Going to the Water

Challenges in Designing a Mission that Travels through Europa's Crust:
Deployment, Operations, Communication

Tom Cwik

Jet Propulsion Laboratory, California Institute of Technology.

KISS Study

October 9-12, 2017

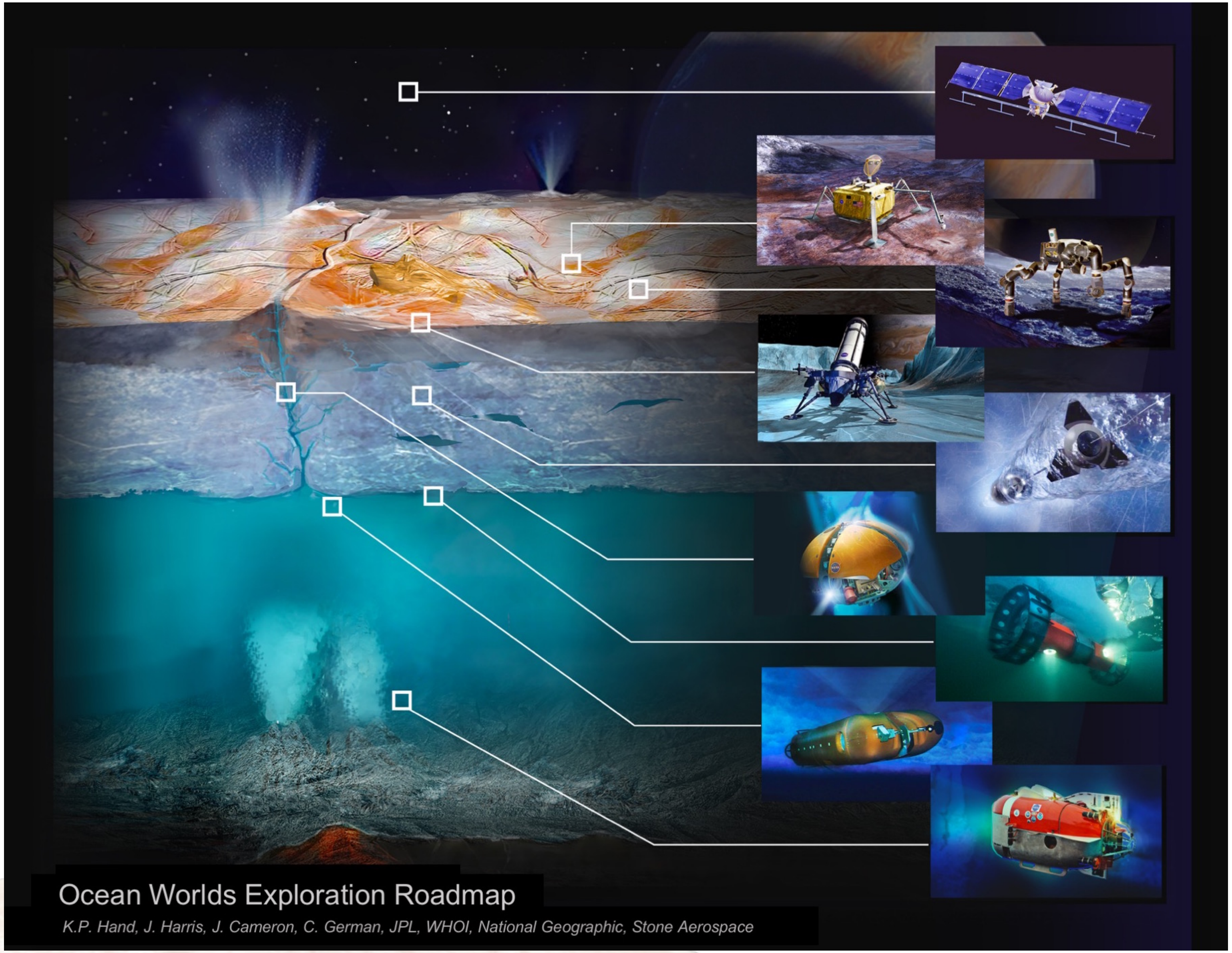
A Potential for Life

Energy Source

Biologically Essential Elements

