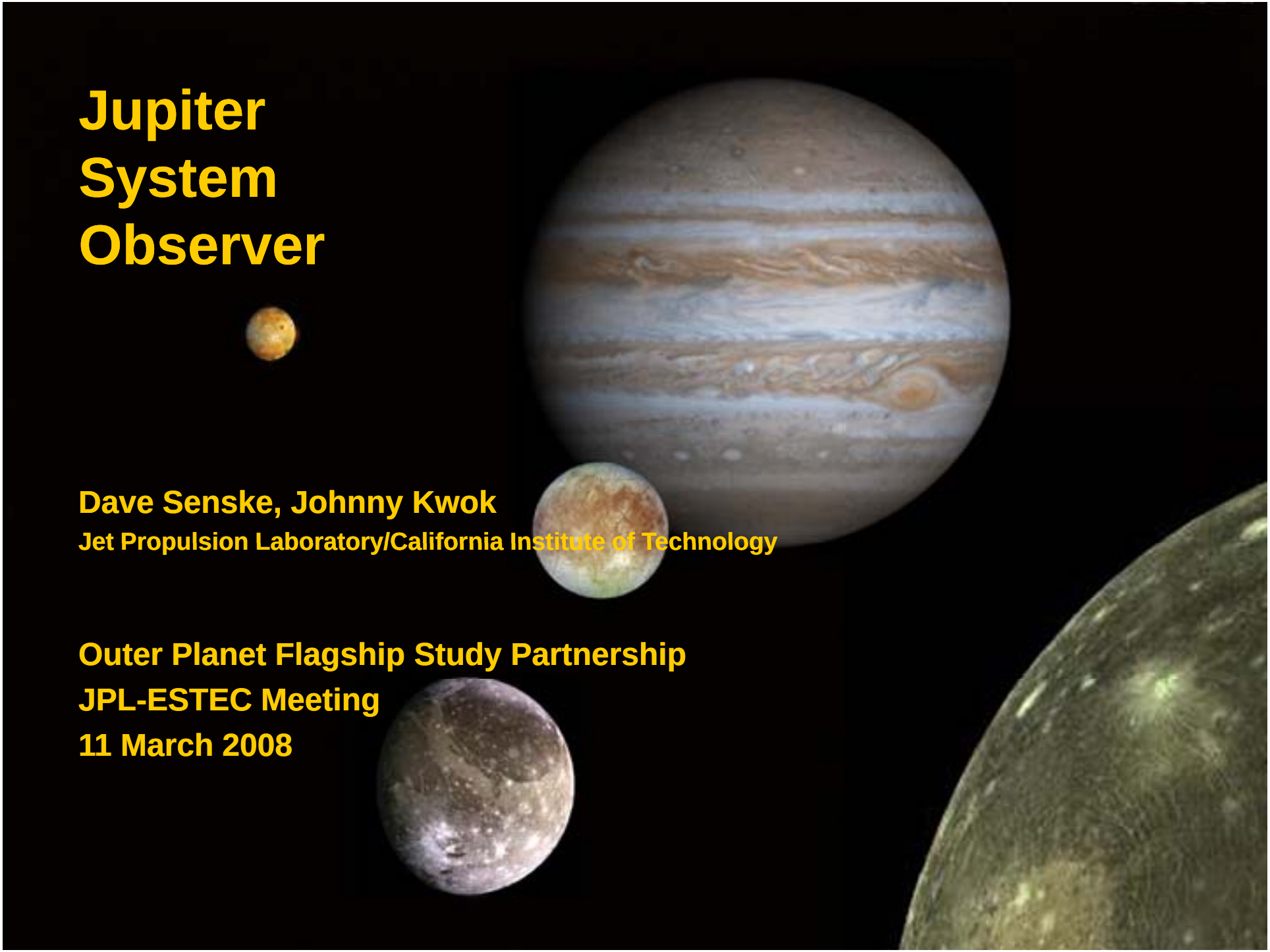
Jupiter System Observer



Dave Senske, Johnny Kwok
Jet Propulsion Laboratory/California Institute of Technology

Outer Planet Flagship Study Partnership
JPL-ESTEC Meeting
11 March 2008

Why Orbit Ganymede (vs Europa)

- Key Ganymede Science Discriminator
  - − Liquid ocean is deeper and harder to measure
  - + Intrinsic magnetic field – one of only three terrestrial bodies with internal dynamo
- Reduced Radiation Environment Enables:
  - + Longer mission lifetime
  - + Diverse Jovian system science
  - + Reduced radiation shielding
- Reduced Jupiter Gravity Perturbation at Ganymede
  - + Existence of large, inclined, stable elliptical orbits
- Larger Ganymede Mass
  - − More propellant needed to capture into orbit
- Ganymede Ancient & Thick Icy Crust
  - + Low probability of contaminating the ocean ➔ Simplify PP design

