A Cryobot for Melting, Cutting and Water-jetting through the Icy Crust of Ocean Worlds

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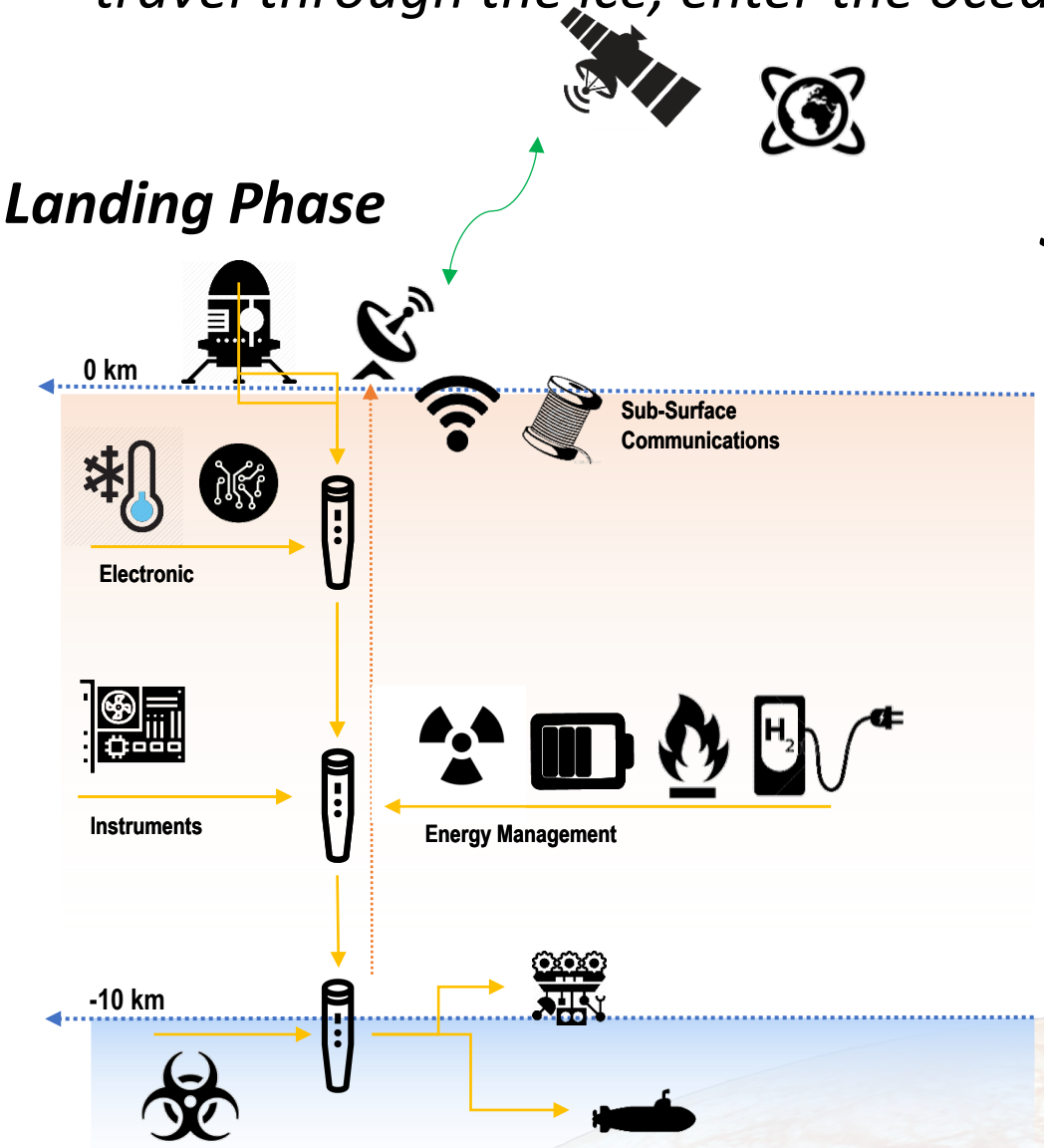
From Europan orbit: concept to deorbit, descend and land, establish a surface system, travel through the ice, enter the ocean, and determine whether-or-not there is extant life