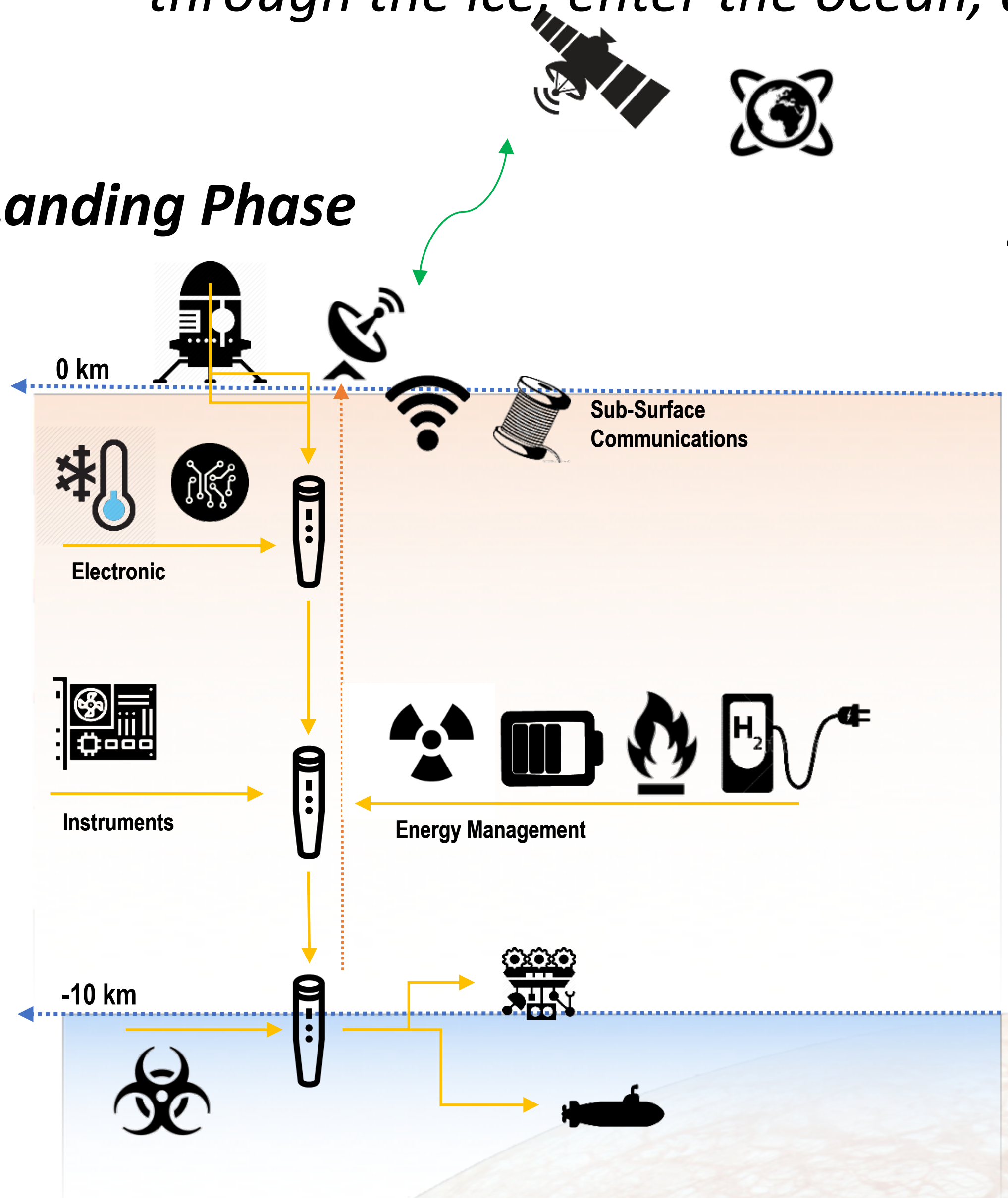
Liquid Water

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



Surface Phase

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

Ice Mobility Phase

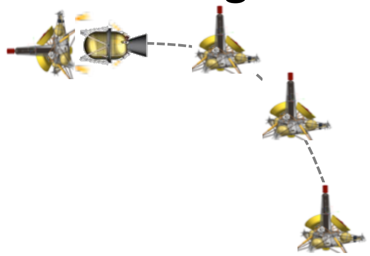
- Mobility to Ocean
- Communications to surface
- Science Instrumentation