Baseline JSO Science Goals

Satellites

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

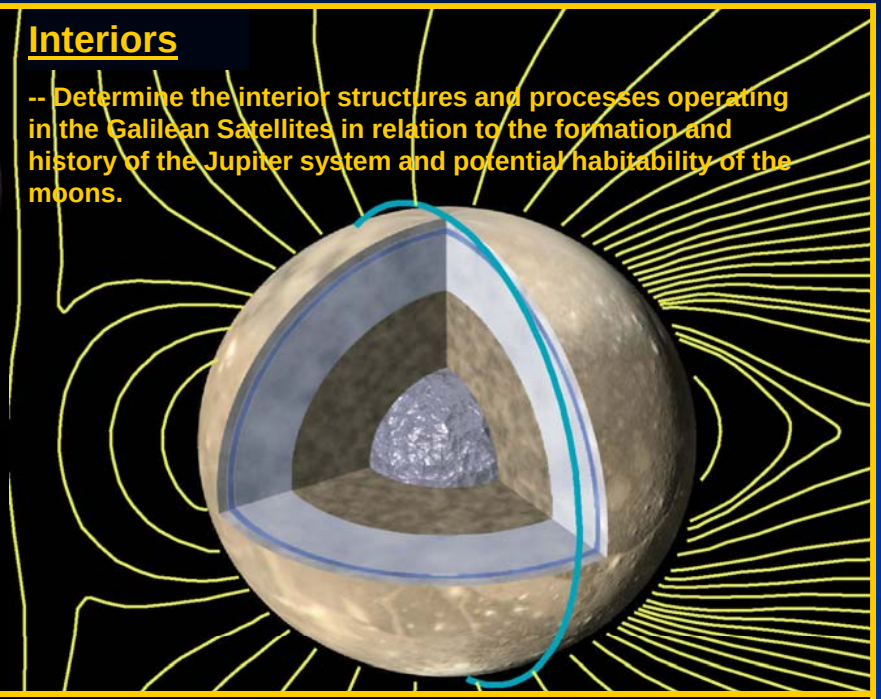
--Determine the surface compositions and implications for the origin, evolution and transport of surface materials

--Determine the compositions, origins, and evolution of the atmosphere, including transport of material throughout the Jovian system

--Determine how the components of the Jovian system operate & interact

Interiors

-- 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.



Magnetosphere

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

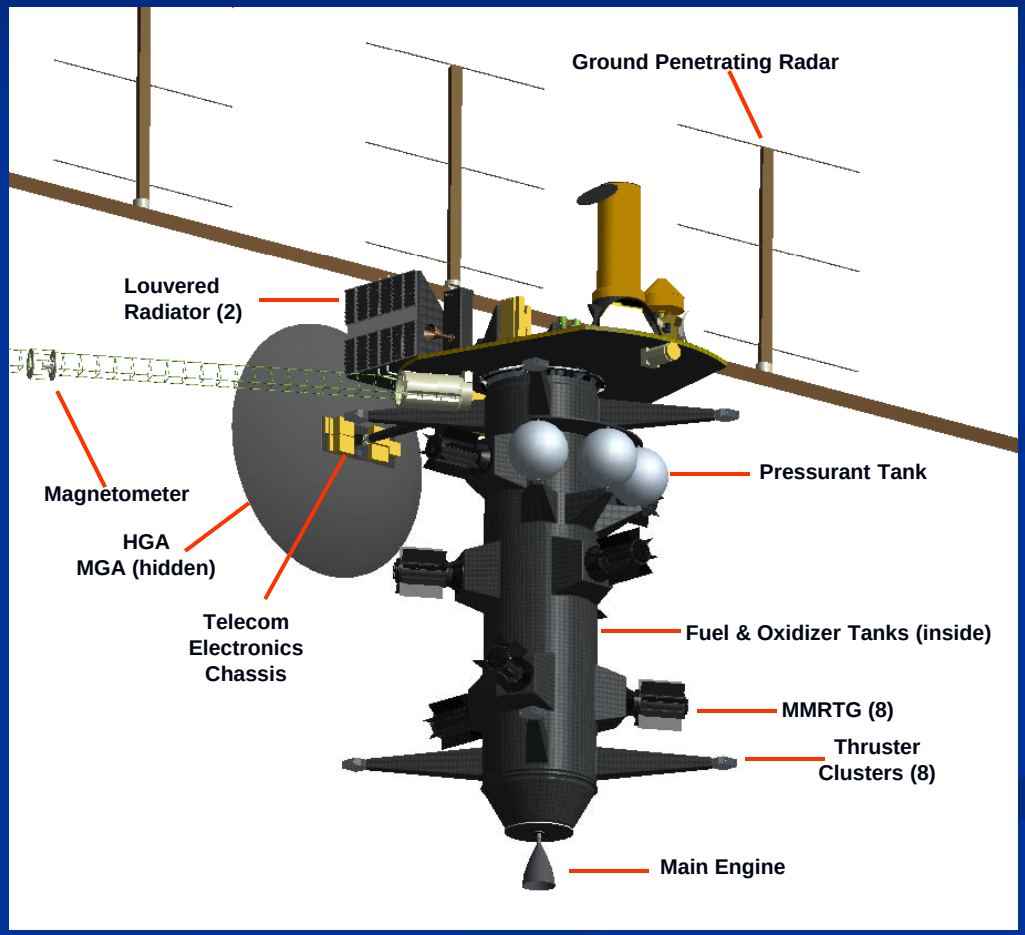
Jupiter Atmosphere

-- Understand the processes that maintain the composition, structure and dynamics of the Jovian atmosphere as a type example of a gas giant planet