Surface Phase

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

Ice Mobility Phase

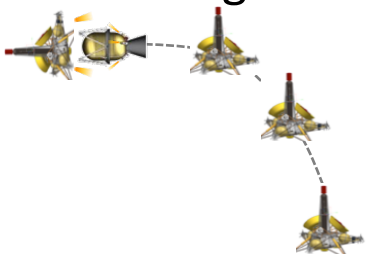
- Mobility to Ocean
- Communications to surface
- Science Instrumentation

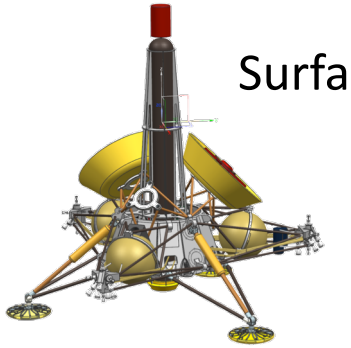
Ocean Access and Mobility Phase

- Entry into ocean at ice-ocean interface
- Explore ice interface and open ocean
- Maintain planetary protection

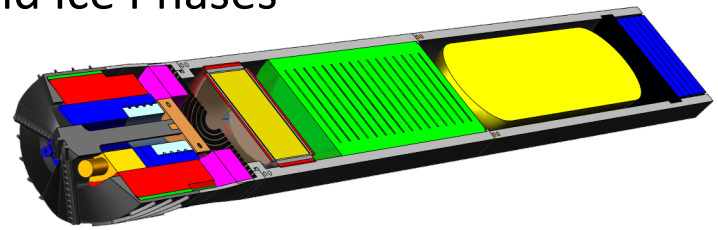
Europan Ice Probe Trade Space

Landing Phase

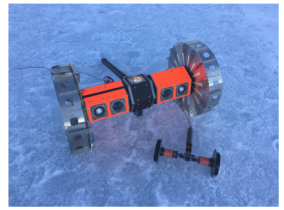




Surface and Ice Phases



Ocean Access Phase



- Deorbit, Descent and Landing
  - Descent method
  - Landing Precision
  - Landing Method
- 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
- Communications
  - Surface Comm
  - Subsurface Comm
  - Ocean Comm
- Ocean Science
  - Nose in
  - Ice-Surface access
  - Underwater vehicle

Ice Descent Approaches

Melt Probe

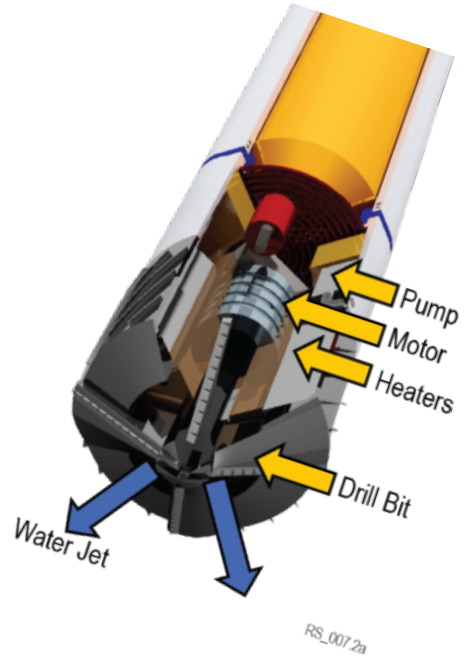
- Thermal energy melts ice ahead and along probe
- Power can be aboard probe or transferred by tether from surface
- Rate of travel depends on amount of thermal energy

- Water Jets are added to further melt ice and move melt water – electrical energy needed to drive pumps

