JUICE/Laplace Mission
Summary & Status

C. Erd
JUICE Instrument WS, Darmstadt
9/11/2011
Activities during the Reformulation Phase

1. Feasible JGO s/c as a starting point
   a. no re-design of s/c necessary
   b. Changes driven by changes of mission profile (Europa flybys, Jupiter high latitude)
   c. Model payload left unchanged

2. Review and release of updated radiation model used for
   a. Comparison with JGO baseline
   b. Evaluation of impact of Europa flyby scenario

3. More detailed simulation of radiation exposure
   a. Shielding approach, background estimates
   b. Evaluation of possible solar array degradation

4. Continuation of technology developments and preparations
From JGO to JUICE: Changes

1. No changes to spacecraft configuration and model payload

2. Changed mission profile

3. Updated radiation environment

4. Planetary protection

5. Planned next steps and tentative schedule
Baseline Spacecraft
Spacecraft Configuration – Unchanged

- LA (Laser Altimeter)
- HRC (High Resolution Camera)
- PP-MU (Power & Propulsion Main Unit)
- WAC (Wide Angle Camera)
- SWI (Supernova & Weak Interactions Instrument)
- UVIS (Ultra-Violet Imaging Spectrometer)
- VIRHIS (Visible & IR Hyperspectral Imaging Spectrometer)
### JUICE Model Instruments

**Total mass: 104 kg**

<table>
<thead>
<tr>
<th>Imaging</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Narrow Angle Camera (NAC)</td>
<td>10 kg</td>
</tr>
<tr>
<td>Wide Angle Camera (WAC)</td>
<td>4.5 kg</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Spectroscopy</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Visible Infrared Hyperspectral Imaging Spectrometer (VIRHIS)</td>
<td>17 kg</td>
</tr>
<tr>
<td>UV Imaging Spectrometer (UVIS)</td>
<td>6.5 kg</td>
</tr>
<tr>
<td>Sub-mm Wave Instrument (SWI)</td>
<td>9.7 kg</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>In situ Fields and Particles</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Magnetometer (MAG)</td>
<td>1.8 kg</td>
</tr>
<tr>
<td>Radio and Plasma Wave Instr. (RPWI)</td>
<td>11.2 kg</td>
</tr>
<tr>
<td>Particle and Plasma Instr.— Ion Neutral Mass Spectr. (PPI-INMS)</td>
<td>18.2 kg</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sounders &amp; Radio Science</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Laser Altimeter (LA)</td>
<td>11 kg</td>
</tr>
<tr>
<td>Ice Penetrating Radar (IPR)</td>
<td>10 kg</td>
</tr>
<tr>
<td>Radio Science Instrument (JRST+USO)</td>
<td>4 kg</td>
</tr>
</tbody>
</table>
JUICE Key Properties for Science Ops

1. Power generation and spacecraft pointing
   a. Ganymede phase:
      - Baseline is yaw steering
      - Temporarily stable nadir pointing (with power saving operations)
   b. Flybys: any spacecraft orientation

2. Simultaneous operations of remote sensing and *in situ* instruments to be studied

3. Fixed HGA (>3 m)
Mission Profile
### Mission Profile – Launch and Interplanetary Transfer

<table>
<thead>
<tr>
<th></th>
<th>Prev. Baseline (EJSM/JGO)</th>
<th>Baseline JUICE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Launch</strong></td>
<td>March 2020 (June 2022)</td>
<td>June 2022 (Aug 2023)</td>
</tr>
<tr>
<td><strong>Launch mass in kg</strong></td>
<td>4212 (4681)</td>
<td>4804</td>
</tr>
<tr>
<td><strong>Interplanetary transfer (Launch to Jupiter arrival) in yrs</strong></td>
<td>5.9 (7.3)</td>
<td>7.6 (8.0)</td>
</tr>
<tr>
<td><strong>Gravity assist sequence</strong></td>
<td>VEE (EVEE)</td>
<td>EVEE</td>
</tr>
<tr>
<td><strong>Jupiter arrival</strong></td>
<td>Feb 2026 (Jun 2029)</td>
<td>Jan 2030 (Aug 2031)</td>
</tr>
<tr>
<td><strong>Total ΔV in m/s</strong></td>
<td>1365 (1685)</td>
<td>1284 (1315)</td>
</tr>
<tr>
<td><strong>Max. available mass at Jupiter in kg</strong></td>
<td>2680</td>
<td>3140 (3100)</td>
</tr>
</tbody>
</table>
1. Europa flybys: 2 flybys immediately following each other; same true anomaly of Europa, outer flyby at $\sim 180^\circ \text{ long}_{\text{Europa}}$, 400 – 500 km, 36 d

