Jupiter System Observer

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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

11 March 2008

Pre-Decisional Information for Planning and Discussion Purposes Only
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.

- High-res Camera/ VIS-NIR Hyperspectral Imager System
- Medium-res Stereo Camera
- UV Spectrometer
- Reaction Wheel Assembly (4)
- Plasma Spectrometer/ Energetic Particle Detector
- Thermal Spectrometer
- Laser Altimeter
- Star Tracker (2)
- Dual Axis HGA Gimbal
- Telecom Radiation Chassis
- Ground Penetrating Radar
- LGA, Ka-band (2)
- LGA, X-band (2)
- Magnetometer Boom
- Dual Axis LGA X-band (2)
Baseline Mission Timeline

VEEGA, 5 ½ to 7 years

9 - 12 mo  18 – 21 mo  6 mo  2 years

<table>
<thead>
<tr>
<th>Cruise</th>
<th>Io Tour</th>
<th>Icy Moon Tour</th>
<th>Capture</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Ganymede Orbit</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Baseline (Ellip + Cir)</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Descope (Ellip only)</td>
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</tbody>
</table>

JOI  GOI

Opportunities

<table>
<thead>
<tr>
<th>Launch</th>
<th>Arrival</th>
<th>Atlas (kg)</th>
<th>DIV</th>
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<tbody>
<tr>
<td>Jan 2015</td>
<td>Jul 2021</td>
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<td>Jun 2015</td>
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<td>Jan 2017</td>
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<td>7332</td>
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<td>Mar 2020</td>
<td>Feb 2026</td>
<td>5270</td>
<td>7760</td>
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<tr>
<td>May 2021</td>
<td>Mar 2028</td>
<td>5053</td>
<td>7416</td>
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</table>

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

24 hr period
60° inclination

Polar 200 km altitude

11 March 2008  Pre-Decisional Information for Planning and Discussion Purposes Only
Radiation TID

Flyby (#)
I - Io (4)
E - Europa (6)
G - Ganymede (7)
C - Callisto (11)

TID (100 mAl, Rad $S$)

Years at Jupiter
Mission Design

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

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

```
<100 m res HiRes
<500 m res VNIR

-120 min

<50 m res HiRes
<250 m res VNIR

-60 min

<10 m res HiRes

Altimeter, Radar (± 5 min)

-10 min

Closest Approach
```
Notional “Elliptical” Orbit Scenario

Most demanding scenario
24 hr DSN coverage

5 hr SSR Playback

2 hr Jupiter system monitoring

4 hr Global mapping
40 m resolution

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

5 hr SSR Playback

2 hr Jupiter system monitoring
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

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

<table>
<thead>
<tr>
<th>Io</th>
<th>Europa</th>
<th>Ganymede</th>
<th>Callisto</th>
</tr>
</thead>
<tbody>
<tr>
<td>Galileo: ~100 m Regional coverage</td>
<td>JSO Coverage &gt; 100x Galileo</td>
<td>JSO Coverage 100%</td>
<td>JSO Coverage &gt;3x Galileo</td>
</tr>
<tr>
<td>JSO Coverage 7x Galileo</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Galileo: ~10-20 m &lt; 1% coverage</td>
<td>JSO Coverage ~ Galileo</td>
<td>JSO Coverage 100%</td>
<td>JSO Coverage 2x Galileo</td>
</tr>
</tbody>
</table>

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 - i.e. recent - hydrated non-ice materials on Europa or Ganymede.
  - 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. CO2, CN, O3, O2, H2O2, etc.
  - Aid in resolving the controversy on the origins of the hydrated non-ice material on Europa (and Ganymede) and the origin of the CO2 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**
- **Cassini/JPL**
  - Temporal Coverage restricted to Fly-by period; Resolution, 120-400 km
- **New Horizons/JHU/APL**
  - Temporal Coverage at high global spatial resolution, up to 4-km (1 to 2 orders of magnitude over previous missions)

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

- 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

Ganymede

200-km Orbit
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