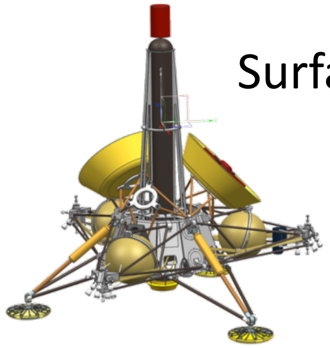
Ocean Access and Mobility Phase

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

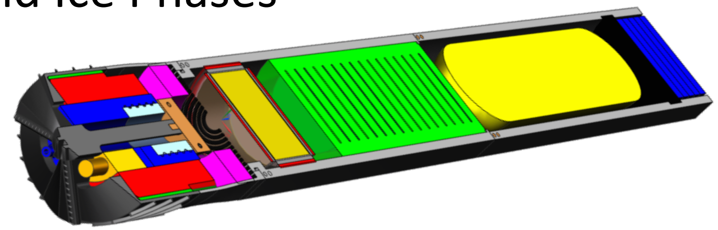
Europan Ice Probe Trade Space

Landing Phase

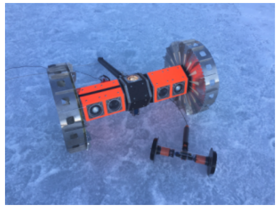




Surface and Ice Phases



Ocean Access Phase



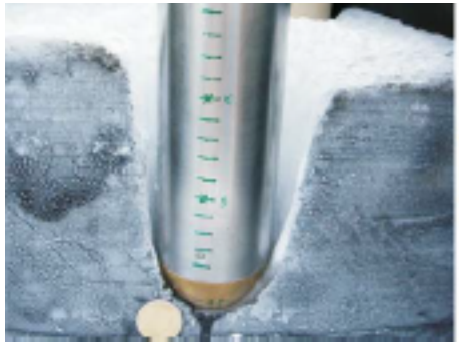
- **Deorbit, Descent and Landing**
  - Descent method
  - Landing Precision
  - Landing Method
- **Ice Descent Method**
  - Cutting
  - Water Jetting
  - Melting
- **Power System**
  - Method
  - Packaging
  - Energy Conversion
- **Thermal Control**
  - Passive
  - Active
- **Autonomous Navigation & 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

Zimmerman, JPL 2001

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



Kaufman et al

- <u>Water Jets</u> can be added to further melt ice and move melt water – electrical energy needed to drive pumps

Mechanical Cutting

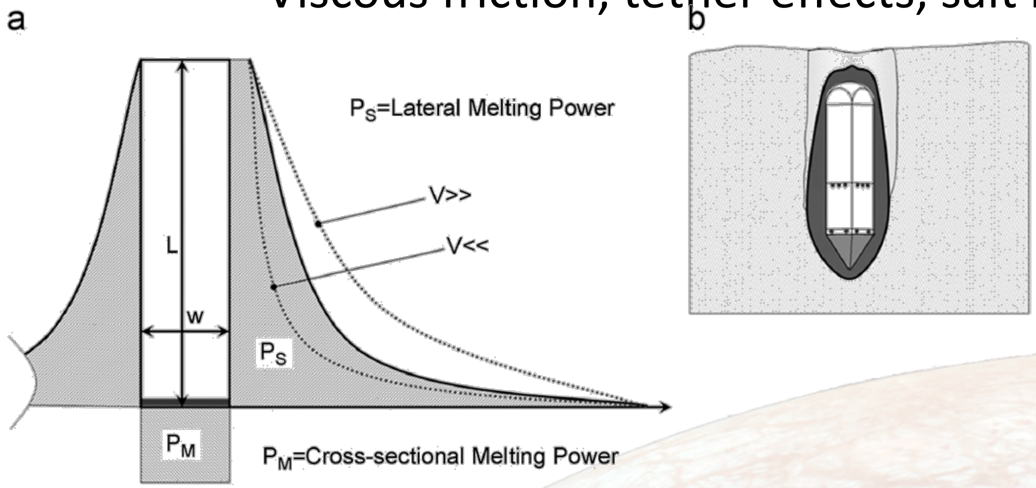
- Electrical energy drives blade to shave ice
- Chips need to be moved from front of probe

