Jupiter System Observer

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Europa Explorer Science Definition Team Meeting

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Overview

- **Overarching Philosophy:**
  - The Goal is to have a Mission that provides the best overall Jupiter System Science
  - Long-term (~5 years) Jupiter System science encompassing objectives for Io, Europa, Ganymede, Callisto, Jupiter and its magnetospheric environment
  - Build on Results from Pioneer 10/11, Ulysses, Voyager, Galileo, Cassini/New Horizons Fly-throughs
  - Build-on and follow-up on Juno Science Results
  - Jupiter system science with satellite focus on Ganymede
  - Traceability of science to Decadal Survey, Solar System Road Map & OPAG Science Goals & Pathways Document
- **Structure of the SDT:**
  - Division of activity into four science areas:
    - Satellite science
    - Interiors
    - Magnetospheres
    - Jupiter atmosphere
  - Build on Jupiter System Science defined by the JIMO SDT
  - Define Goals, Objectives, Investigations and Measurements that will lead to requirements and mission architectures

Flow of Science Discussion

Decadal Survey Goals, NASA Roadmap Science Questions → JSO Goals, Objectives Investigations & Measurements → Notional Instrument Payload & its ability to perform JSO Science

Traceability from NRC-NASA Reports

- NRC Decadal Survey:
  - “Scientific Goals”
- NASA Solar System Exploration Roadmap, and NASA 2007 Science Plan:
  - “Science Questions”
- Building on NASA JIMO Science Requirements
- JSO Focus on Questions of Physical Processes Associated with Planetary System Formation and Evolution

High-level Scence Focus	Solar System Exploration ("Decadal") Survey	2006 SSE Roadmap and 2007 NASA Science Plan	JSO Science Theme
	• Learn how the Sun's retinue of planets originated and evolved	• How did the Sun's Family of planets and minor bodies originate?	**Satellites Interiors Atmosphere Magnetospheres**
	•Discover how the basic laws of physics and chemistry, acting over aeons, can lead to the diverse phenomena observed in complex systems, such as planets	• How did the solar system evolve to its current diverse state?	
	• Understand how physical and chemical processes determine the main characteristics of the planets and their environments, thereby illuminating the workings of the Earth.		
	• Determine how life developed in the solar system, where it may coexist, whether extant life froms exist beyond Earth and in what ways life modifies planetary environments	• What are the characteristics of the solar system that lead to the origin of life?	**Satellites Interiors**
		• How did life begin and evolve on Earth and has it evolved elsewhere in the solar system	
	• Explore the terrestrial space environment to discover what potential hazards to Earth's biosphere may exist	• What are the hazards and resources in the solar system environment that will affect the extension of human presence in space	**Magnetospheres Satellites**

Science Flow

Theme	Goal	# of Obj.	# of Inv	# of Meas
Satellites	1) Formation of Surface Features 2) Surface Composition 3) Atmospheres 4) System Interactions	Io: 7 Europa: 9 Ganymede: 6 Callisto: 5 Rings/small Satellites: 1	24 24 19 15 4	46 46 35 27 9
Interiors	Interior structures & processes	4	11	38
Magnetospheres	Magnetospheric environment of Jupiter and its Satellites	5	19	50
Jupiter Atmosphere	Atmospheric Structure & Dynamics	9	24	83
	Total	**46**	**140**	**334**

JSO Instruments

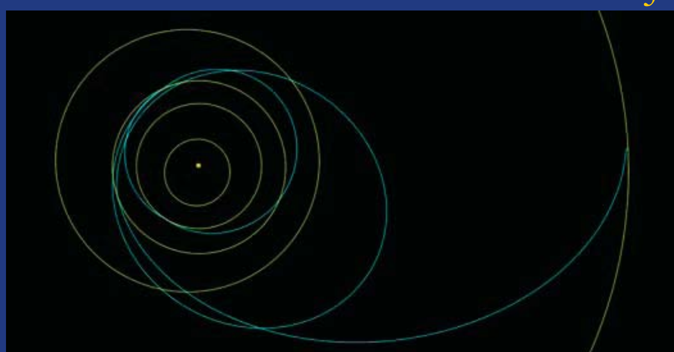
THEME	GOAL	High-Resolution Camera (50 cm Aperture)	VIS-NIR Hyperspectal Imager (50-cm Aperture)	Medium-resolution stereo Camera	UV Imaging Spectrometer	Thermal Specrometer	Ground Penetrating Radar	Laser Altimeter	Magnetometer	Plasma Spectrometer/Energetic Particle Detector	Radio Science
Satellites	**1) Surface Formation**	X	X	X	X	X	X	X			
	2) Surface Composition	X	X		X	X	X				
	3) Atmospheres		X		X						
	4) System Interactions	X	X			X					
Interiors	**Interior Structure & Processes**	X		X			X	X	X		X
Magnetospheres	**Magnetospheric Environment of Jupiter & its Satellites**	X	X		X				X	X	
Jupiter Atmosphere	**Atmospheric Structure and Dynamics**	X	X		X	X					X

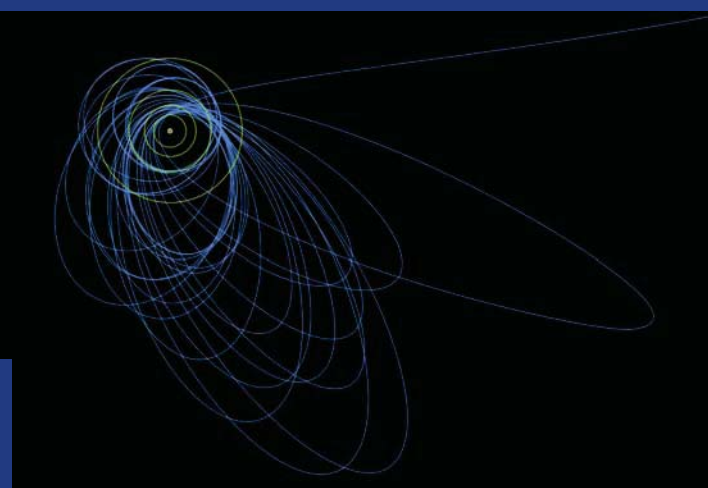
Mission Timeline

VEEGA, 5 ½ to 7 years | 5 to 5 ½ years

Cruise	Io Tour	Icy Moon Tour	Capture	Ganymede Orbit Baseline (Ellip + Cir) Descope (Ellip only)
	9 - 12 mo	18 – 21 mo	6 mo	2 years