Baseline Spacecraft

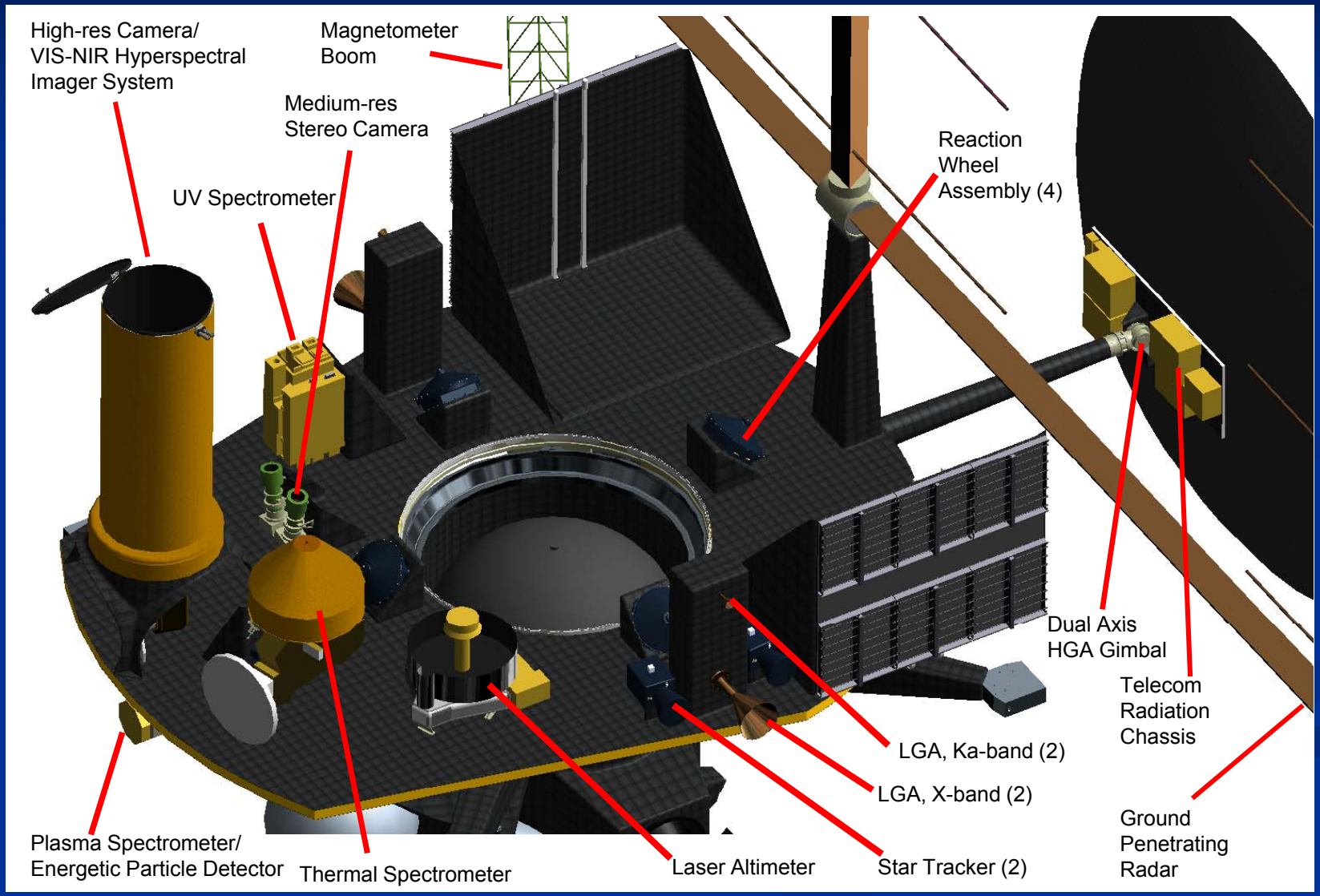
JSO Spacecraft would be a capable robust design that would accommodate the instrumentation and the mission while taking advantage of the environment

- 7262 kg (4612 kg, descoped) wet mass
- 228 kg (208 kg, descoped) planning payload
- Eight (seven, descoped) MMRTGs and two 38 A-hr batteries
- Two-axis gimbaled, 2.75 m HGA
- Two-way doppler at both X-/Ka-band for radio science - gravity investigation
- USO for radio science - atmosphere investigation
- 600 kb/s to 70m from 6.5 AU at Ka-band
- 9.6 Gb solid state recorder
- Dual-mode propulsion system; 2705 m/s (1855 m/s, descoped)
- Reaction wheels for long arcs without non-gravity disturbances
- Single-fault tolerant; redundant assemblies
- Radiation-hardened electronics
- 1.8 Mrad radiation design point
- 12 year mission life