Mechanical Cutting

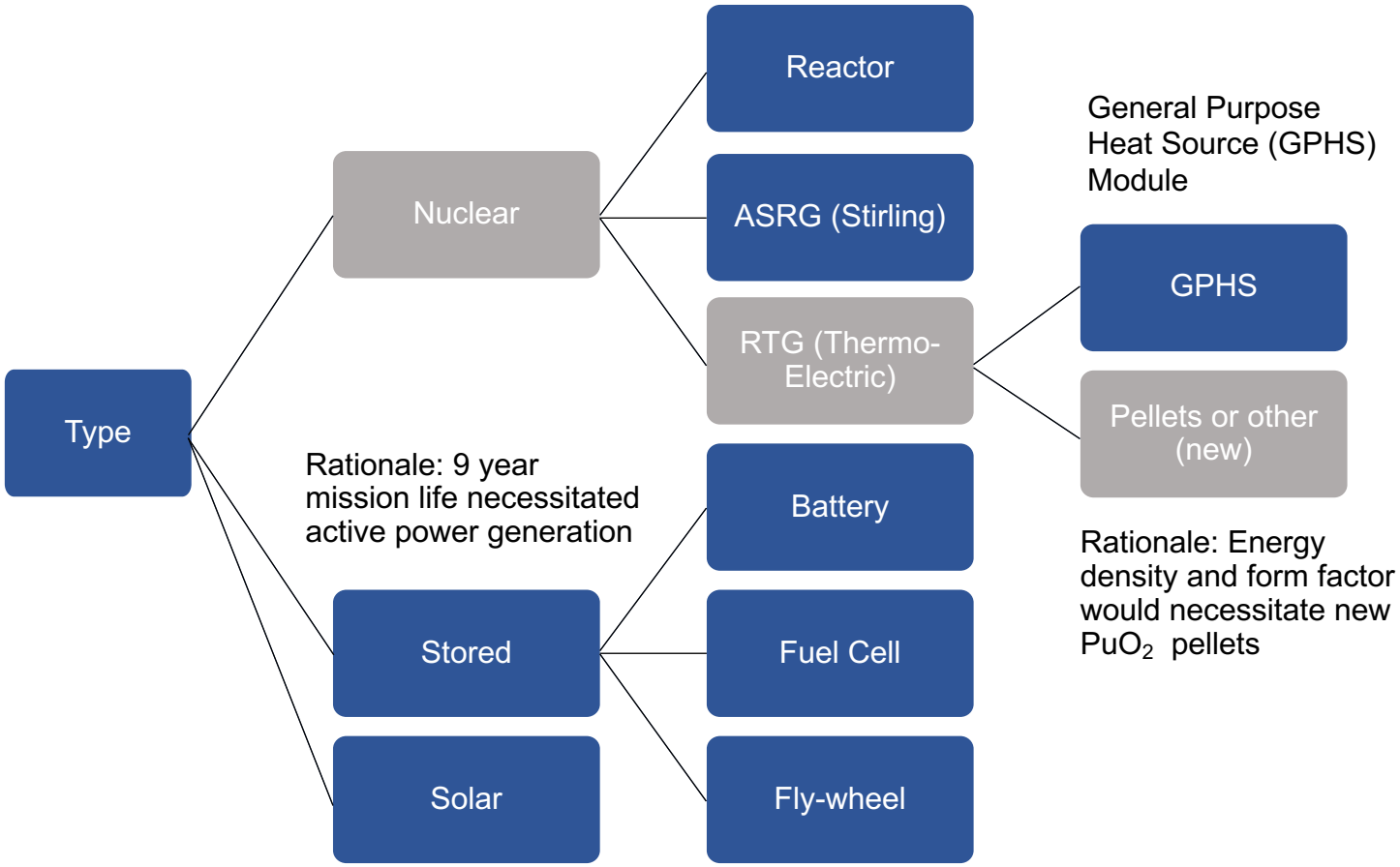
- Electrical energy drives blade to shave ice
- Chips need to be moved from front of probe