JOI | GOI





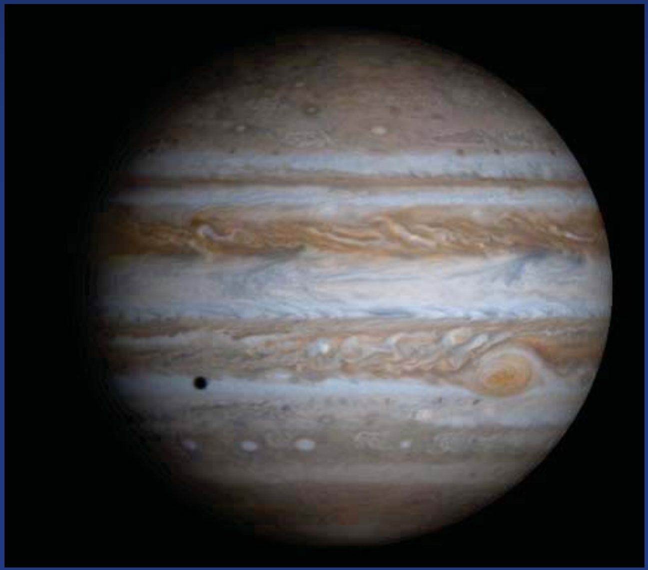
Opportunities

Launch	Arrival	Atlas (kg)	DIV	
Jan 2015	Jul 2021	4964	7287	
Jun 2015	Jul 2021	4627	6781	
Sep 2016	Oct 2023	5050	7423	
Jan 2017	Aug 2022	4888	7196	Baseline selection
Sep 2018	Oct 2025	4999	7332	
Mar 2020	Feb 2026	5270	7760	
May 2021	Mar 2028	5053	7416	

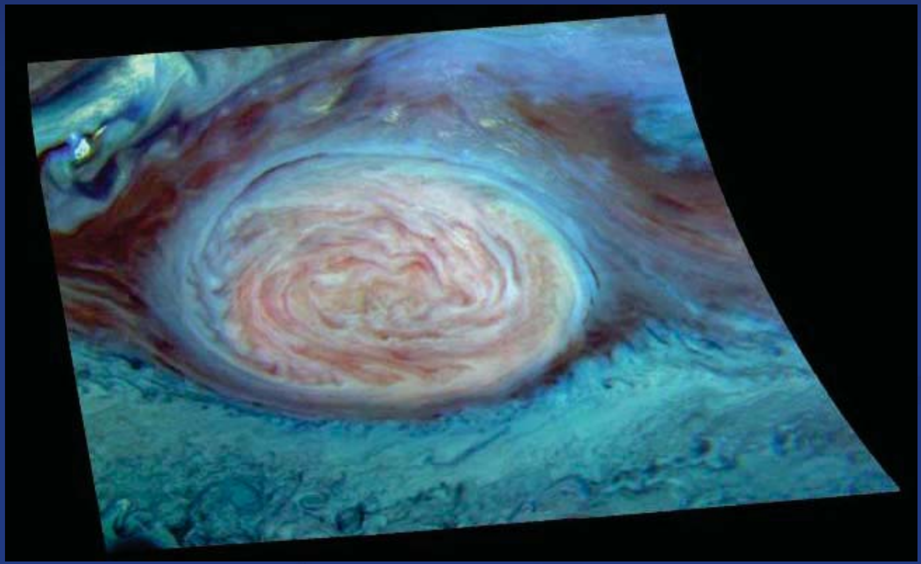
Flybys
- 4 Io
- 6 Europa
- 7 Ganymede
- 11 Callisto

Jupiter Atmospheric Science

Goal: Understand the processes that maintain the composition, structure and dynamics of the Jovian atmosphere as a type example of a Gas Giant planet



Cassini ISS, **144 km/pixel** image of Jupiter. JSO Global-scale atmospheric monitoring of atmospheric circulation would be routine at scales of 10's of km/pixel



Galileo SSI image of the Great Red Spot at **~30 km/pixel**. JSO targeted observations could be acquired at a spatial scale ten times better

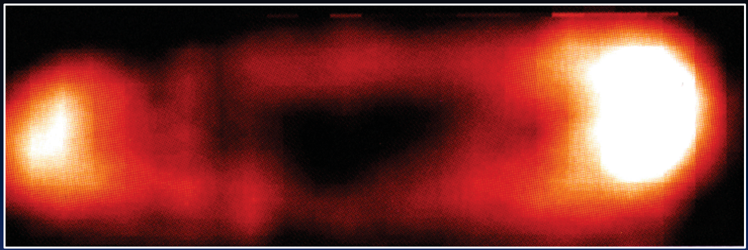
Long-term Atmospheric Observations at spatial scale 1-2 orders of magnitude would be greater than previously achieved

