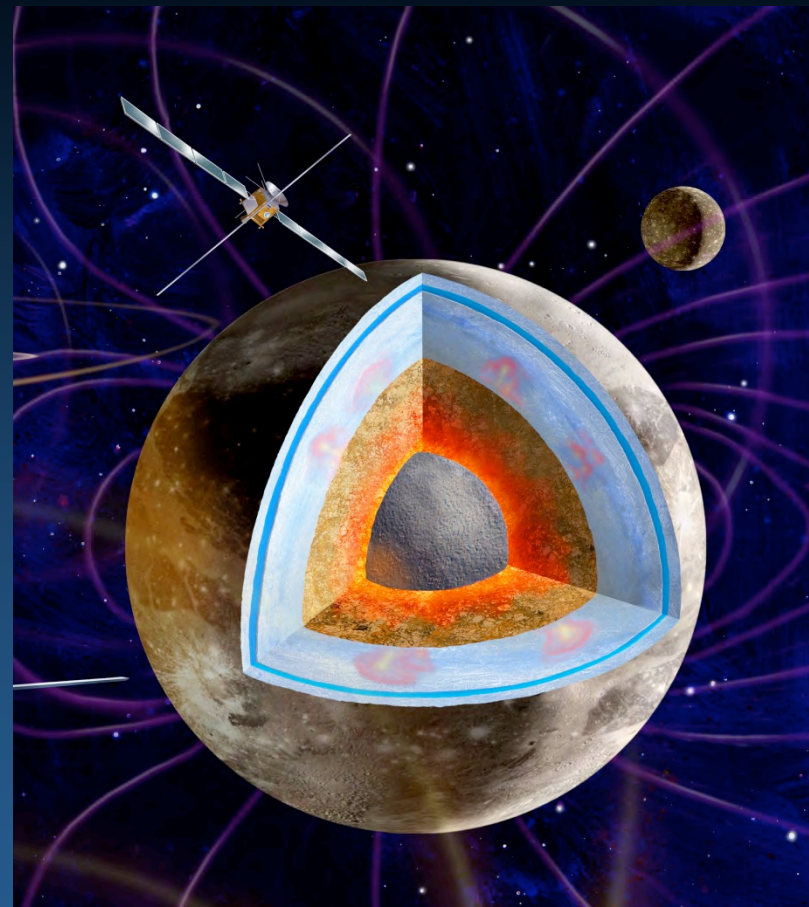
- Io: 3 flybys
 - Opportunities for imaging, IR spectroscopy, and altimetry
 - *In situ* analysis of extended atmosphere with INMS at 75 km
- Europa: 6 flybys
 - Radar and altimetry characterization and calibration
 - Imaging at up to 10–50 m resolution, NIR 250–1250 m
- Ganymede: 6 flybys
 - Radar sounding of grooved and dark terrains
 - Range of lats, lons for magnetosphere sampling
- Callisto: 9 flybys
 - High-latitude flyby for gravity field determination
 - Ocean characterization with magnetometer
 - Radar for subsurface structure of ancient cratered terrain

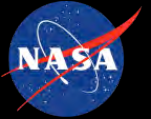
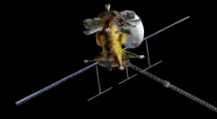
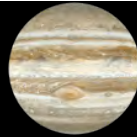
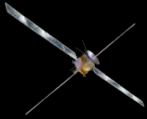
Satellite	≤1000m	≤200m	≤50m	≤10m	Length IPR (km)	Length LA (km)
Io	30%	20%	5%	-	1000	7400
Europa	60%	60%	15%	0.01%	6600	19000
Ganymede	50%	50%	10%	0.02%	17000	28000
Callisto	85%	75%	5%	0.01%	15000	30000