Zimmerman, JPL 2001



Honeybee Robotics

Energy Source Approach – Thermal and Electric

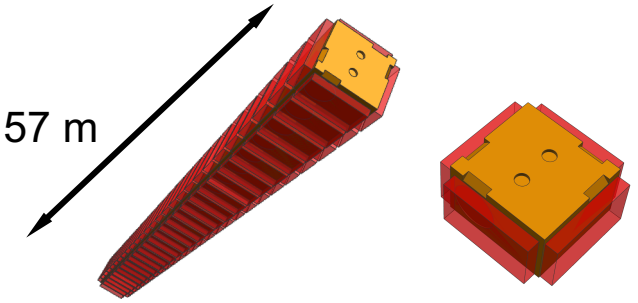


Rationale: 9 year mission life necessitated active power generation

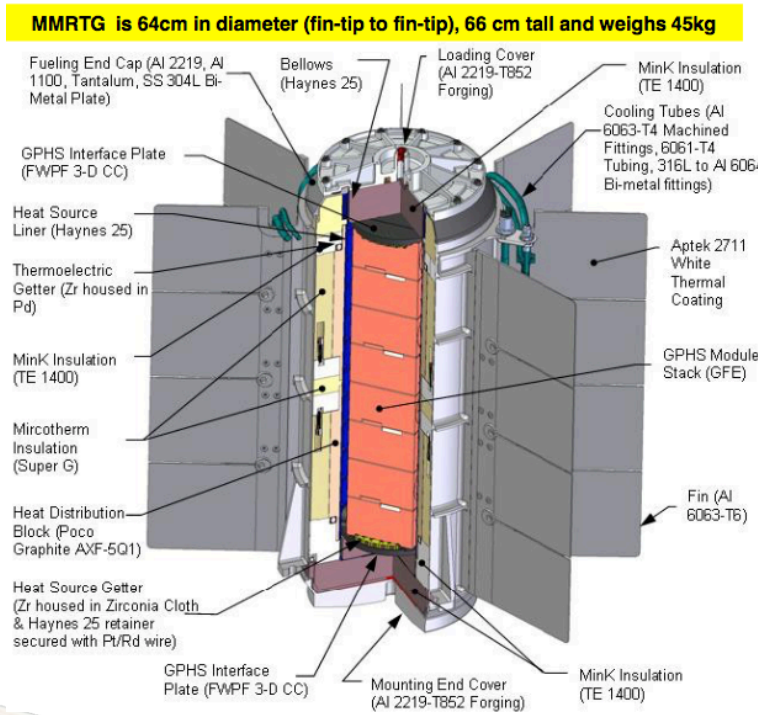
Rationale: Solar is deemed insufficient for zeroth order thermal energy needed to melt ice