Magnetosphere Science

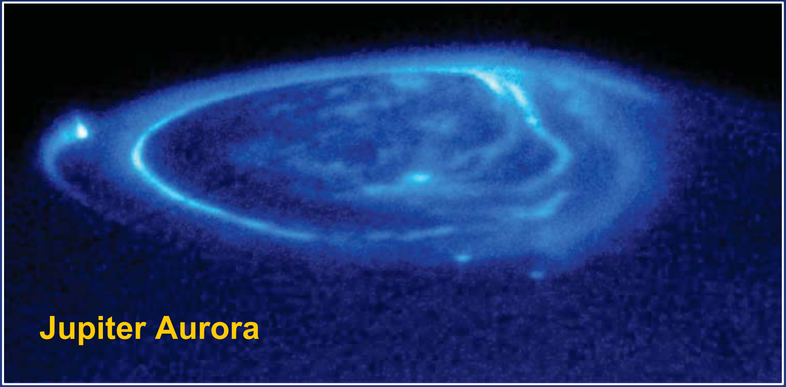
Goal: Understand the magnetospheric environments of Jupiter, its moons and their interactions

- *Jupiter Magnetosphere:* Study the global dynamics of the Jovian magnetosphere
- *Io torus*: Understand the contributions of Io to the composition, and to the transient and periodic dynamics of the Jovian magnetosphere
- *Moon-Magnetosphere Interactions:* Determine the effect of the Jovian magnetosphere on the icy moons
- *Moon Interior Structure:* Establish internal structure of icy moons including presence and properties of putative conducting layers

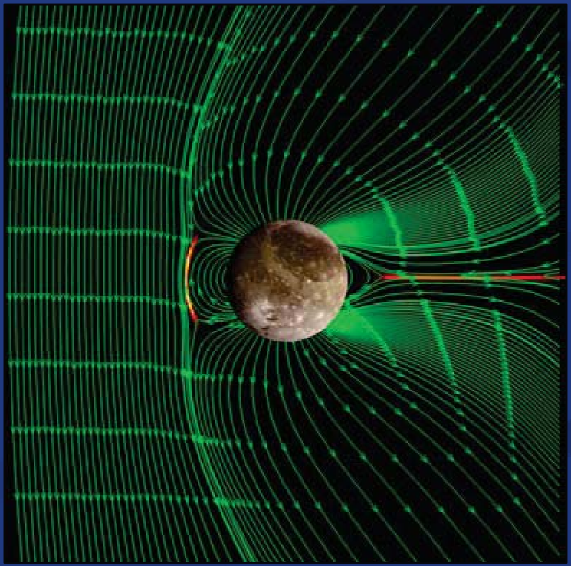
Long mission duration, extensive tour phase and orbital operations at Ganymede would allow detailed study of numerous phenomena



LASP EUV image from Cassini



NASA/ESA

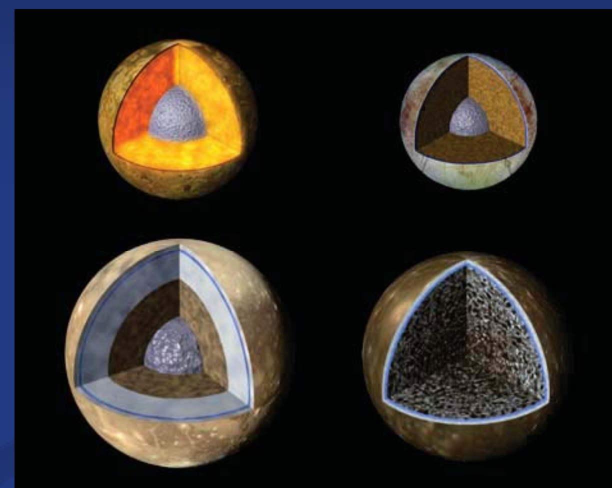


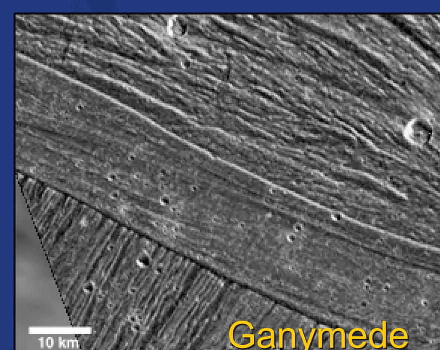
Ganymede's magnetosphere, simulated by X. Jia, UCLA, 2007

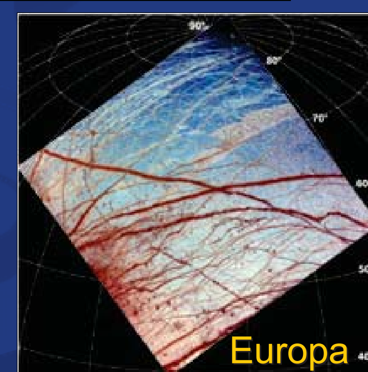
Interior Science

Goal: To determine the interior structures and processes operating in the Galilean satellites in relation to the formation and history of the Jupiter system and potential habitability of the moons

- **Determine the presence and location of water within the Galilean moons**
- **Characterize the operation of magnetic dynamo processes in the Jovian system and their interaction with the surrounding magnetic field**
- **Identify the dynamical processes that cause internal evolution and near-surface tectonics of all four moons**
- **Characterize the formation and chemical evolution of the Jupiter system**





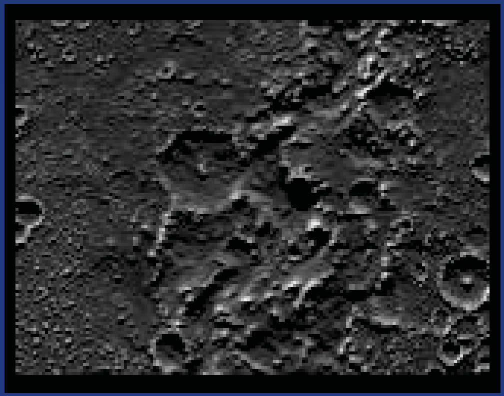


Gravity tracking during flybys would better constrain interior structure with detailed in-orbit study of Ganymede