JGO Science: Overview

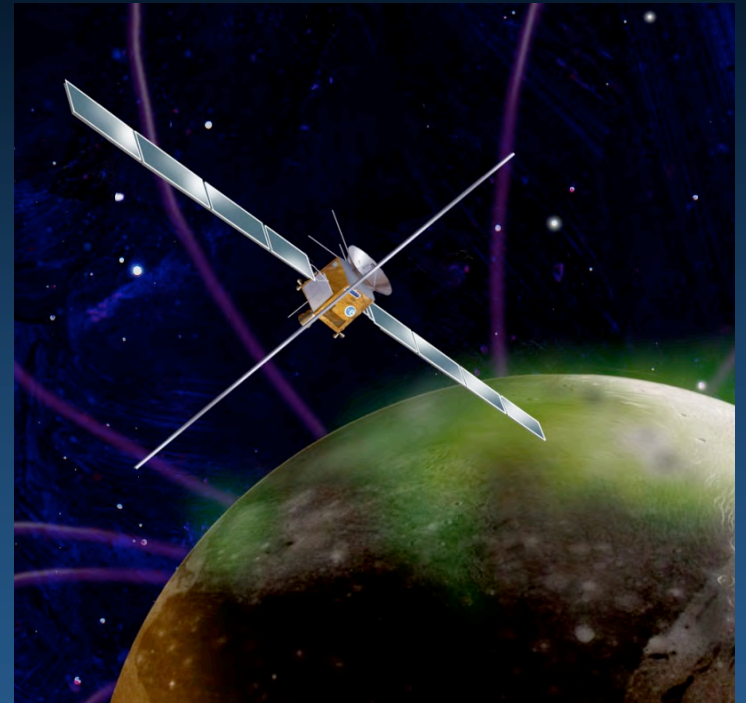
- Key JGO science phases
 - **Jupiter system:** In-depth exploration
 - From Jupiter orbit, synergistically with JEO
 - **Callisto:** In-depth study and mapping
 - Multiple flybys using a resonant orbit
 - **Ganymede:** Detailed orbital study
 - Elliptical orbit first, then circular orbit
- Science Objectives:
 - **Ganymede:** Characterize Ganymede as a planetary object, including its potential habitability
 - **Satellite System:** Study the Jovian satellite system
 - **Jupiter:** Study the Jovian atmosphere
 - **Magnetosphere:** Study the Jovian magnetodisk / magnetosphere
 - **Jupiter system:** Study the interactions occurring in the Jovian system

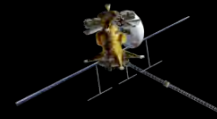
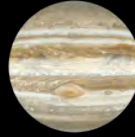
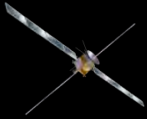




