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The Europa and Beyond

(Kinsetics by a Small RPS)

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Outline

- Study assumptions and ESSP concept mission scenario
- ESSL science requirements and instrument options
- Study drivers (e.g., mass limit, radiation, landing method, small-RPS concept)
- Parametric results and point concepts
- Conclusions
- Beyond Europa with Small-RPSs (e.g., RPSs, ARPSs & fusion)

Study Assumptions

- Technology cutoff by 2012 (assumptions will support feasible trades and not far-out technologies)
- The ESSP is deployed from an assumed JIMO orbit
- As assumed in this study, JIMO would provide 1" of aluminum shielding until ESSP deployment (a simplification for this study)
- the high radiation environment may necessitate this type of help from JIMO
- Radiation hardened components on ESSP up to 1 MRad tolerance
- Dual string design
- Advanced technology for all components
- 30% contingency on mass and power (required by design principles for concept studies)
- Some instrument operation cycled to reduce power requirements
- Cost, Planetary Protection & Surface Contamination issues were not addressed for this trade space exploration

Conceptual ESSP Mission Scenario

- ESSP would cruise to Europa inside or attached to JIMO
- JIMO would orbit Europa on a 100 km orbit with an inclination of 110°
- During its 30-day science floor first JIMO would map Europa, from which a landing location would be determined
- The Europa Surface Science Package would deploy for a 3 / 7 / 14 (Earth-day Europa surface mission)
- Data would be communicated from ESSP to JIMO during overpasses utilizing JIMO's telecom system
- JIMO would downlink the ESSP data to DSN

ESSP Science Requirements and Instrument Options

- Study Assumptions

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Science Goals Expressed by the JIMO SDT

- **Astrobiology**
  (Search for organic materials, determine composition; chemical patterns, orgaics indicative of biological origin)

- **Geophysics**
  (Acoustic/seismic; icy crust thickness; ocean depth; geophysical and mechanical ice properties; magnetic field at surface, surface package tracking for geodynamics)

- **Geological-compositional**
  (provide "ground truth"; elemental composition; mineralogical characterization; physical properties & high-resolution morphology & density & thermal & electromagnetic properties & surface processes & radioisotopes of surface materials)

Reference:
Geordie R. Johnson, J., Report of the JIMO Science Definition Team for the SDR Project, MSCO-Oberth (JIMO) - SSA Report, February 12, 2004

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**Two Representative ESSP Instrument Set Examples**

**Team-X Study**
Instrument mass: ~5 kg; ~30% contingency

- **Instrument package**:
  - **Detector**: 10 kW
  - **Telescope**: 50 cm
  - **Antenna**: 10 m

**NPFS Study**
Instrument mass: ~12 kg w/30% contingency

- **Meets missions goals of JIMO SDT**

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**Use of Reflective Optics in High-Radiation Environments**
Three-Mirror Assembly (Fig. 1)

- All reflective optical systems represent an optimal solution in high-radiation environments.
- They have been preferred in spacecraft environments in which the instrument will be exposed to high radiation doses, such as in Europa and Ganymede.
- All reflective systems are inherently radiation-hard, but they may require mirror changes as areas degrade due to changes in the glass's crystal structure after exposure to radiation.
- All reflective optics are inherently achromatic, but this has the same optical performance over a wide spectral bandwidth.

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**Mission Scenario Example for 3 Days of Surface Operation**

- **Day 1**
  - 10:00 a.m.: Touchdown
  - 10:30 a.m.: Deployment of instruments and antennas
  - 11:00 a.m.: Surface exploration

- **Day 2**
  - 8:00 a.m.: Surface analysis
  - 9:00 a.m.: Sample collection
  - 10:00 a.m.: Surface imaging

- **Day 3**
  - 7:00 a.m.: Surface exploration
  - 8:00 a.m.: Sample analysis
  - 9:00 a.m.: Surface imaging

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**Study Drivers**

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**Trajectory/Telecom Example Based on the Assumed JIMO Orbit**

- **34 Days of Onboard Science by IOM**

  - **Telecom availability**:
    - 2 days: 10 minutes
    - 7 days: 0.5 minutes
    - 16 days: 1.5 minutes
  