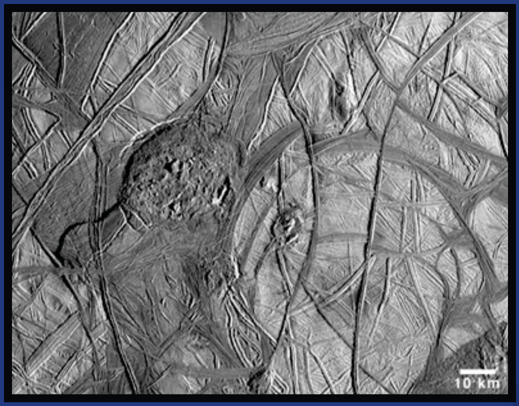
Satellite Science

Goal 1: Understand the mechanisms responsible for the formation of surface features and implications for geological history, evolution, and levels of current activity

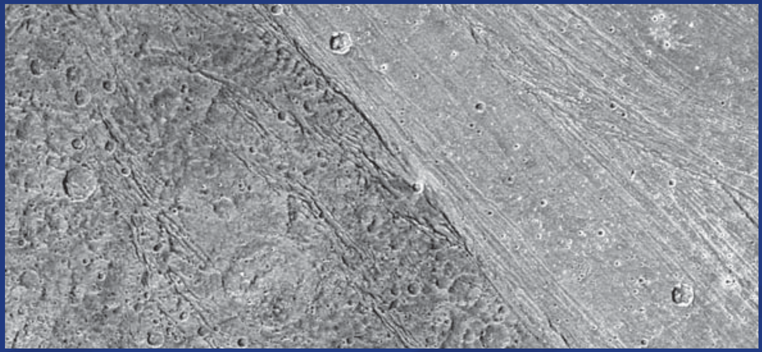
Callisto--insight into early impact history



Europa--cryovolcanic processes



Ganymede--Tectonic resurfacing; Cryovolcanic activity?



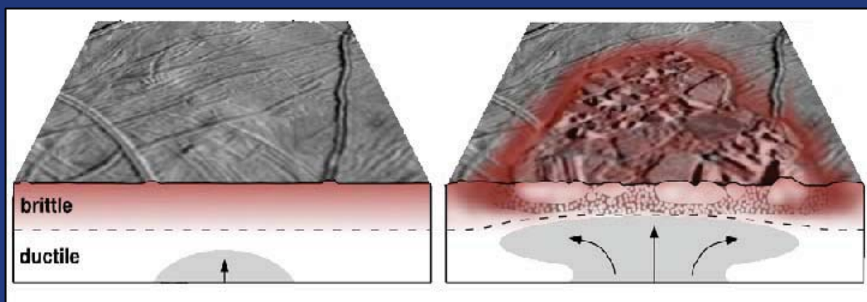
Io--A window into an era of magma oceans?

Highly capable payload would quantitatively understand the three dimensional structure, morphology and relations to interior processes

Satellite Science

Goal 2: Determine the surface compositions and implications for the origin, evolution and transport of surface materials

Europa-Surface interior interactions; sample chemistry of subsurface ocean?

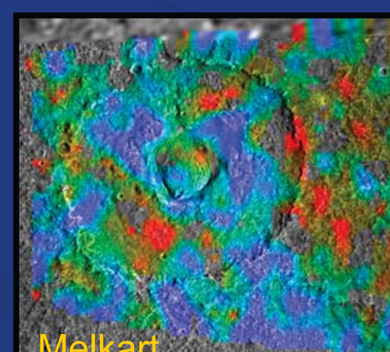


Callisto--Composition of non-ice materials

Highly capable, state-of-the-art, remote sensing payload would provide new understanding of satellite composition

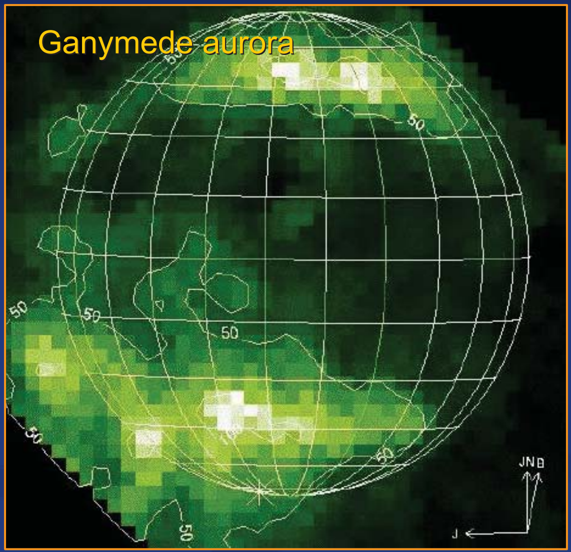
Io--Composition of volcanics; mafic to ultramafic lavas

Ganymede--Composition of different terrains



Satellite Science

Goal 3: Determine the compositions, origins, and evolution of satellite atmospheres, including transport of material throughout the Jovian system