JSO Notional Payload

JSO would accommodate 9 capable instruments and 2 radio science investigations



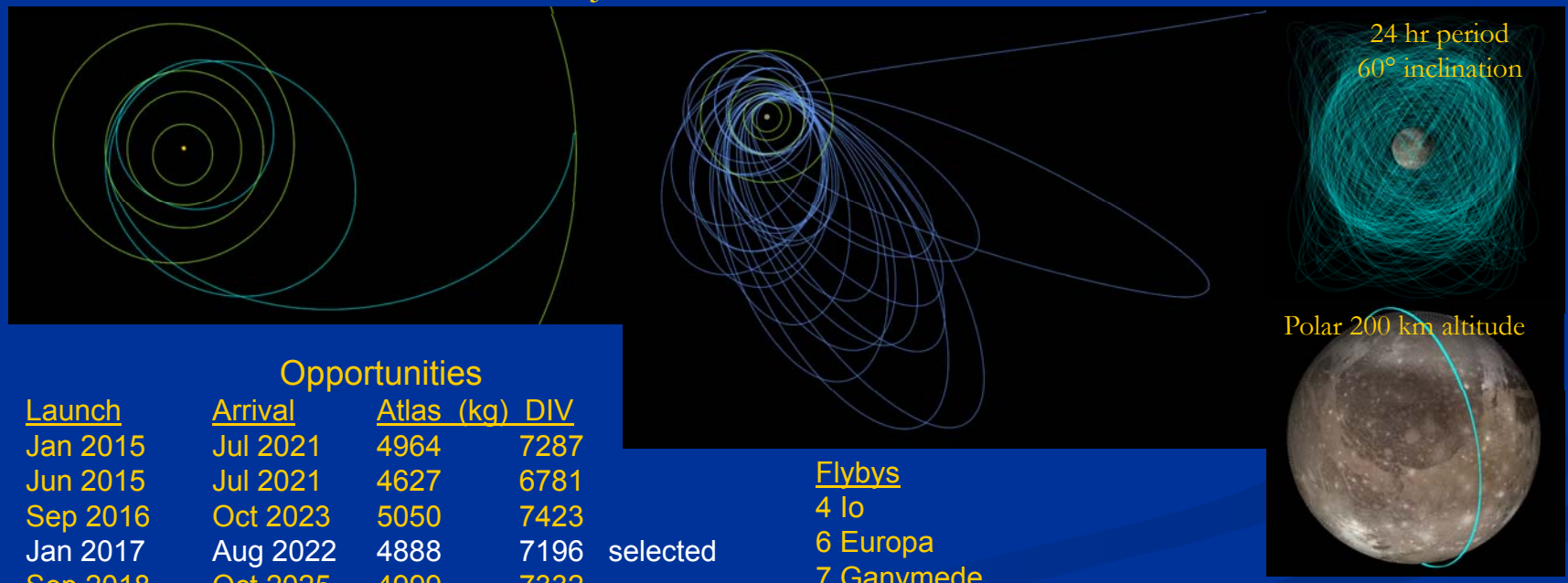
Baseline Mission Timeline

VEEGA, 5 ½ to 7 years

5 to 5 ½ years

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

JOI GOI

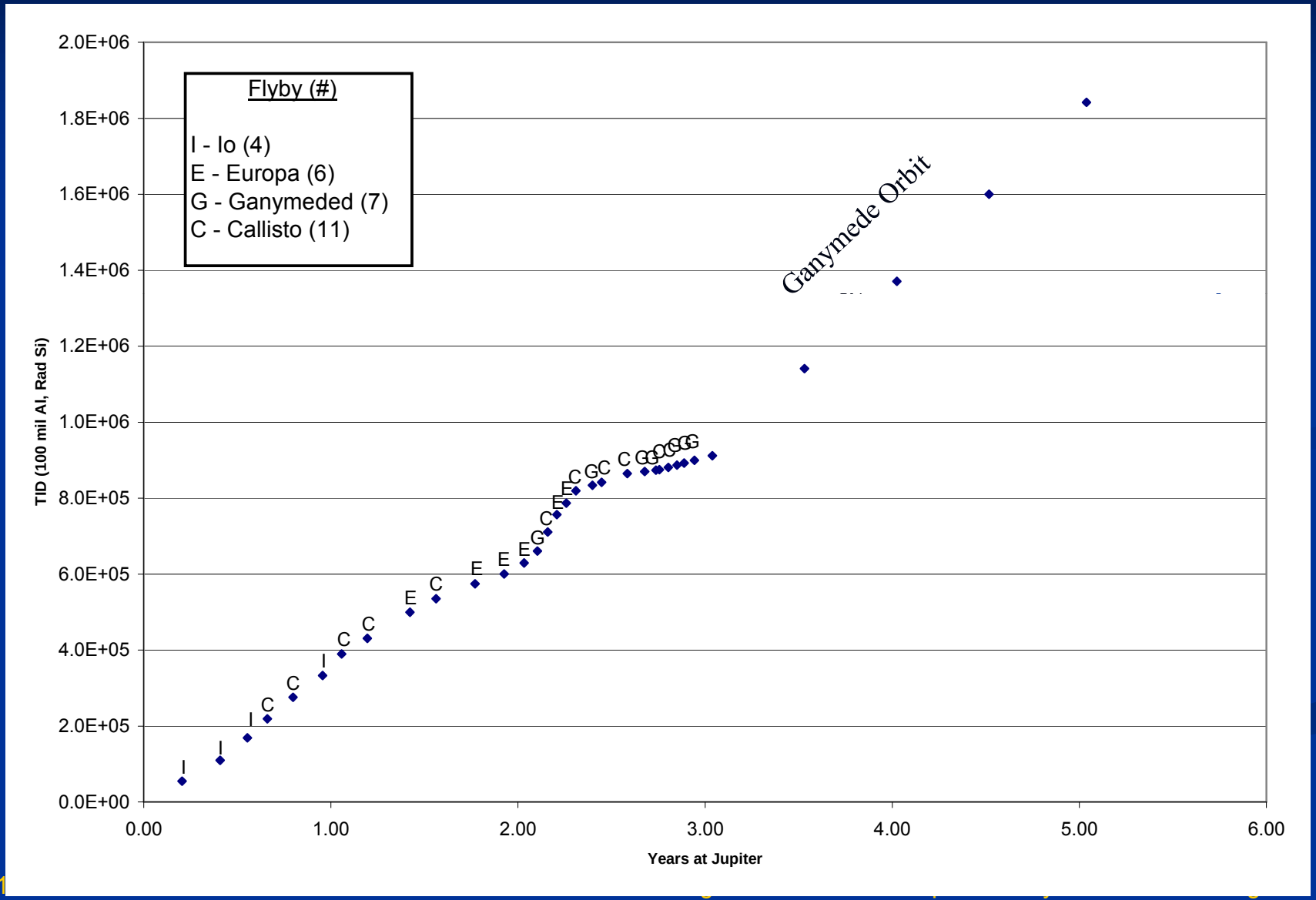


Opportunities

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	selected
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