2. Callisto flybys to increase of inclination: reaching Jupiter latitudes up to 30°, 11 flybys (200 d)

3. Ganymede (polar) phases
   a. Elliptic phase starting 10,000x200 km, 30 d
   b. High altitude circular phase 5,000 km, 90 d
   c. Elliptic phase ending 10,000x200 km, 30 d
   d. 500 km circular, 102 d
   e. 200 km circular, 30 d

4. Disposal on Ganymede’s surface
<table>
<thead>
<tr>
<th>Event</th>
<th>Baseline</th>
<th>Backup</th>
</tr>
</thead>
<tbody>
<tr>
<td>Launch</td>
<td>Jun 2022</td>
<td>Aug 2023</td>
</tr>
<tr>
<td>Interplanetary transfer</td>
<td>7.6 yrs</td>
<td>8.0 yrs</td>
</tr>
<tr>
<td>JOI</td>
<td>Jan 2030</td>
<td>Aug 2031</td>
</tr>
<tr>
<td>JOI to Callisto</td>
<td></td>
<td>11 months</td>
</tr>
<tr>
<td>Arrival at Callisto</td>
<td>Dec 2030</td>
<td>Jul 2032</td>
</tr>
<tr>
<td>Europa Flybys</td>
<td></td>
<td>36 days</td>
</tr>
<tr>
<td>Reduction of $V_{\text{inf}}$</td>
<td></td>
<td>60 days</td>
</tr>
<tr>
<td>Start Callisto High Lat Phase</td>
<td>Mar 2031</td>
<td>Oct 2032</td>
</tr>
<tr>
<td>Callisto High Latitude Phase</td>
<td></td>
<td>200 days</td>
</tr>
<tr>
<td>End Callisto High Lat Phase</td>
<td>Oct 2031</td>
<td>Apr 2033</td>
</tr>
<tr>
<td>Callisto to Ganymede + Reduction of $V_{\text{inf}}$</td>
<td>11 months</td>
<td></td>
</tr>
<tr>
<td>GOI</td>
<td>Sep 2032</td>
<td>Mar 2034</td>
</tr>
<tr>
<td>Ganymede Elliptical Phase 1</td>
<td></td>
<td>30 days</td>
</tr>
<tr>
<td>Ganymede 5000 km circular Phase</td>
<td></td>
<td>90 days</td>
</tr>
<tr>
<td>Ganymede Elliptical Phase 2</td>
<td></td>
<td>30 days</td>
</tr>
<tr>
<td>Ganymede alt reduction</td>
<td>Feb 2033</td>
<td>Aug 2034</td>
</tr>
<tr>
<td>Ganymede 500 km circular Phase</td>
<td></td>
<td>102 days</td>
</tr>
<tr>
<td>Ganymede alt reduction</td>
<td>May 2033</td>
<td>Dec 2034</td>
</tr>
<tr>
<td>Ganymede 200 km circular Phase</td>
<td></td>
<td>30 days</td>
</tr>
<tr>
<td>End of mission</td>
<td>Jun 2033</td>
<td>Dec 2034</td>
</tr>
</tbody>
</table>
Europa Flyby Scenario

1. 36 day flyby period from leaving Callisto until return to Callisto

2. 2 Europa fly-bys

3. First flyby 9.5 days after leaving Callisto

4. Second flyby 14 days after the first
Europa Flybys Ground Tracks

![Graph showing Europa flybys ground tracks with various annotations and data points.](image)
6 swing-bys are necessary to transfer from equatorial to maximum inclination

The maximum inclination is ~29 deg

The time to transfer is 100 days (100x2=200 days for the end-to-end transfer)
Callisto Coverage

Previous: Pseudo-orbiter

Now: Jupiter High Latitudes
# JUICE Mission Profile - Summary

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<th>Duration</th>
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<tr>
<td>Launch</td>
<td>June 2022</td>
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<td>(Aug 2023)</td>
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<td></td>
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<td>Jan 2030</td>
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<td>36 days</td>
</tr>
<tr>
<td>Jupiter high latitude phase</td>
<td>200 days</td>
</tr>
<tr>
<td>Callisto to Ganymede</td>
<td>9 mon</td>
</tr>
<tr>
<td>Ganymede (polar)</td>
<td></td>
</tr>
<tr>
<td>10,000x200 km &amp; 5000 km</td>
<td>150 days</td>
</tr>
<tr>
<td>500 km circular</td>
<td>102 days</td>
</tr>
<tr>
<td>200 km circular</td>
<td>30 days</td>
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![Image of Europa, Callisto, and Jupiter Pole]
Radiation Environment
1. Increase of modelled radiation exposure (2x wrt previous baseline)
2. Inclusion of Europa flybys (adds ~20% to total dose)
Environment Spectra