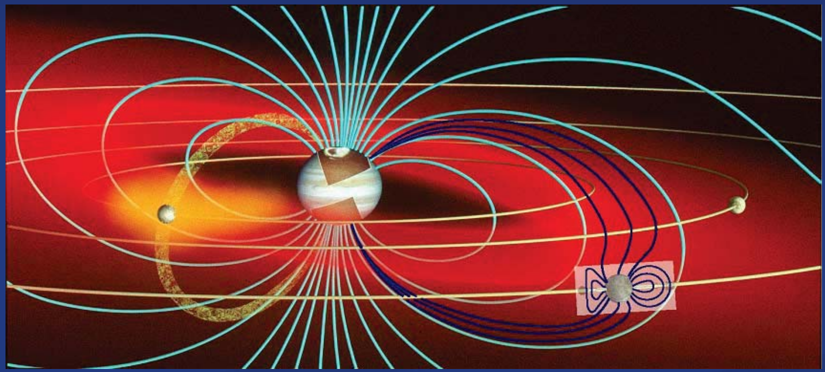
NASA/HST/McGrath et al. 2004

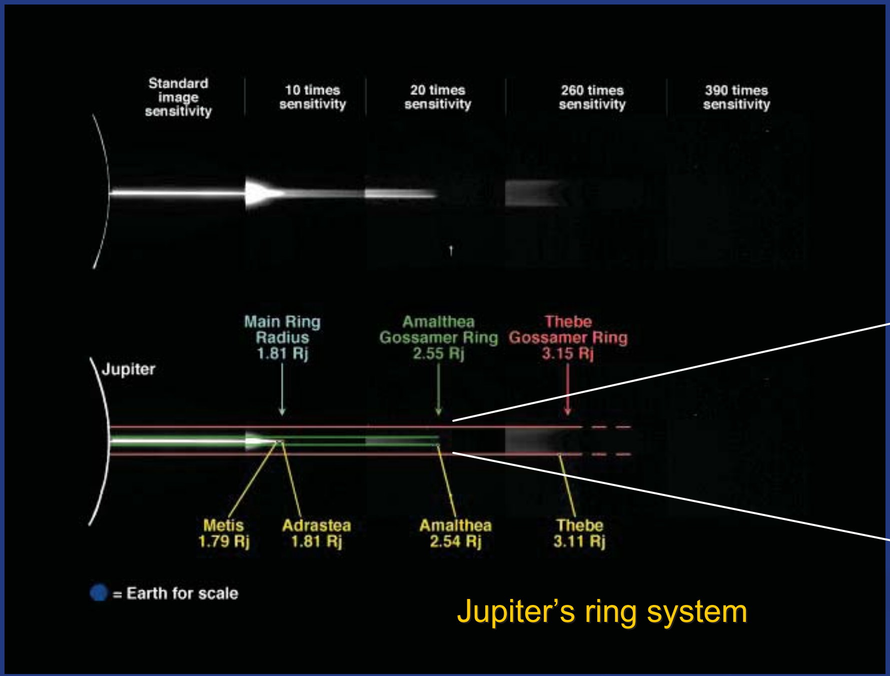
High temporal and spatial coverage would monitor satellite atmospheres and interactions with Jovian Magnetosphere

Satellite Science

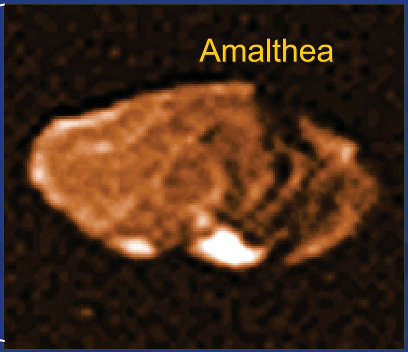
Goal 4: Determine how the components of the Jovian System operate and interact

High temporal and spatial coverage could study distribution and transport of material throughout the Jovian System