Radiation TID



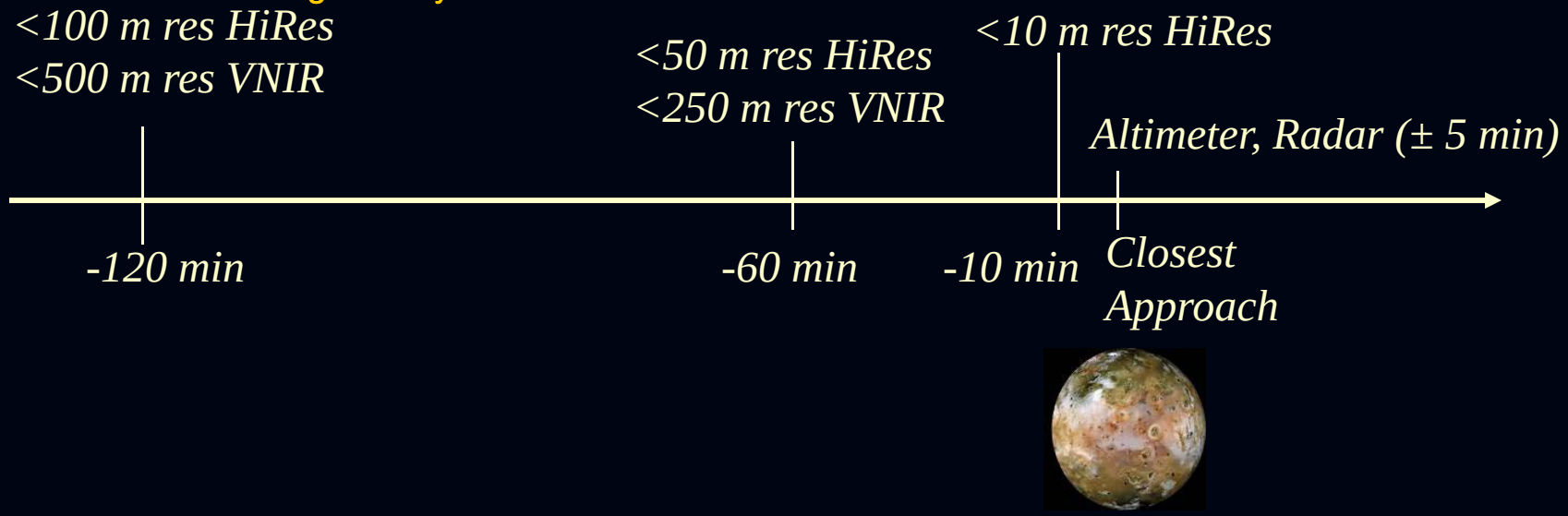
Mission Design

JSO science mission would be uniquely designed to meet the science goals and fully utilize the instrumentation

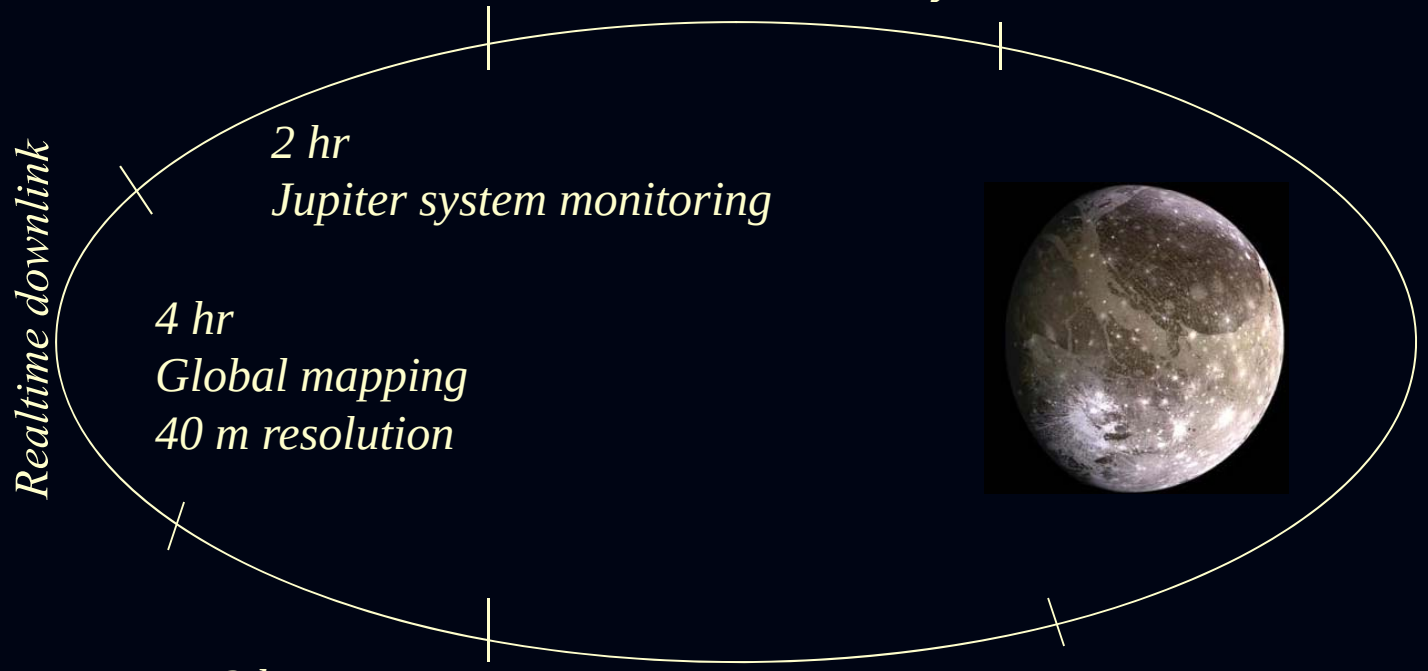
	Encounters	Jovian Tour	Ganymede Elliptical Orbit	Ganymede Circular Orbit
High-Res Camera	X	X	X	X
VIS-NIR Hyperspectral Imager	X	X	X	X
Medium-res Camera	X	X	X	X
UV Spectrometer	X	X	X	X
Thermal Spectrometer	X	X	X	X
Ground-Penetrating Radar	X		X	X
Laser Altimeter	X		X	X
Magnetometer	X	X	X	X
Plasma Spectrometer/Energetic Particle Detector	X	X	X	X
Radio Science - Gravity	X		X	X
Radio Science - Atmospheres	X	X	X	X