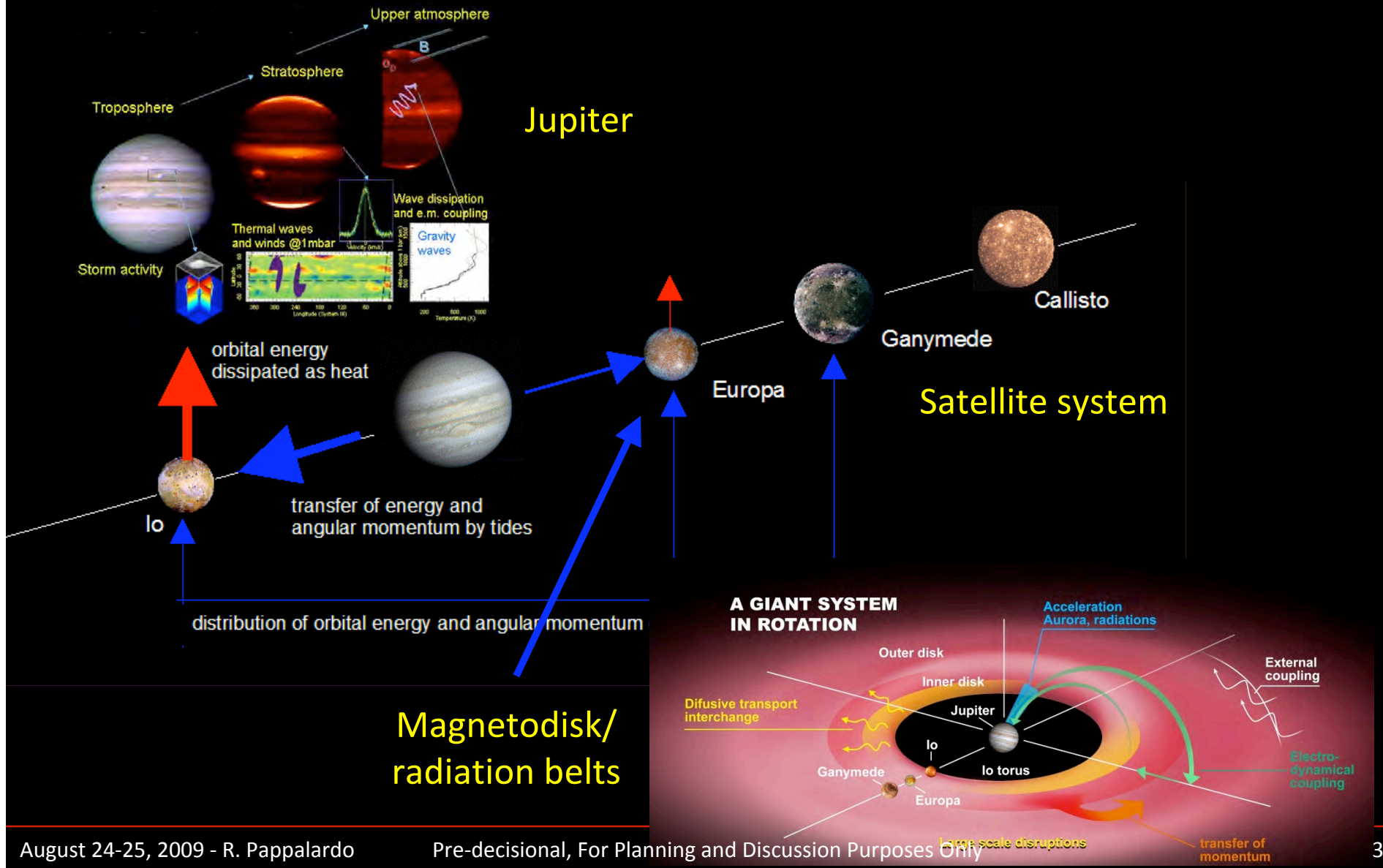
JGO Payload Definition Document (PDD) Study Model Payload

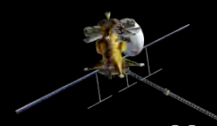
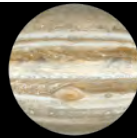
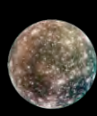
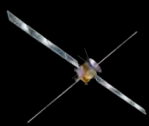
PDD Model Instrument Name	Acronym
Medium-Res Camera & Wide Angle Camera	WAC+MRC
Magnetometer	MAG
Radio Science Transponder and USO	JRST+USO
Visible InfraRed Hyperspectral Imaging Spectrometer	VIRHIS
Plasma Package & Ion and Neutral Mass Spectrometer	PLP/INMS
Sub-mm Instrument	SWI
Radio and Plasma Wave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





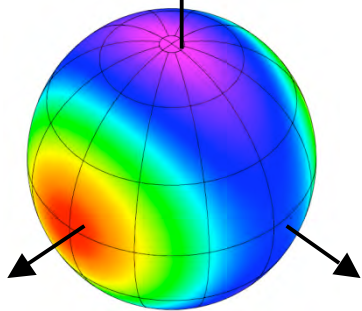
The Jupiter System: Three Coupled Components



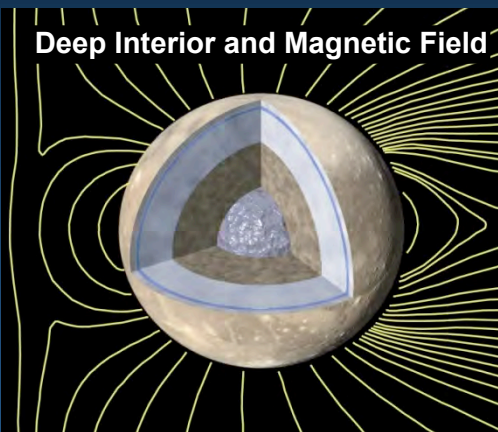


Ganymede: Europa's "False Twin"