Jupiter's ring system

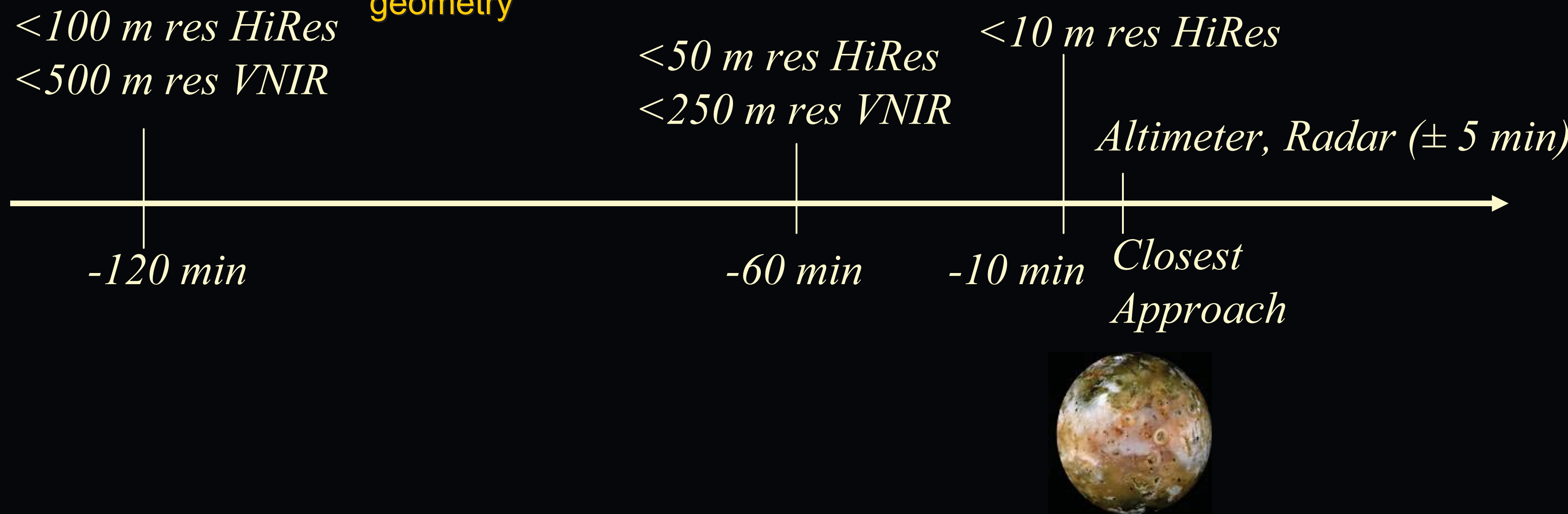


Science Requirements on Mission Design

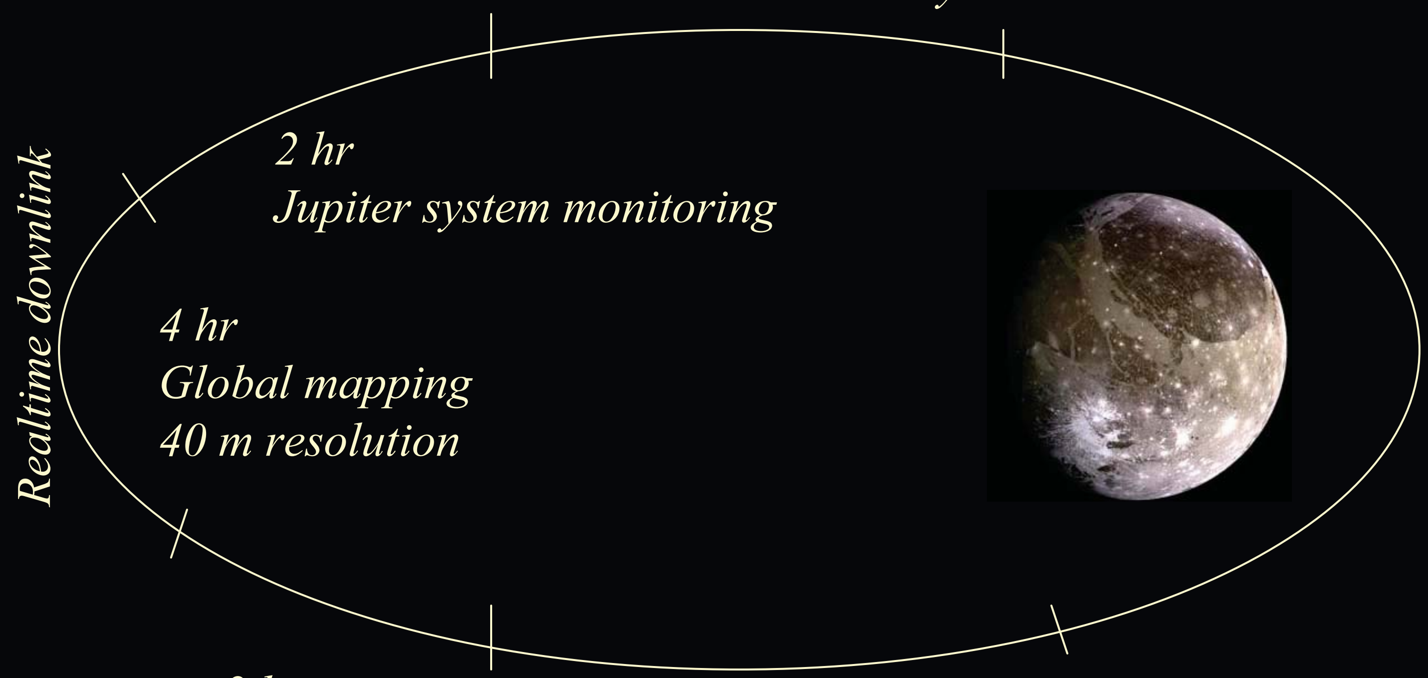
Science Theme	Tour	Fly-by	Ganymede Orbit
Satellites			
Io	Dedicated obs. campaigns	≥ 2 at low alt. (100-200 km)	Dedicated obs. campaigns
Europa		≥ 6 at low alt.,(100-200 km) globally Distributed	Dedicated obs. campaigns
Ganymede			Global coverage, high inc. >85°orbit
Callisto		≥ 6 at low alt. (100-200 km), globally Dist.	Dedicated obs. campaigns
Interiors		All satellites Low alt (100-200 km), globally distributed	High inclination > 85°, circular, low alt. (100-200 km) orbit
Magnetospheres	Different parts of the Mag. Env.	Dedicated observing campaigns	Elliptical orbit to sample both Ganymede's field and Jovian field
Jovian Atmosphere	Dedicated observing campaigns		Dedicated observing campaigns

Notional Encounter Scenario

- 6 hr encounter mode based on battery sizing
- Strategy:
  - Start with empty SSR and fully charged battery
  - Turn on fields and particle instruments (on 100% of the time)
  - Altimeter and Radar could only measure near closest approach (800 sec)
  - Turn on remaining remote sensing instruments to fill data capability
    - Balance of regional-scale and hi-res observations
    - Global color and spectral coverage probably obtained 2 to 5 days out on either side of encounter
    - Best resolution areas for global coverage would be restricted by encounter geometry



Notional “Elliptical” Orbit Scenario



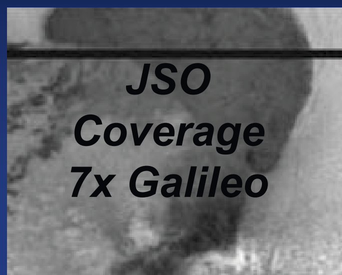
Circular Orbit Strategy

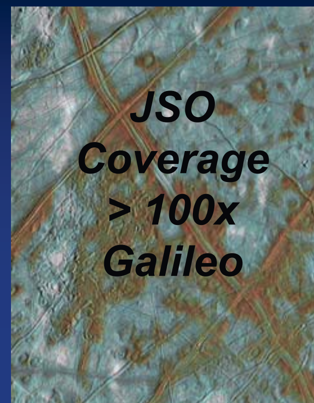
- For Baseline only
- For 16-24 hr DSN coverage periods:
  - S/C occulted 40% of orbit
  - Power limited due to telecom on
    - ~33% duty cycling of remote sensing instruments
- At 200 km altitude, ground speed will be ~1.76 km/s
  - Hi-res camera will need to use summation mode, but will still get ~2 m resolution
- Focus on
  - Detailed gravity & magnetic field mapping
  - Fields & particle instruments, laser altimeter on 100%
  - Balancing radar with other remote sensing instruments could use remaining data volume capability
- Orbit reconstruction needed to 1-m radial accuracy
  - Thruster firings would be restricted to ≤1/day for at least first 2 Ganymede days (14 Earth days)