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 could be 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



Most demanding scenario
24 hr DSN coverage

5 hr
SSR Playback

2 hr
Jupiter system monitoring

Realtime downlink

4 hr
Global mapping
40 m resolution

6 hr
Altimeter, radar and gravity mapping
40 cm res @200km

Realtime downlink

2 hr
Jupiter system monitoring

5 hr
SSR Playback

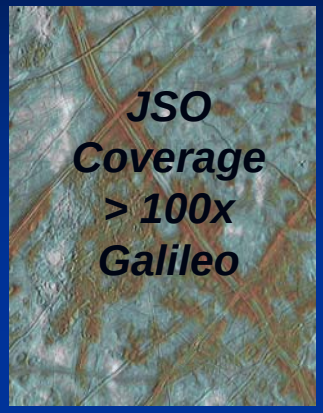
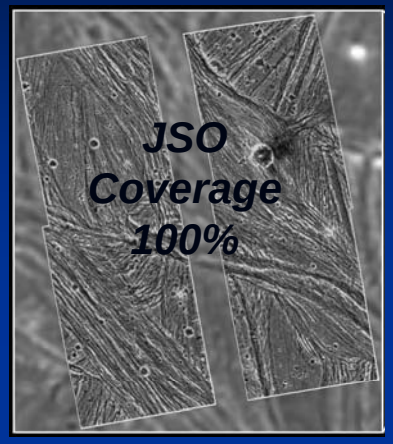
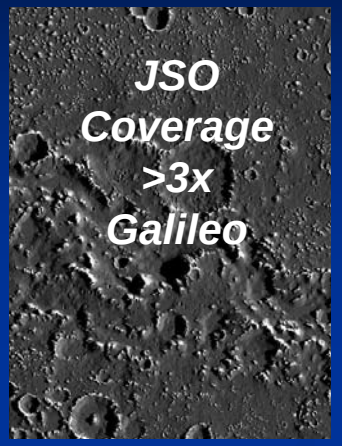
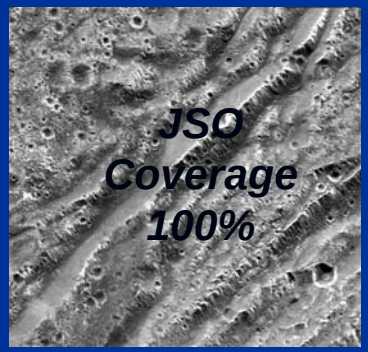
Circular Orbit Strategy

- 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 would be ~1.76 km/s
  - Hi-res camera would need to use summation mode, but would 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 would use remaining data volume capability
- Orbit reconstruction needed to 1-m radial accuracy
  - Thruster firings restricted to ≤1/day for at least first 2 Ganymede days (14 Earth days)

Baseline DSN Coverage

Phase	Sub-phase	Duration	DSN Coverage-hours/day	Sub-net	Activity Summary
Interplanetary	Launch and Early Operations	1 month	Continuous	34m	Flight system characterization, calibrations, maintenance, housekeeping, and cruise science
	Cruise	Up to 83 months	8 twice a week, except: 1) Continuous +/- one week @ Venus and Earth gravity assists 2) Continuous for two days @ tracking data cutoff for TCMs		
	Jupiter Approach	2 months	Continuous	34m	Optical navigation, Jupiter imaging
Jovian Tour	JOI and Capture Orbit	7 months	8 during cruise 24 during encounter day and within +/-2 days around perijove	70m equivalent @ encounters 34m	Continuous fields and particles, Mapping activities for target satellites, GPR and altimetry when altitude <2000 km Io monitoring, Jupiter atmospheric monitoring Close satellite flybys for gravity assists
	Io Sub-tour	23 months			
	EGC Sub-tour				
	Ganymede Approach	6 months	Continuous in last month prior to GOI		
Ganymede Science	Elliptical Orbit	1 year	Continuous for 1st month 16 over next 2 months 8 over last 9 months	70 m equivalent 34 m for X & Ka uplink/downlink for radio science	Fields and particles science - 24/7 High-resolution global mapping of Ganymede, selected targets
	Circular Orbit	1 year	Continuous for 1st month 16 over next 2 months 8 over last 9 months 8/day Ka for 1st month		Fields and particles science - 24/7 GPR, Altimetry, Gravity map, Mag map Selected high-res targets