Honeybee, Inc

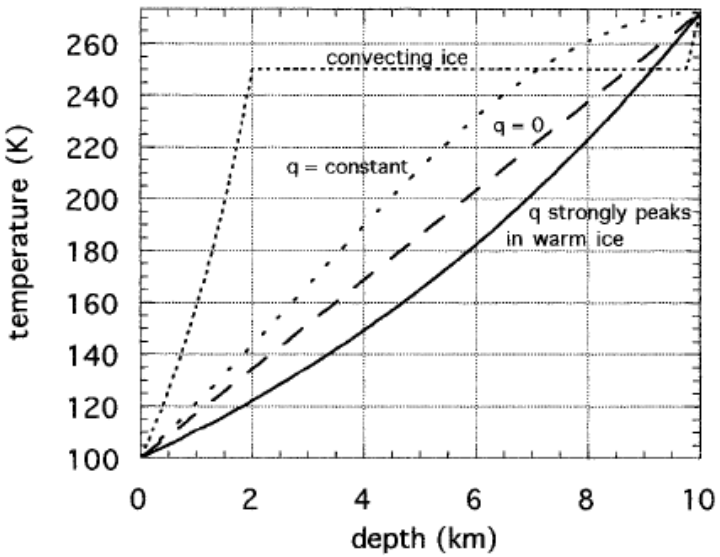
Ice Mobility – Melt Probe Power

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, …

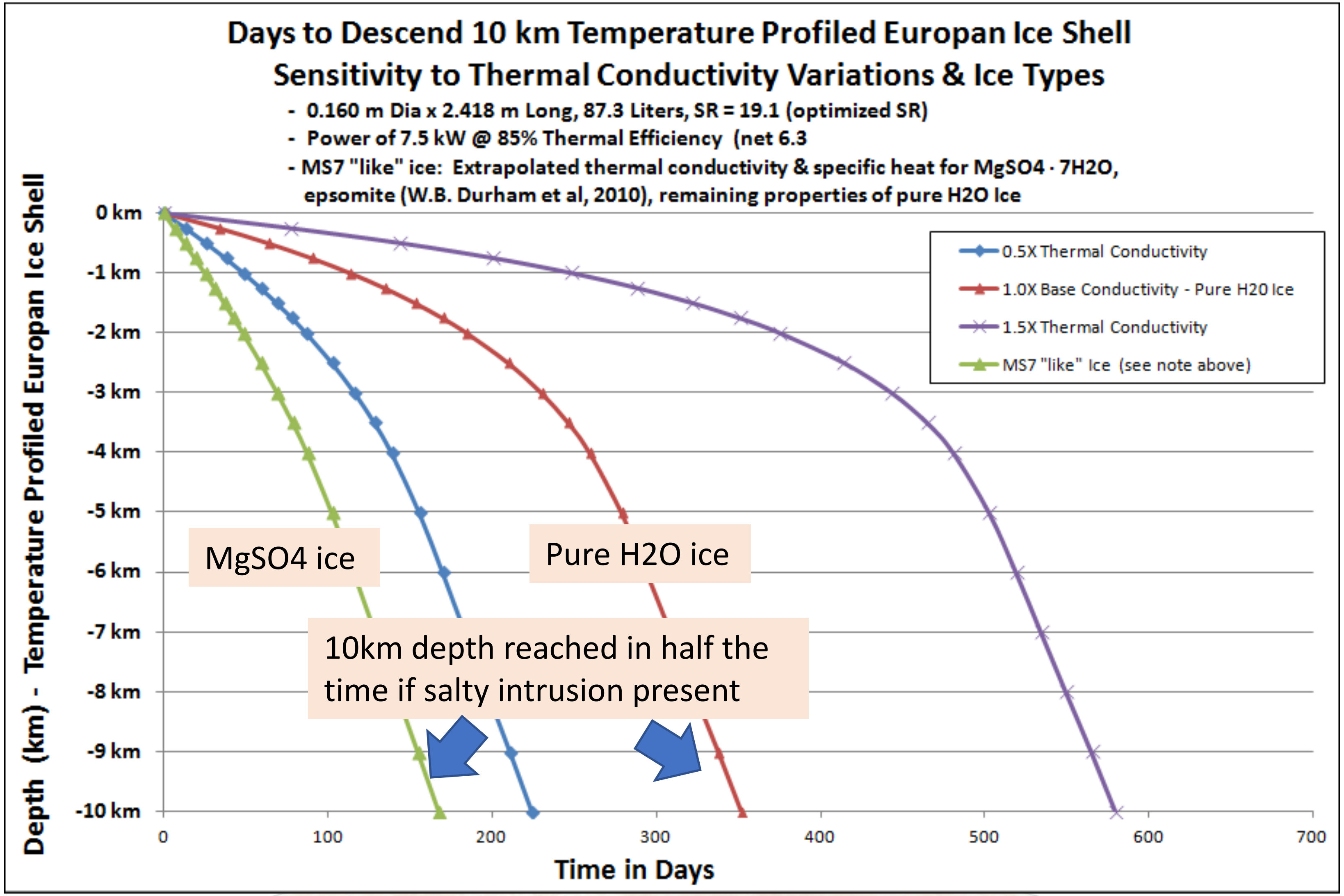


Weiss, Planetary and Space Science 56 (2008) 1280–1292



Chyba, ICARUS 134, 292–302 (1998)

Ice Mobility – Days for Melt Probe to Travel 10Km



Stone Aerospace

Ice Mobility – Water Jetting and Cutting

In addition to melting ice for mobility, need to

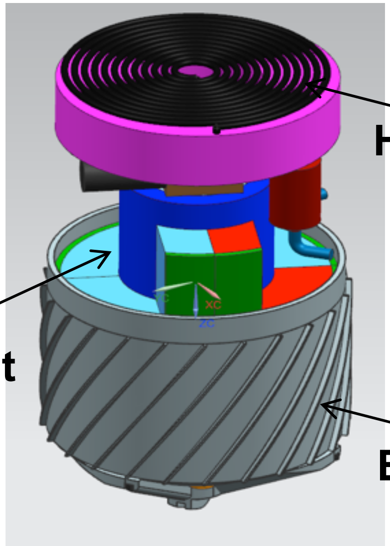
- Travel through potential sediment layers
- Force sediment and melt water past probe