**Electrons**
- + V Reduction
- □ Europa
- × Jup. h.lat.w. Call.
- ◊ Call. to Gan.
- △ Ganymede

**Protons**
- + V Reduction
- □ Europa
- × Jup. h.lat.w. Call.
- ◊ Call. to Gan.
- △ Ganymede

Integral Fluence cm$^{-2}$ sr$^{-1}$

MeV

$10^8$ $10^{10}$ $10^{12}$ $10^{14}$ $10^{16}$ $10^{18}$

$0.01$ $0.10$ $1.00$ $10.00$ $100.00$
Dose-Depth per Mission Phase

Dose-Depth Curves

- Interpl. transfer
- V Reduction
- Europa
- Jupiter high lat. w. Callisto
- Callisto to Ganymede
- Ganymede
- Total

Dose in krad vs. Al Solid Sphere Shielding in mm
Dose per Particle Species

Dose-Depth Curves

- Total
- Electrons
- Bremsstrahlung
- Trapped Protons
- Solar Protons

Dose in krad vs. Al Solid Sphere Shielding in mm
Cumulative Mission Dose

Cumulative Dose per Mission Phase

- V Reduction
- Europa
- Jupiter high lat. w. Callisto
- Callisto to Ganymede
- Ganymede

Relative dose at 10 mm Al solid sphere
Model of the Radiation Environment

1. Increase of radiation environment model (2x wrt previous baseline)
2. Inclusion of Europa flybys (adds ~20% to total dose)
3. Radiation mitigation
   a. 3d shielding simulations: reduction of dose by $\frac{1}{2} - \frac{1}{3}$ due to geometry from solid sphere to more representative geometry
   b. 40% (conservative) due to shielding by Ganymede during the low altitude phases ($\leq 500$ km): 31% of the total exposure at Ganymede
   c. Higher shielding mass than during Assessment Phase
   d. Use of high Z material (Ta) for shielding
   e. Components tolerance required up to 30 krad
4. Radiation environment close to Europa has higher instantaneous flux
   a. Higher background for sensors
   b. No severe increase of Single Event Effects (SEE’s)
Planetary Protection
1. Europa flyby requires mission to be in PP Cat III
   a. Requirement: $10^{-4}$ probability of ocean contamination during mission life and 300 years (in case of failure)

2. Probability of collision with Europa (allocations)
   a. JGO: orbit has too high energy for collision with Europa; very low likelihood – assumption from previous study
   b. Only change with respect to JGO is 2 ballistic Europa flybys
      - Probability of spacecraft failure: $\sim 2 \times 10^{-3}$ (40 days after 12 years mission)
      - Allocation for likelihood of collision with Europa after failure: <1%

3. Requirement of $10^{-4}$ probability appears to be feasible, but full analysis to be performed in next phase including
   a. Orbit propagation and collision probability analysis
   b. Failure tree
Approach to Planetary Protection

1. Assume that spacecraft reliability can be demonstrated
2. Active bioburden reductions are assumed as risk (cost impact)

3. Activities in phase A/B1:
   a. Failure tree analysis and likelihoods
   b. Quantification of risks
   c. Consolidation of PP requirements

4. Review at preliminary requirements review

5. Instruments should follow the same approach
Next Steps & Tentative Schedule
Next Steps: Plans for Reviews and Milestones

1. New issue of Yellow Book ready Dec 2011
2. ESA internal review Nov/Dec 2011
4. SPC Down-selecion Feb 2012

5. If down-selection successful –
   a. ITT for industrial Phase A/B1 Q2/2012 (tentative)
   b. Issue of instrument AO Q2/2012 (tentative)
Summary Spacecraft Updates

1. Configuration and model payload unchanged

2. Increase of radiation exposure balanced by
   a. Moderate increase of shielding mass by \( \sim 50 \) kg
   b. High Z shielding material (Ta as opposed to Al)
   c. Higher component tolerance (up to 30 krad)
   d. Mitigations justified by preliminary transport simulations

3. Minor additional \( \Delta V \) required for the additional mission options
   a. Higher Jupiter latitude with Callisto gravity assists
   b. Europa flybys

4. Increased dry mass feasible due to
   a. Higher launch capability (+360 kg)
   b. Longer interplanetary transfer (reduction of \( \Delta V \))

5. Mission dry mass margin close to 20%
   a. No adverse effect on solar panels
1. Radiation environment
   a. 3d transport simulations very important (Monte Carlo)
   b. Need representative models early

2. Planetary protection
   a. Need estimate for active bioburden reduction as risk

3. Resource optimizations important
   a. Mass criticality