  - 2 day increments / chart
  
  Time-step: 1 minute

Rabahon sources through the proposed JIMO mission:
- Van Allen Radiation Belts
- Galactic Radiation
- Jupiter's Radiation Environment
- JIMO's Fusion Reactor
- Small-RPSs on the ESSP

**Study Details - Radiation Environment**

<table>
<thead>
<tr>
<th>Total Ionizing Dose (TID) Radiation during JIMO tour</th>
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<tbody>
<tr>
<td>Photon Flux</td>
</tr>
<tr>
<td>-------------</td>
</tr>
<tr>
<td>(10^-6 cm^-2</td>
</tr>
<tr>
<td>0.72</td>
</tr>
<tr>
<td>0.51</td>
</tr>
<tr>
<td>0.80</td>
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</tbody>
</table>

- The TID is the radiation dose that ESSP is expected to experience on Europa's surface.
- All electronic components are assumed to tolerate up to 1 MeV.
- RFP - Radiation Design Factor is similar to the radiation exposure value in 2.
- The TID values do not include radiation from Radiant Power Systems.

**Study Details - Shielding Mass Estimates for an ESSP Concept**

- Dose designed for the ESSP should provide tolerance for shielding, including optimization.

**Study Details - Comparison of Landing Methods**

- Small-RPS Concept - based on 1 GPHS module
  - Small-RPSs are under consideration by the US DoD and by NASA
  - Notice of Intent (NOI) to develop was issued in September 2004
  - Request for Proposals (RFP) from the DoD is expected in early 2005
  - Could be made available as early as the 2011 Mars mission launch opportunity
**Key drivers for Europa Surface Science Package:**

- Limited initial mass (up to 375 kg, that is 25% of the proposed JIMO mission’s mass per unit)
- High radiation environment adds significant shielding mass (the shielding alone accounts for about 125 kg; without shielding help on JIMO)
- Rocket equation: Propulsion alone is 50% of the total mass
- Constraint: a) set initial mass; b) technology size the needed mass; c) advanced advanced technologies; d) radiation time shielding mass

**With realistic assumptions for a 2012 technology cutoff date**

- ESSP mass allocation must be possible within the 375 kg limit.
- 390 kg and 150 kg initial masses are likely not feasible.
- Soft landing delivered the highest payload compared to hard and rough landing configurations.
- Airbag and Crushable rough landings are less efficient on planetary bodies without atmospheres, thus such designs will exceed landed mass limit. It is more efficient to remove all delta V with one type of propulsion system/landing method.

**Conclusions on the ESSP Study**

- ESSP mass allocation must be possible within the 375 kg limit.
- For a 7 to 14-day mission small-RPSs could be considered.
**Beyond Europa: Mission Concepts – Enabled by Small-RPSs and above**

- **Milliwatt range (10s to 100s of mW)**
  - Micro landers, rovers and inspectors
  - Deployable release micro instruments, land on science stations, basins
  - Targeting smallsats, moons (Moon, Euros, Titan, Mars, planetary rings)

- **Multiwatt power range (10s of kW)**
  - Lander and rovers to Europa, Titan, Ganymede, Callisto, the Moon, Mars
  - Venus masts
  - Communication relay satellites (Orbiter satellites)
  - Sub-satellites and inflex payloads on flagship-class missions

- **Multi-hundred watt range (100s of kW to ~1 kW)** with WSs and ARPs
  - Tens of kW to hundreds of kW and above with fission reactors

*Note: a more complete list of small-RPS and standard RPS enabled mission concepts is given in...*


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**Beyond Europa: Small-RPS Enabled Mission Concept Examples**

**Earth Not solar Concepts**

- [Diagram of a non-solar concept for Earth missions]

**Moon Rover Concepts**

- [Diagram of a rover concept for Moon missions]

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**Special thanks to the JIMO SDT, to Curt Niebur, and to all contributing members of JPL’s Team X, NPD and MBS missions.**

**Thanks for your attention. Any questions?**

*Further information on this topic can be found in the ESSP report.*