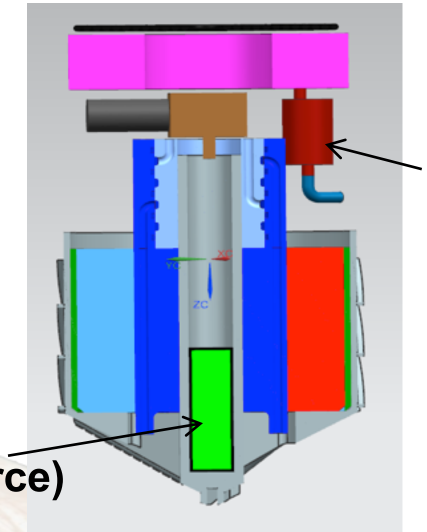
Include

- 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





Ice Mobility – Heat and Electric Source

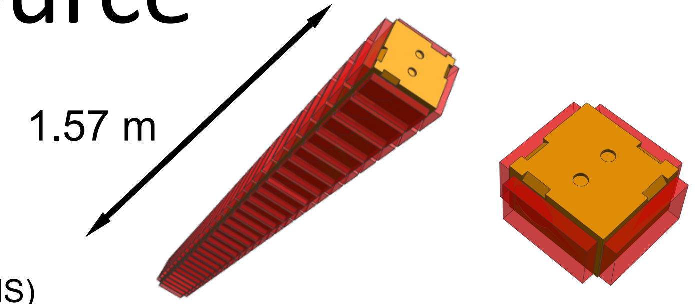
- Type
  - Nuclear
    - Reactor
    - ASRG (Stirling)
    - RTG (Thermo-Electric)
      - GPHS
      - Pellets or other (new)
  - Stored
    - Battery
    - Fuel Cell
    - Fly-wheel
  - Solar

Rationale: 9 year mission life necessitated active power generation

General Purpose Heat Source (GPHS) Module

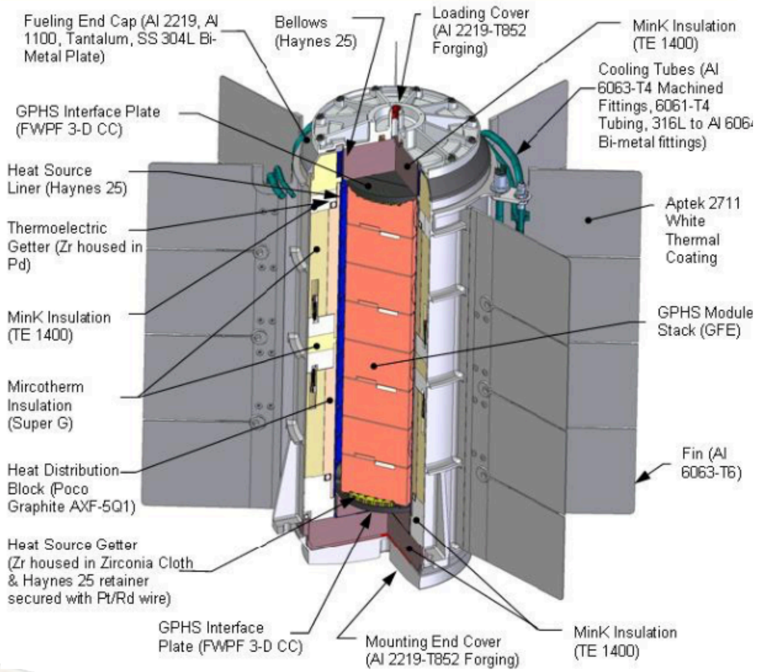
Rationale: Energy density and form factor would necessitate new PuO_2 pellets