General Purpose Heat Source (GPHS) Module

Rationale: Energy density and form factor would necessitate new PuO_2 pellets



27 GPHS Blocks
6.75kW thermal



Communications in Ice and to Earth

Orbiter Configuration

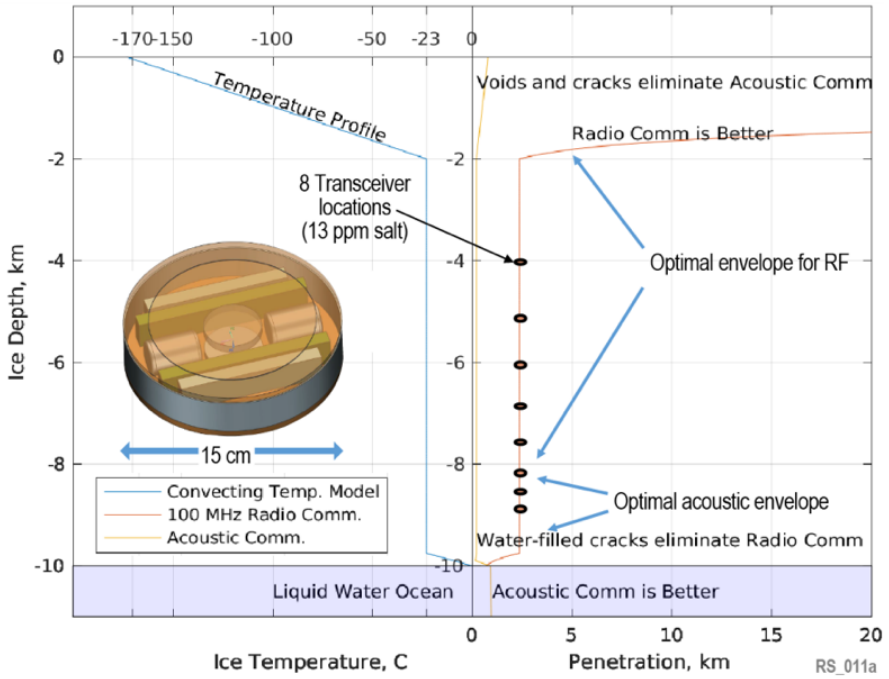
- 2 m antenna
- 100 W TWTA
- X-band

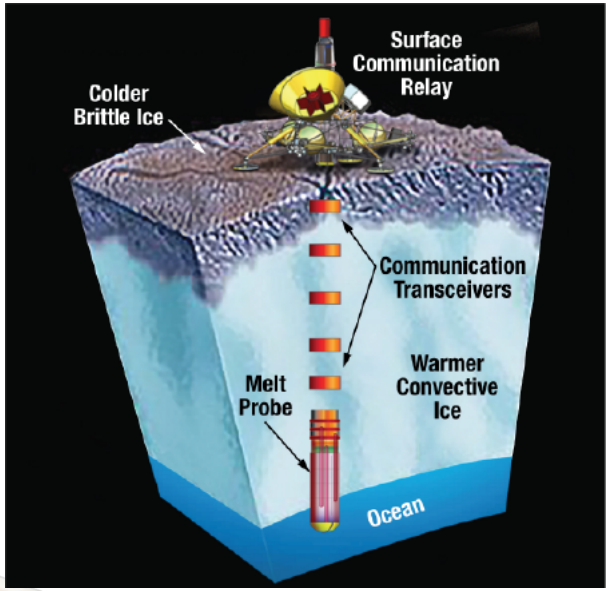
Lander Configuration

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

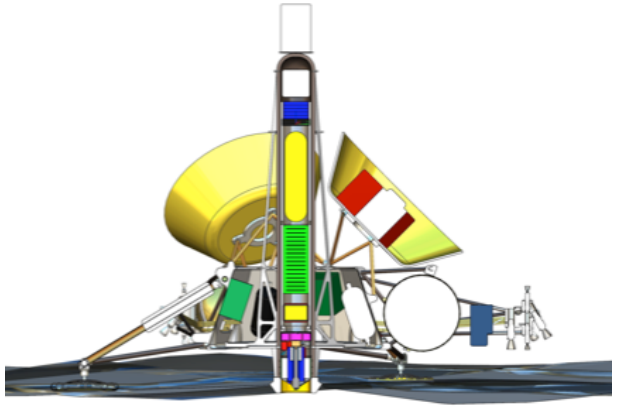
Probe Configuration

- 8 transceivers (6 + 2 additional)
- Turbo coding