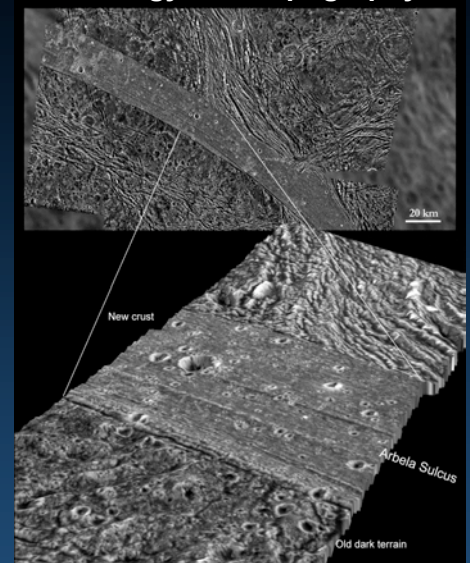
Tidal deformation



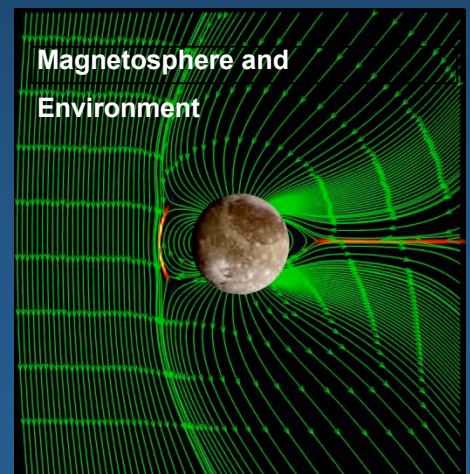
Deep Interior and Magnetic Field



Geology and Topography

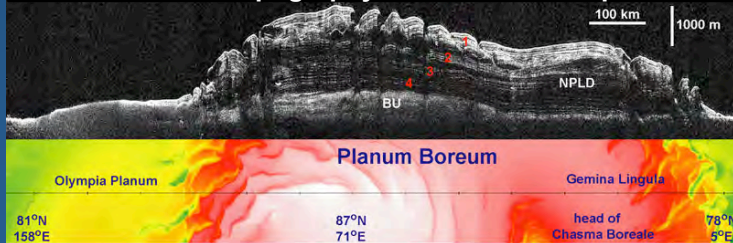


Magnetosphere and Environment

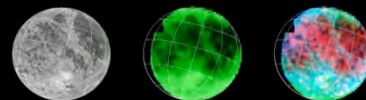


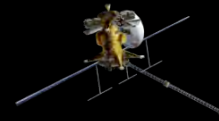
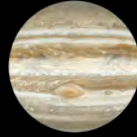
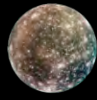
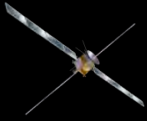
- Presence and extent of a subsurface ocean
- Ice shell and subsurface water
- Deep internal structure, dynamo, magnetic field
- Coupling among surface, exosphere, and magnetosphere
- Surface composition and chemistry
- Surface features, tectonic processes
- Thermal evolution, geology, and the Laplace resonance