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

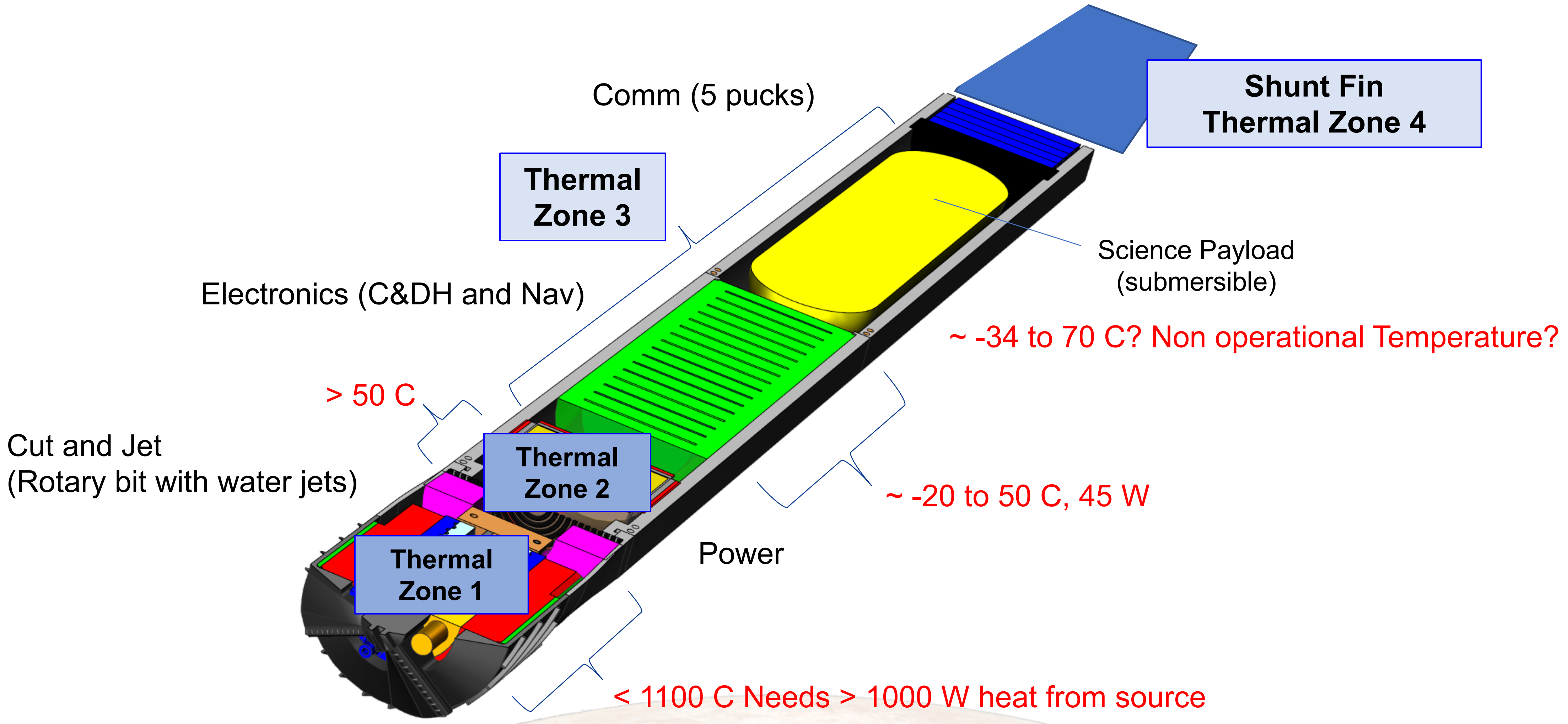


27 GPHS Blocks
6.75kW thermal

MMRTG is 64cm in diameter (fin-tip to fin-tip), 66 cm tall and weighs 45kg



Probe Thermal Configuration



Ice Mobility – Communications

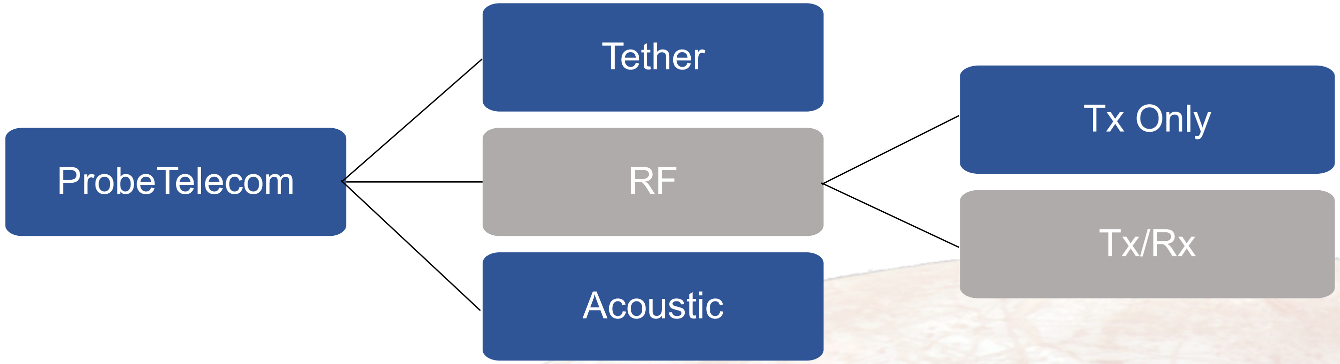
RF Communications in ice is feasible