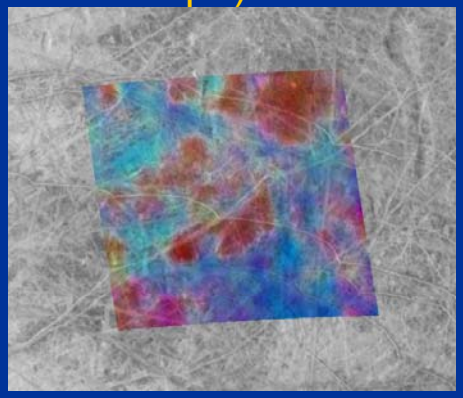
Baseline Remote Sensing Resolution & Coverage

	Io	Europa	Ganymede	Callisto
Galileo: ***~100 m Regional ~1-5% coverage***				
Galileo: ***~10-20 m < 1% coverage***				

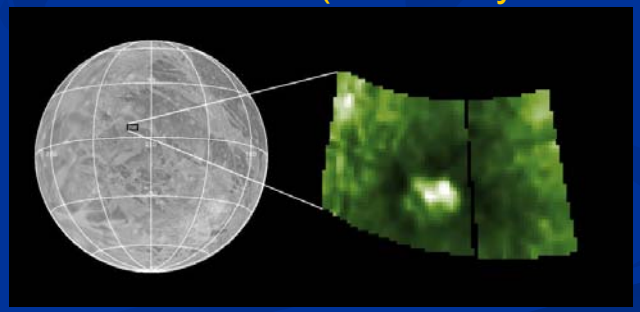
Instrument Payload would be more capable than any previously flown to Jupiter

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



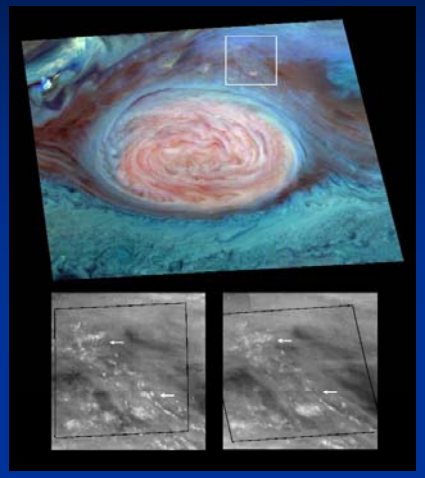
Ganymede: False color albedo of dark-rayed Antum Crater

Jupiter Atmospheric Science

Voyager

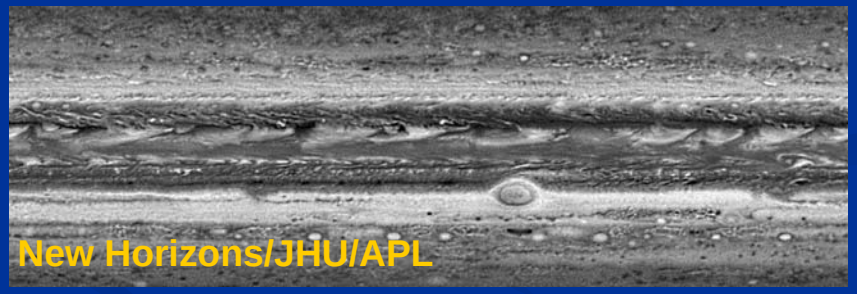
Temporal Coverage restricted to Fly-by period; Resolution, 100's km