Structure and topography of Mars' Polar Cap



Compositional Differences

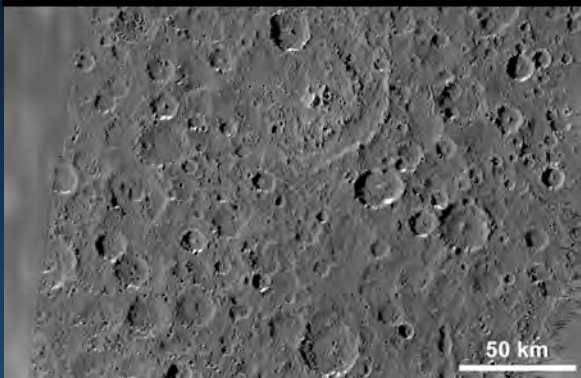




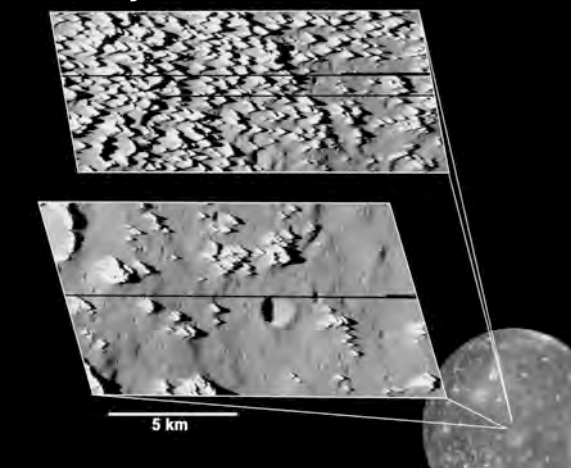
Callisto: A Witness of the Early Ages

- Presence and extent of a subsurface ocean
- Ice shell and subsurface water
- Deep internal structure, including degree of differentiation
- Cratering record and early geological history
- Surface composition, including organics and CO₂
- Surface degradational processes (erosion and sublimation)

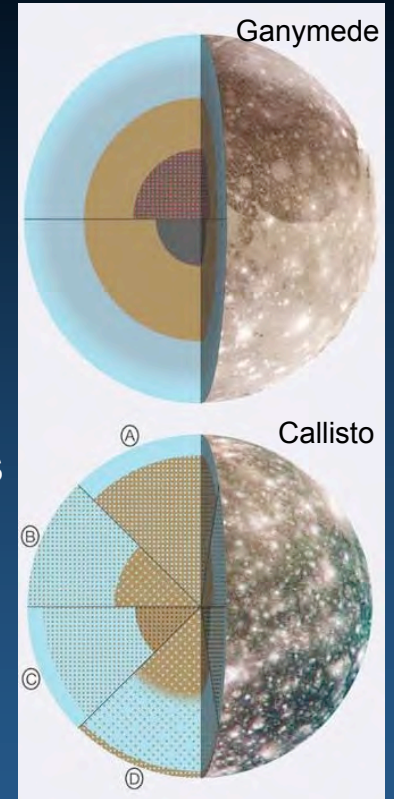
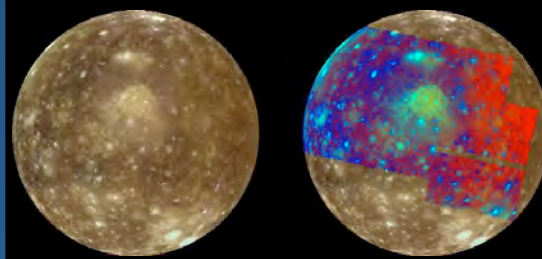
Crater Distribution and Morphology



Knobby Terrain: Erosion Processes

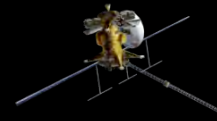
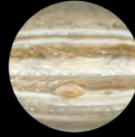
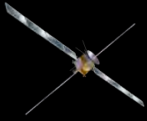