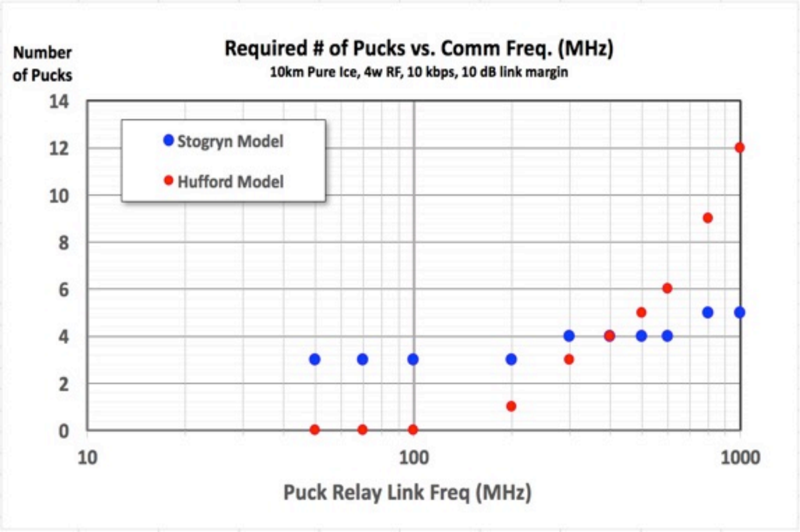
- Data rate depends on ice temperature dependent attenuation
- Released pucks can store and forward data
  - Requires stand-alone power

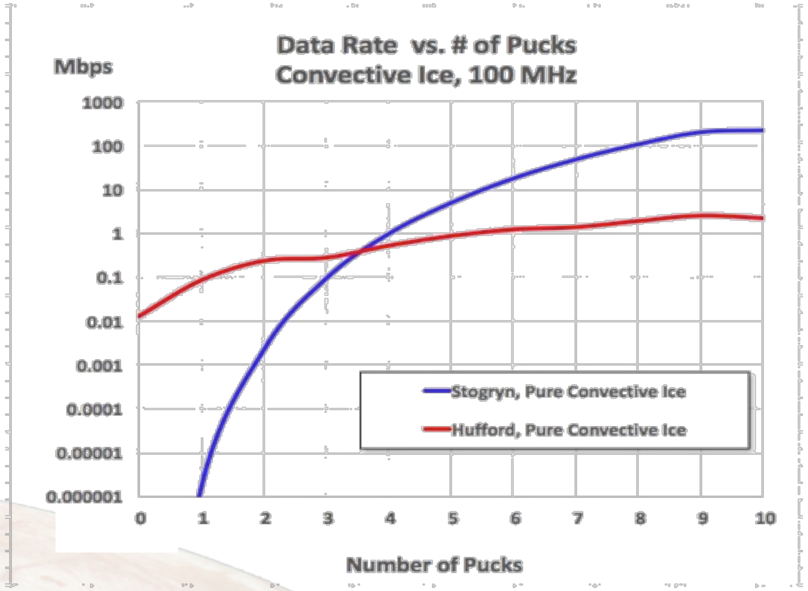
Tether allows max bandwidth

- Mechanical strength in Europan ice is unknown

Combine pucks and tether (and acoustic)?