- 100 MHz transmission



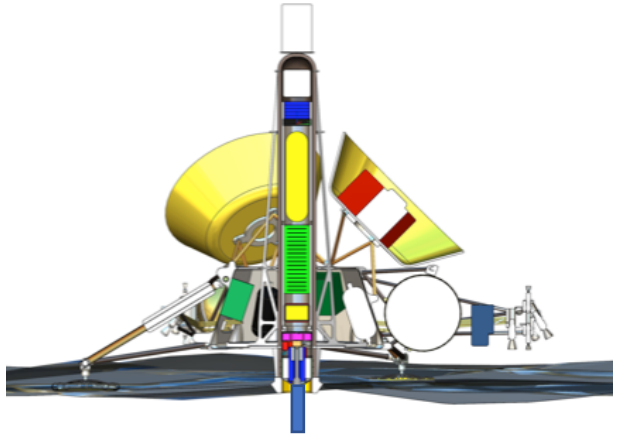


Surface Phase: Initial Access into Ice



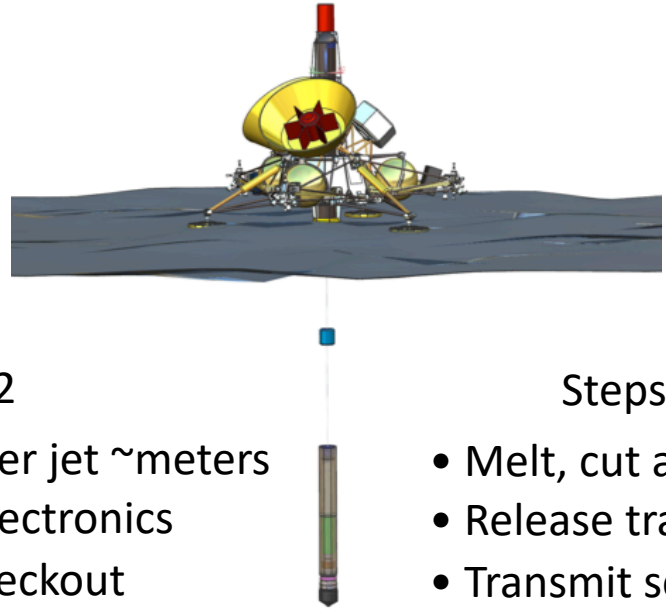
Step 0

- Lower and level
- Initial System checkout
- Install cap at surface



Step 1

- System checkout
- Initial melt, cut and water jet operations



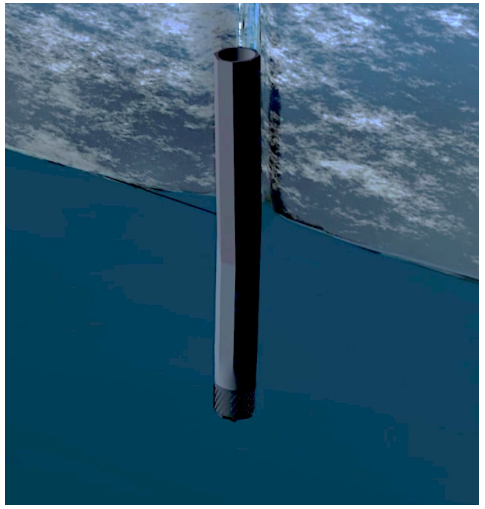
Step 2

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

Steps 3 to n

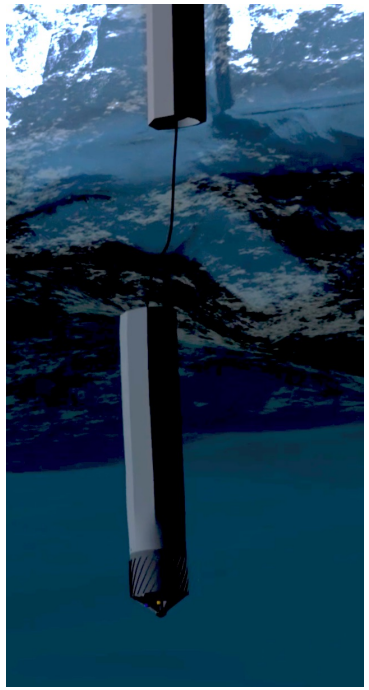
- Melt, cut and water jet
- Release transceivers
- Transmit science

