Going to the Water

Key Technology Needs for Accessing the Ocean of an Icy Moon

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A Potential for Life

Energy Source

Biologically Essential Elements

Liquid Water

Time
From Europan orbit: deorbit, descend and land, establish a surface system, travel through the ice, enter the ocean, and determine whether-or-not there is extant life

**Landing Phase**
- Deorbit
- Descend
- Land

**Surface Phase**
- Release probe into ice
- Communications: DTE and/or to orbiter; Tethered or wireless to probe
- Maintain operations in radiation

**Ice Mobility Phase**
- Mobility to Ocean
- Communications to surface
- Science Instrumentation

**Ocean Access and Mobility Phase**
- Entry into ocean at ice-ocean interface
- Explore ice interface and open ocean
- Maintain planetary protection
**Europan Ice Probe Trade Space**

- **Landing Phase**
  - Deorbit, Descent and Landing
  - Descent method
  - Landing Precision
  - Landing Method

- **Surface and Ice Phases**
  - Ice Descent Method
    - Cutting
    - Water Jetting
    - Melting
  - Power System
    - Method
    - Packaging
    - Energy Conversion
  - Thermal Control
    - Passive
    - Active
  - Autonomous Navigation & Operations
    - Passive Nav
    - Active Nav
    - Autonomous Operations

- **Ocean Access Phase**
  - Communications
    - Surface Comm
    - Subsurface Comm
    - Ocean Comm
  - Ocean Science
    - Nose in
    - Ice-Surface access
    - Underwater vehicle
Ice Descent

Melt Probe
- Thermal energy melts ice ahead and along probe
- Power can be aboard probe or transferred by tether from surface
- Rate of travel depends on amount of thermal energy
- **Water Jets** can be added to further melt ice and move melt water – electrical energy needed to drive pumps

Mechanical Cutting
- Electrical energy drives blade to shave ice
- Chips need to be moved from front of probe
Ice Mobility – Days for Melt Probe to Travel 10Km

Days to Descend 10 km Temperature Profiled Europian Ice Shell
Sensitivity to Thermal Conductivity Variations & Ice Types

- 0.160 m Dia x 2.418 m Long, 87.3 Liters, SR = 19.1 (optimized SR)
- Power of 7.5 kW @ 85% Thermal Efficiency (net 6.3 kW)
- MS7 “like” ice: Extrapolated thermal conductivity & specific heat for MgSO4 - 7H2O, epsomite (W.B. Durham et al, 2010), remaining properties of pure H2O Ice

10km depth reached in half the time if salty intrusion present

MgSO4 ice
Pure H2O ice

Stone Aerospace
### Ice Mobility – Heat and Electric Source

**Type**

- **Nuclear**
  - Reactor
  - ASRG (Stirling)
  - RTG (Thermo-Electric)
  - GPHS
    - Pellets or other (new)

- **Stored**
  - Battery
  - Fuel Cell
  - Fly-wheel

- **Solar**

**Rationale:**

- **Nuclear:** 9 year mission life necessitated active power generation.
- **GPHS:** Solar is deemed insufficient for zeroth order thermal energy needed to melt ice.
- **Energy density and form factor would necessitate new PuO₂ pellets.**

**General Purpose Heat Source (GPHS) Module**

- 27 GPHS Blocks
  - 6.75kW thermal

- 1.57 m
Communications in Ice and to Earth

Orbiter Configuration
- 2 m antenna
- 100 W TWTA
- X-band

Lander Configuration
- 27 dBi surface antenna
- 4 W RF
- X-band

Probe Configuration
- 5 comm pucks
- Turbo coding
- 100 MHz
Autonomous Guidance Navigation and Operations

**Science Comm**
- Science Ops
- Science Transmit

**Puck Release**
- Release Puck
- Anchor Puck
- Transmit Checkout

**Navigate**
- Radar / Sonar
- Differential Heating
- Differential Jetting

**Ice Descent**
- Melt
- Water Jet and Cut
- Unfurl Tether
- Sense Position/Orientation
- Tx Housekeeping Data
Surface Phase: Initial Access into Ice

**SOL 0**
- Lower and level
- Initial System checkout
- Install cap at surface

**SOL 1**
- System checkout
- Initial melt, cut and water jet operations

**SOL 2**
- Melt cut and water jet ~meters
- Deposit lander electronics
- Relay telecom checkout
- Science instrument checkout