Remote Sensing Resolution & Coverage

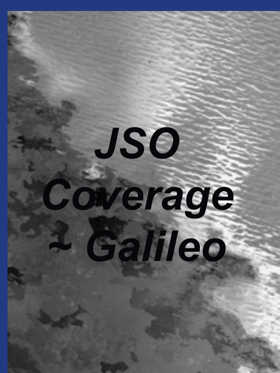
Io | **Europa** | **Ganymede** | **Callisto**

Galileo:
~100 m
Regional
~1-5%
coverage





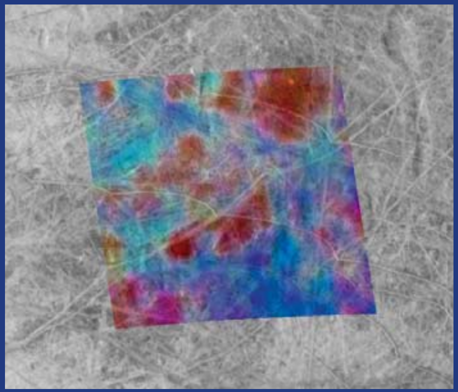
Galileo:
~10-20 m
< 1%
coverage



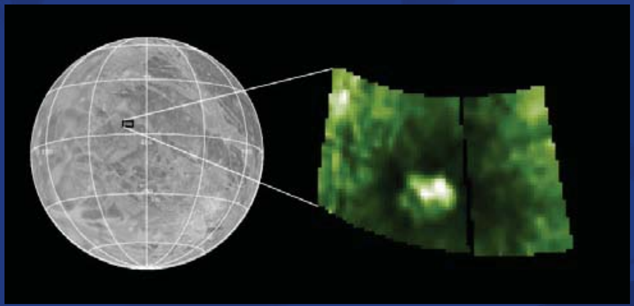
Instrument Payload would be more capable than any previously flown to Jupiter

Hyperspectral Imaging

- Significant increase in ability to make specific compositional identifications would come primarily from a factor of 2.5 to 5 better spectral resolution than NIMS.
- Improved spectral resolution would:
  - Identify crystalline - ie. recent - hydrated non-ice materials on Europa or Ganymde.
  - Enable mapping of ice temperatures using temperature sensitive bands. (NIMS was designed before the nature of the temperature sensitive bands in ice were fully understood).
  - Map the spectral properties and in some cases determine if preliminary identifications are correct, of trace materials on the moons: e.g. CO_2, CN, O_3, O_2, H_2O_2, etc.
  - Aid in resolving the controversy on the origins of the hydrated non-ice material on Europa (and Ganymede) and the origin of the CO_2 on Callisto (and Ganymede and Europa).



Europa: Dark material interpreted to be sulfuric acid or salty minerals



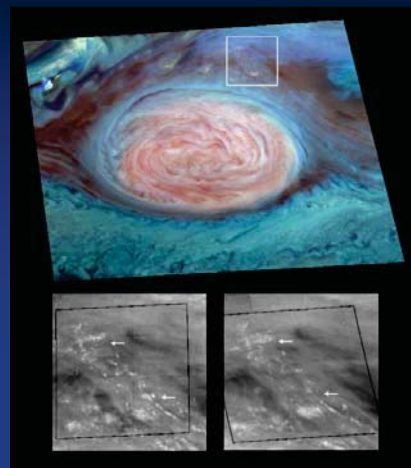
Ganymede: False color albedo of dark-rayed Antum Crater

Jupiter Atmospheric Science

Voyager

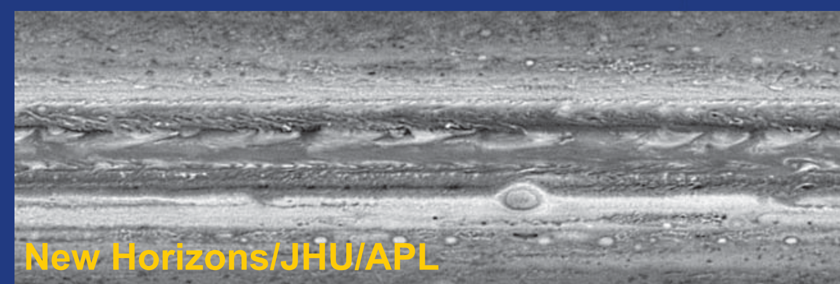
Temporal Coverage would be restricted to Fly-by period; Resolution, 100's km

Galileo



Long-term intermittent Temporal Coverage with limited spatial Coverage; Resolution, 30-40 km

Cassini & New Horizons

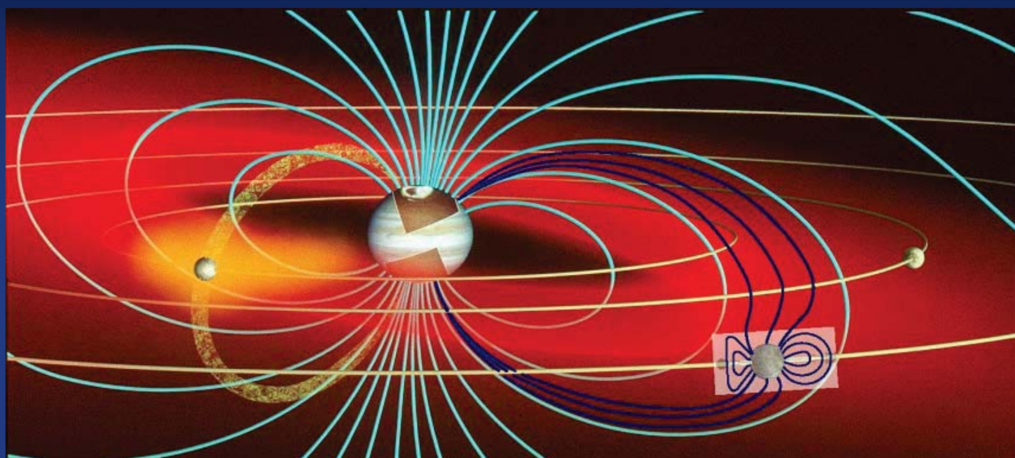


Temporal Coverage would be restricted to Fly-by period; Resolution, 120-400 km

Long-term Temporal Coverage at high global spatial resolution, up to 4-km (1 to 2 orders of magnitude over previous missions)