Ocean Access and Mobility: Four Science Segments



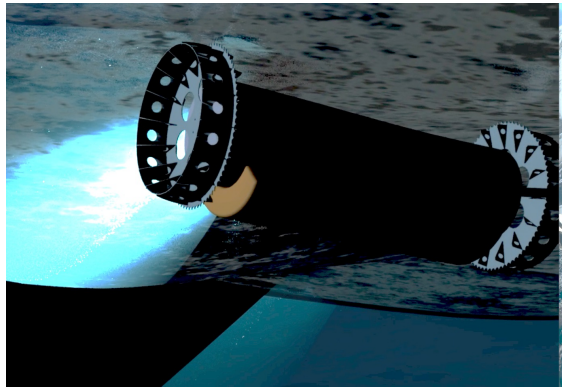
1 - Probe Nose In

Anchor
Image ocean
Sample water



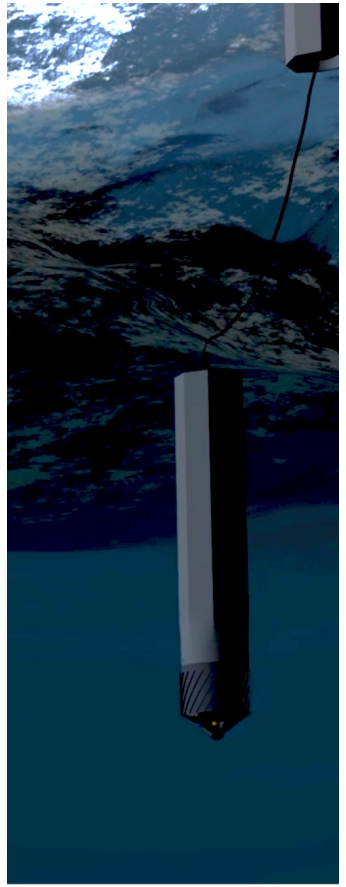
2 - Probe Fully Submersed

Deploy ocean probe
Tethered Ops



3 - Underwater Vehicle Ops

Buoyant operation
Science Ops
Mobility Ops



4 - Free Fall & End Of Mission

Cut Tether

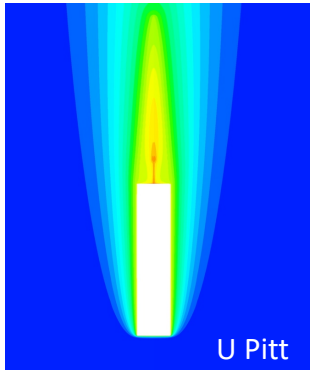
SESAME Cryobot Plans

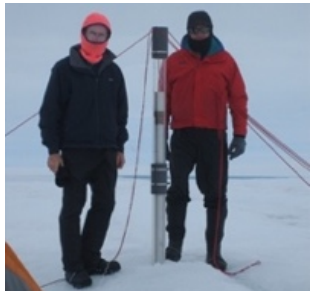
1. Develop state-of-the-art simulation of ice probe performance (JPL and several collaborators)

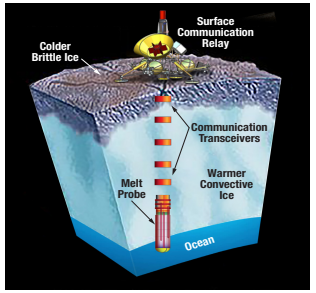
2. Design and demonstrate the Cryobot frontend, integrating three ice penetration modes (Honeybee)

3. Advance the frontier of Cryobot field deployments, using terrestrially-adapted ice probe technology (UW)

4. Integrate lessons from #1-3 into an architecture for a flight concept (all)







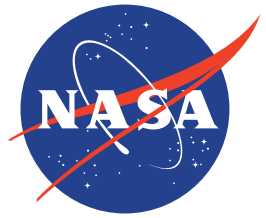
Later today

This Session:

A Notional Mission Architecture for Enabling Near-Term Scientific Ocean Access Missions on Icy Worlds, *Jean-Pierre Fleurial*

Poster Session this Afternoon:

The Cryobot Descent Simulator, *Miles W Smith*



JPL Caltech

Dare Mighty Things