Galileo



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

Cassini & New Horizons

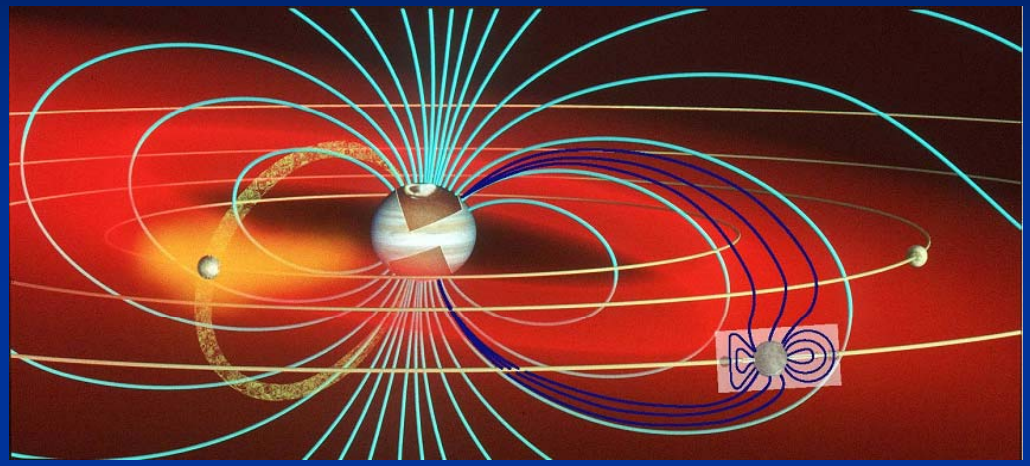


Temporal Coverage restricted to Fly-by period; Resolution, 120-400 km

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

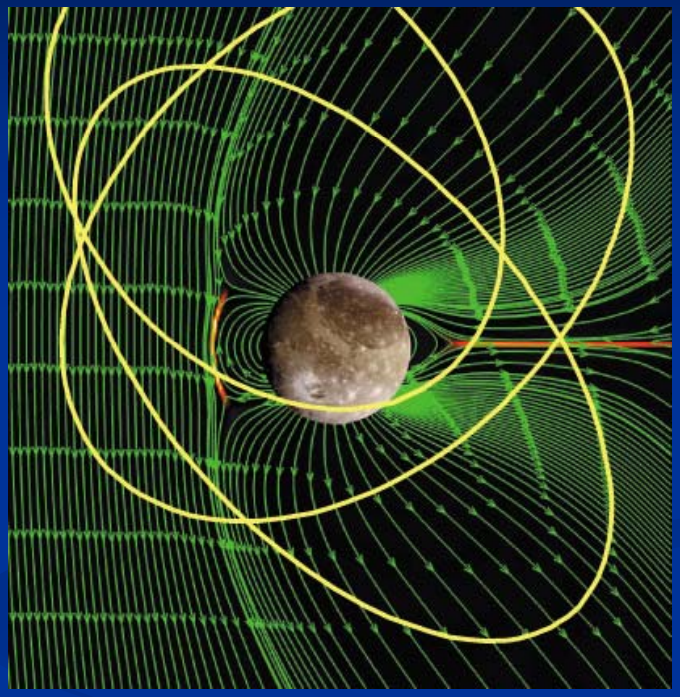
Magnetosphere Science

Tour of the Jovian System



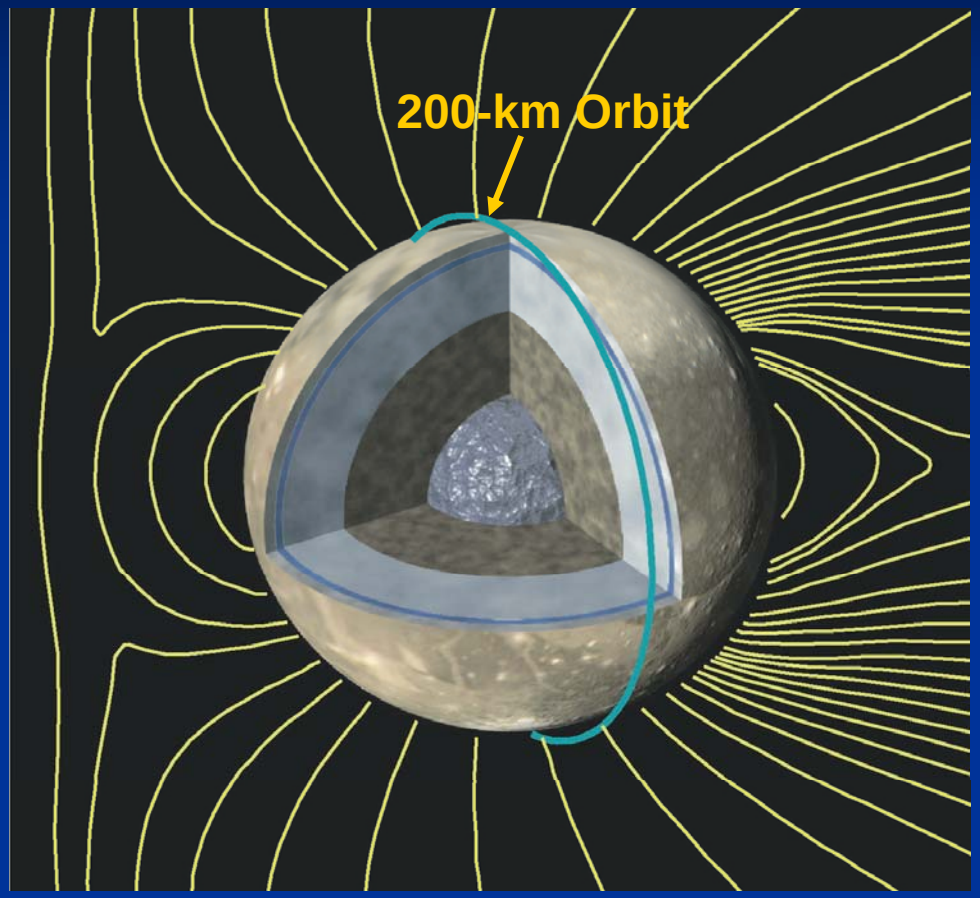
- ***Long-term sampling of different components of the Jovian Magnetosphere Environment***
- ***Highly capable instruments to study aurora, Io torus at resolutions not previously attained***
- ***Follow-up on results from Juno Mission***

"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
- Confirm presence of deep Ganymede Ocean

Add'l Descoped Options & Trade Studies

- Alternative Descoped Missions
  - Atlas V with circular Ganymede orbit
    - Reduced Io flyby to 2
    - Reduced MMRTG to 6
    - Direct insertion to circular orbit
  - Atlas V with slightly elliptical final Ganymede orbit
    - Determined by available propellant
- Orbit Studies
    - High fidelity orbit transition from satellite tour to elliptical orbit capture
    - Explore other capture orbit options to reduce GOI ΔV
      - Lagrangian point dynamics, distant retrograde orbit
    - Study different elliptical orbit at different inclinations and eccentricity
    - Explore escape from elliptical orbits

Movie