Compositional Heterogeneities

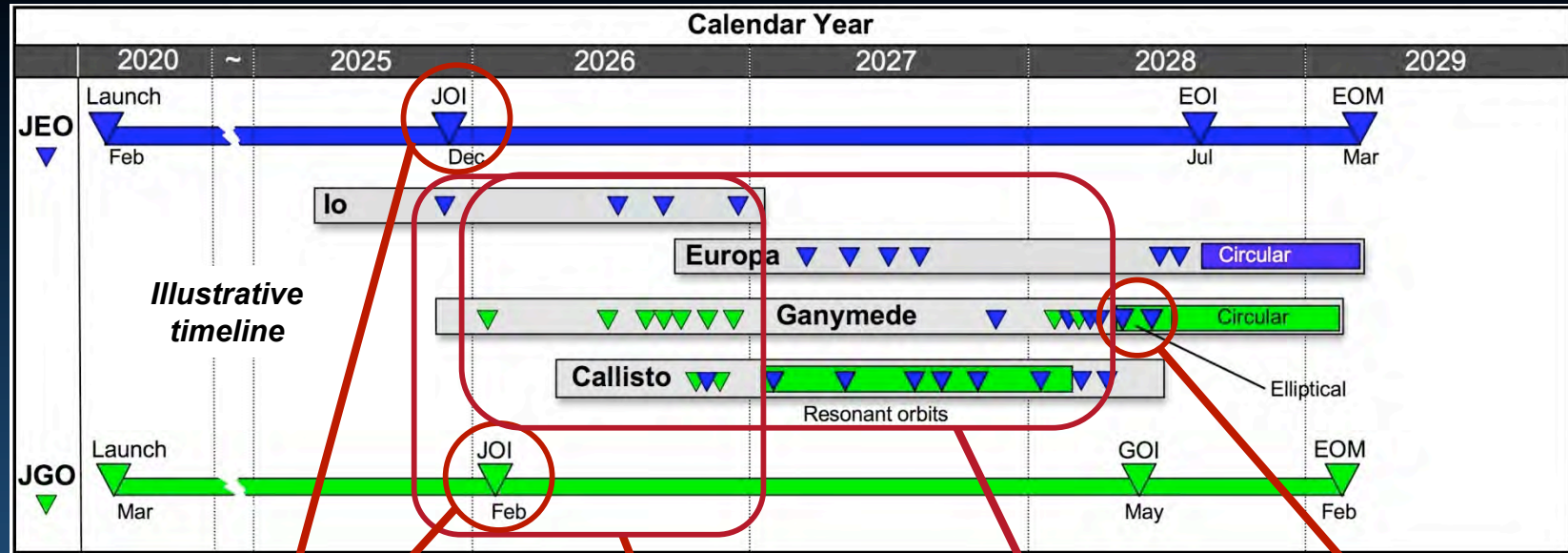


**Internal differentiation:
Where is Callisto ?**

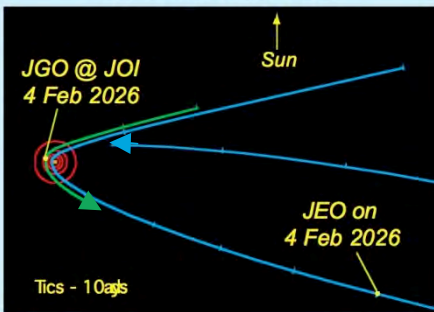
Image after Bagenal et al. [2004]



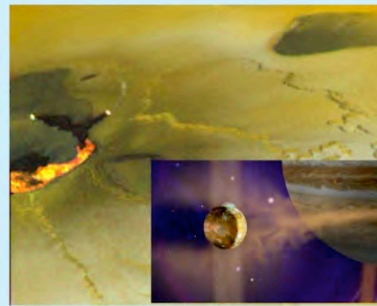
EJSM Candidate Synergistic Science



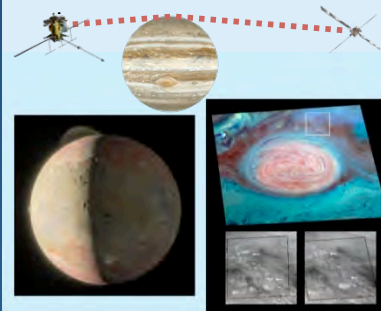
Jupiter Magnetosphere Studies



Io Volcanism & Io Torus Dynamics

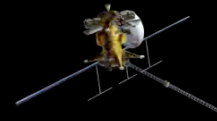
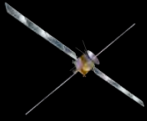


Satellite & Jupiter Monitoring; Radio Occultation Science?