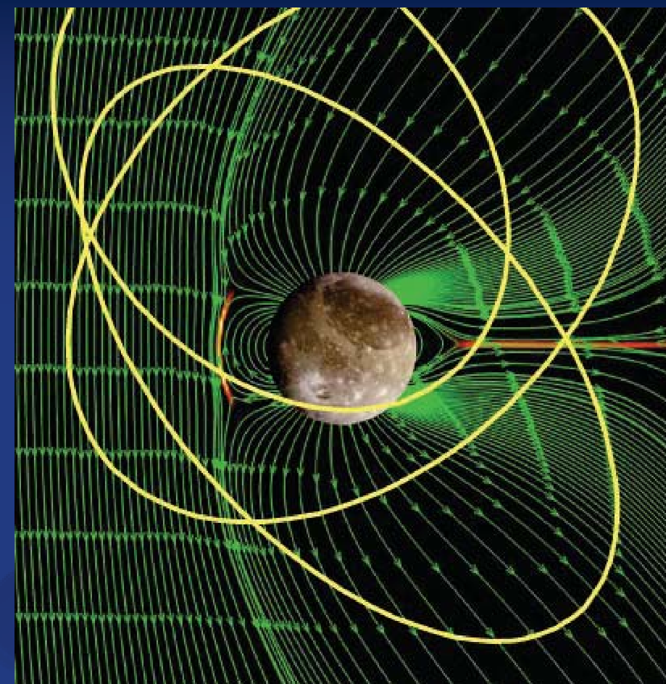
Magnetosphere Science

Tour of the Jovian System



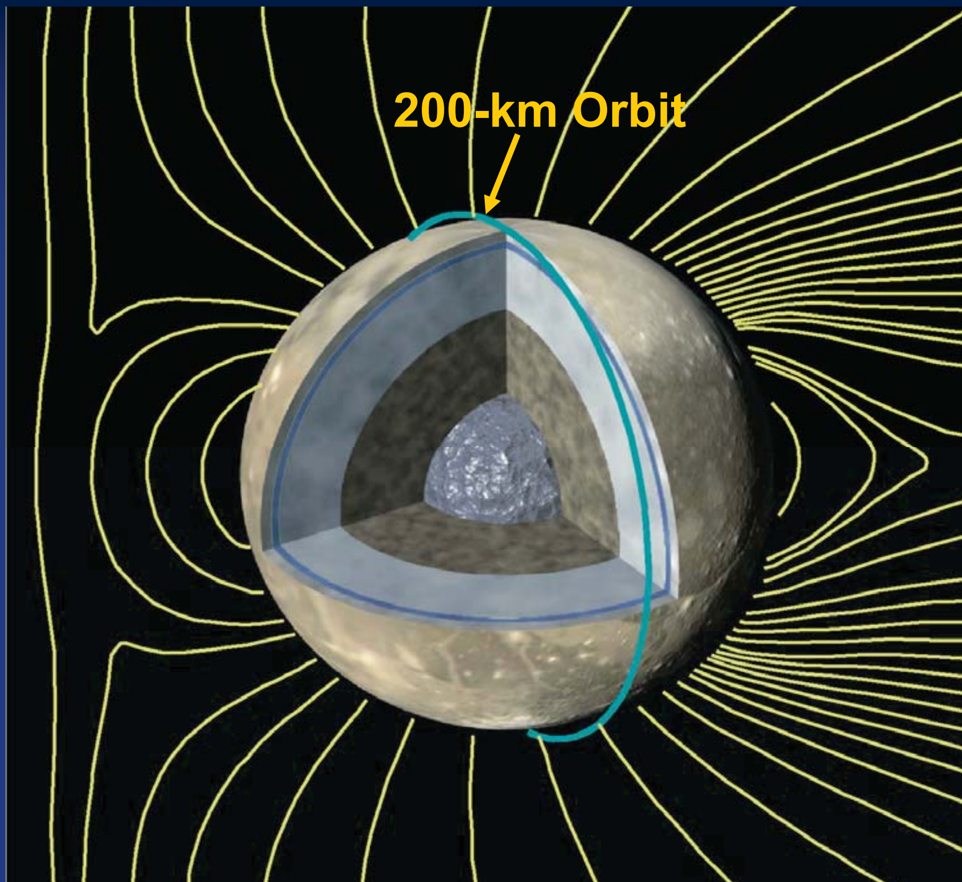
- ***Long-term sampling of different components of the Jovian Magnetosphere Environment***
- ***Highly capable instruments would study aurora, Io torus at resolutions not previously attained***
- ***Follow-up on results from Juno Mission***

"Elliptical" Orbit at Ganymede



Long-term Characterization of Ganymede's magnetic field--What drives the dynamo?

Interiors



Ganymede

- Detailed characterization of gravity field--planetary differentiation and interior mass distribution
- Long-term understanding of Ganymede's magnetic field--processes that drive the dynamo--One of only 3 terrestrial bodies to have an intrinsic magnetic field
- Structure of the upper crust via radar sounding
- High resolution (m/pixel scale) remote sensing to understand link between surface geology and interior processes
- Orders of magnitude increase in data resolution relative to Galileo

Summary

JSO would be a long-term platform for studying the Jovian System, providing a means to advance our understanding of fundamental processes of planetary systems; their formation and evolution

Jupiter System Observer:

Probing the Foundations of Planetary Systems