**SOL 3 to n**
- Melt, cut and jet
- Unfurl tether
- Release puck
- Transmit science
Landing Phase

Deorbit – Descent – Landing (DDL)

Europa Lander Heritage
Elimination of Skycrane
Prior Knowledge of Landing Site
Prior knowledge of ice thickness
Ocean Access and Mobility: Four Science Segments

1 - Probe Nose In
   Anchor
   Image ocean
   Sample water

2 - Probe Fully Submersed
   Deploy ocean probe
   Tethered Ops

3 - Underwater Vehicle Ops
   Buoyant operation
   Science Ops
   Mobility Ops

4 - Free Fall & End Of Mission
   Cut Tether
Ice Mobility – Melt Probe Power

Amount of thermal energy needed to melt ice:

- *Aamot* model provides first order requirements vs melt rate
- Dependent on diameter and length of probe
- Assumptions
  - Temperature vs Depth
  - Thermal Conductivity, Specific Heat & Ice Density vs Temperature
  - Salt Content
  - Sublimation (especially at ice interface)
  - Viscous friction, tether effects, salt layering, voids, ...

Weiss, Planetary and Space Science 56 (2008) 1280–1292
Looking ahead: What we will know and have shown

Ice shell structure by RADAR
- Resolution of +/-10m @3km depth and +/-100m @30km depth

Detailed topographic surface map
- At 50m with higher resolution regions

Surface thermal map
- Identification of higher temp anomaly zones suggesting recent up-welling or cryo-volcanism

Mapping image spectroscopy

Powered landing to 100m accuracy
- Terrain relative navigation
- Hazard detection LIDAR

High resolution descent/surface imaging

Surface operations
- Cutting and handling of ice and salts at temperature

Organic/inorganic quantification at surface

Seismometer sensing of crustal motion

Europa Ocean Exploration

Europa Clipper

Europa Lander Concept
Ice Mobility – Water Jetting and Cutting

In addition to melting ice for mobility, need to
  • Travel through potential sediment layers
  • Force sediment and melt water past probe

Include
  • Water jetting by pumping and ejecting melt water at nose
  • Cutting with motorized blade and removing chips

Requires electrical power drawn from thermal energy
  • Balance of RTG electrical generation and thermal
Probe start-up activity
• Release Europan probe into ice
• Control initial sublimation at ice/salt surface

Survive radiation through mission life
• Use ice to protect electronics from radiation
• Melt electronics package into ice

Communication
• Direct to Earth or through Orbiter
• To and from Europan ice probe
Ice Mobility – Communications

RF Communications in ice is feasible
- Data rate depends on ice temperature dependent attenuation
- Released pucks can store and forward data
  Requires stand-alone power

Tether allows max bandwidth
- Mechanical strength in Europian ice is unknown

Combine pucks and tether (and acoustic)?
Probe Thermal Configuration

- **Power Electronics (C&DH and Nav)**
- **Science Payload**
  (submersible)
- **Comm (5 pucks)**
- **Cut and Jet**
  (Rotary bit with water jets)

**Thermal Zones**
- **Thermal Zone 1**: < 1100 C Needs > 1000 W heat from source
- **Thermal Zone 2**: ~ -20 to 50 C, 45 W
- **Thermal Zone 3**: > 50 C
- **Thermal Zone 4**: Shunt Fin
  Thermal Zone 4

**Temperature Ranges**
- ~ -34 to 70 C? Non operational Temperature?
- ~ -20 to 50 C, 45 W
Design Assumptions

Begin with Europa Lander systems and mass parameters
- SLS launch with same dry mass as Lander concept project
- Same trajectory design to Jupiter and Europa
- Same Deorbit system
- Same Mass to the surface (but not skycrane lander system)

Begin with known power sources (radioisotope)
- What advances can we make?

Baseline 10Km ice thickness
- Baseline Ice temperature profile, salt content

Set approximately two-year time for ice travel
Conceptual Design

7 KWth Main + 1 KWth Nose Power Sources

<table>
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<th>Ice Probe</th>
<th>CBE Mass (Kg)</th>
<th>CBE Power (We)</th>
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<tr>
<td>Total Probe</td>
<td>210.8</td>
<td>597.6</td>
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<td>Navigation</td>
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<td>Thermal</td>
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<tr>
<td><strong>Margin (%)</strong></td>
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<td><strong>29</strong></td>
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*Mass margin calculated against 335 Kg landed mass allocation for Europa Lander Class DDL
*Power margin based on 836 WEOL (9 years)