Ganymede Magnetosphere Studies



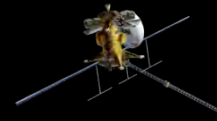
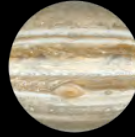
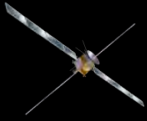


JEO: Untangling Fundamental Mysteries

- Europa science objectives have been honed for over a decade
- Science and technical teams have worked together closely to optimize the JEO science return
- JEO would achieve outstanding Decadal Survey science
- JEO would fundamentally alter our understanding of the nature of habitable worlds around gas giants
- EJSM has the science, technology, and “opportunity”
- GPP science input is welcome!



Solving fundamental mysteries of Europa and the Jupiter system



For More Information...



Jet Propulsion Laboratory
California Institute of Technology

<http://opfm.jpl.nasa.gov>
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OPFM
Outer Planet Flagship Mission

[Home](#)

Europa Jupiter System Mission (EJSM)

Jupiter Europa Orbiter (JEO) Concept

Jupiter Ganymede Orbiter Concept

Joint Science Definition Team: Europa-Jupiter

Jupiter Europa Orbiter Radiation and Planetary Protection Tutorials

[Radiation Study Reports](#)

Radiation Study Reports

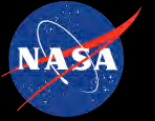
Read the [Roadmap to Design Guidelines](#) (PDF, 49 KB)

Read the [Radiation Fact Sheet for the Jupiter Europa Orbiter \(JEO\) Mission](#) (PDF, 782 KB)

- Note: Reports forthcoming - pending documentation clearance.

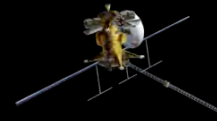
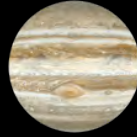
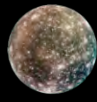
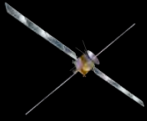
1. JEO Designing Circuits and Systems for Single Event Effects
This document discusses the effects of single energetic particles in space on microelectronic and optoelectronic devices. Examples are provided of the complex responses of advanced microelectronics, including functional interrupts that disrupt the basic way in which devices respond to electrical signals. Various circuit and system design approaches are included.

A wealth of resources are available at the OPFM website

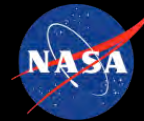
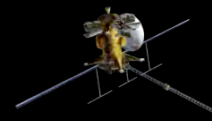
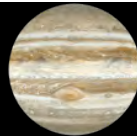
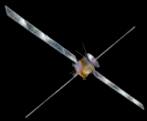


The Europa Jupiter System Mission: The Emergence of Habitable Worlds Around Gas Giants





Backup Slides



Jupiter Signal-to-Noise Estimates

Camera Package:

- 1 s exposures sufficient to achieve SNR ~ 44 in CH_4 bands (based on 2% reflectance). For viewing Jupiter, exposure time can be increased as needed.
- Higher reflectance (20-30%) increases SNR to 260 at 930 nm and higher QE increases SNR ~ 860 at 750 nm.

Thermal Instrument:

- Lowest signal comes from $17.2 \mu\text{m}$. Using an irradiance of 1.6 W/cm^2 and assuming Jupiter fills the TI FOV, SNR ~ 70 .

VIRIS:

- $4\text{-}5 \mu\text{m}$: Thermal emission radiances of $30\text{-}40 \mu\text{W/cm}^2/\text{sr}/\mu\text{m}$ (or $245\text{-}250 \text{ K}$, $75\text{-}100 \text{ nW/cm}^2/\text{sr}/(\text{cm}^{-1})$). SNR $\sim 145\text{-}170$ for 38 ms (detector well filled in 100 ms).
- $4.0 \mu\text{m}$ reflectivity is 1% (smaller than Europa 2%, SNR 70), so SNR ~ 35 .
- $2.6\text{-}2.7 \mu\text{m}$ reflectivity is 5-8% (greater than Europa 2%, SNR 160), implying SNR > 300 for Jupiter.

Radio Science:

- With Ka downlink power of 25 W, SNR should exceed that of Voyager/Cassini with $> 50 \text{ dB-Hz}$. Dual s/c would boost SNR $\sim 1000\times$.

JEO model payload provides excellent SNR for Jupiter atmospheric studies