Communications in Ice and to Earth

Orbiter Configuration

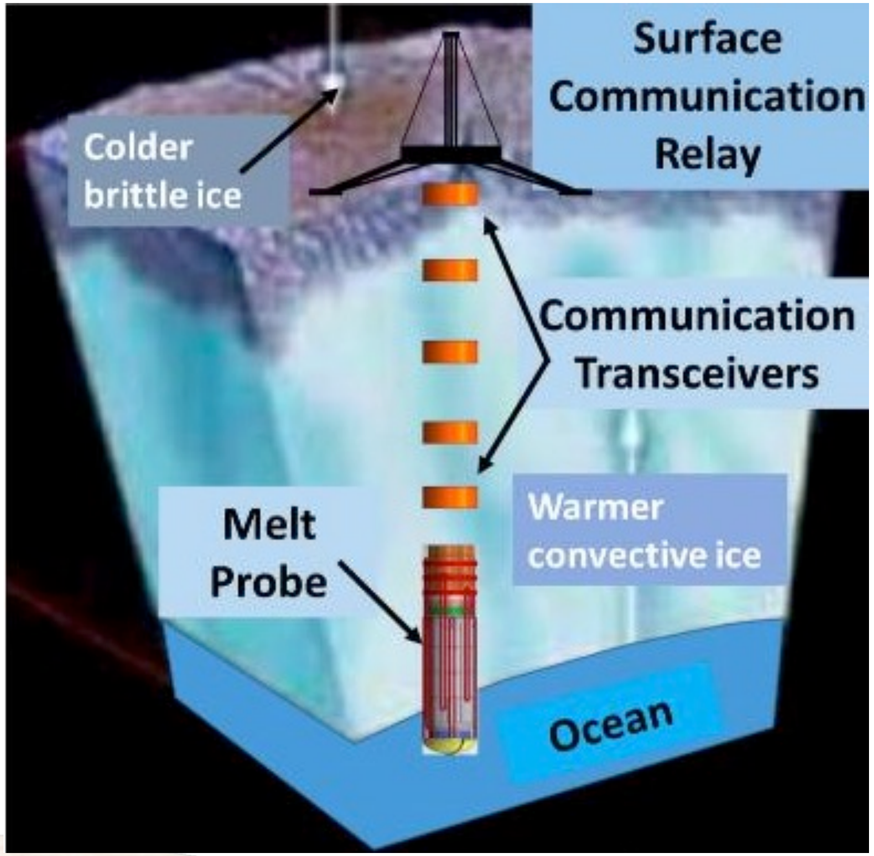
- 2 m antenna
- 100 W TWTA
- X-band

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

Ice Descent

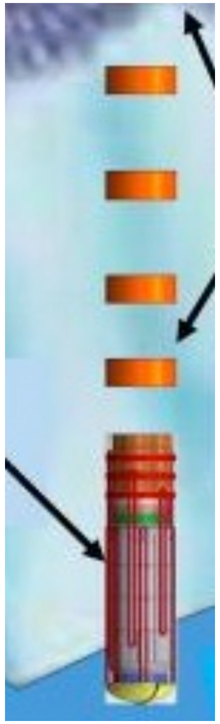
Melt
Water Jet and Cut
Unfurl Tether
Sense Position/Orientation
Tx Housekeeping Data

Puck Release

Release Puck
Anchor Puck
Transmit Checkout

Navigate

Radar / Sonar
Differential Heating
Differential Jetting



Surface Phase Functions

Probe start-up activity

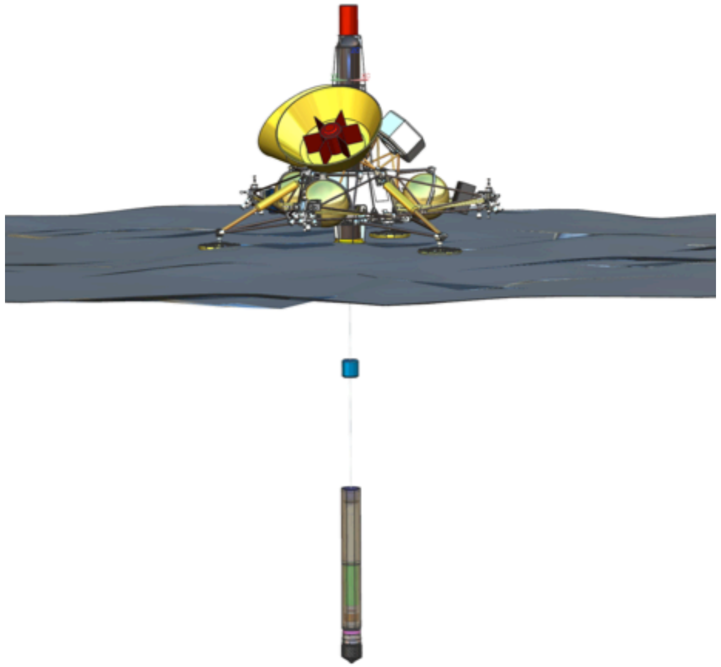
- Release Europan probe into ice
- Control initial sublimation at ice/salt surface

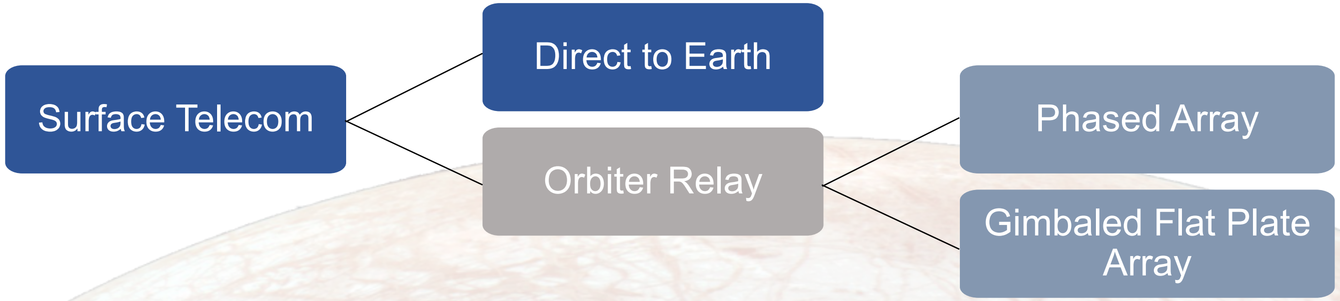
Survive radiation through mission life

- Use ice to protect electronics from radiation
- Melt electronics package into ice

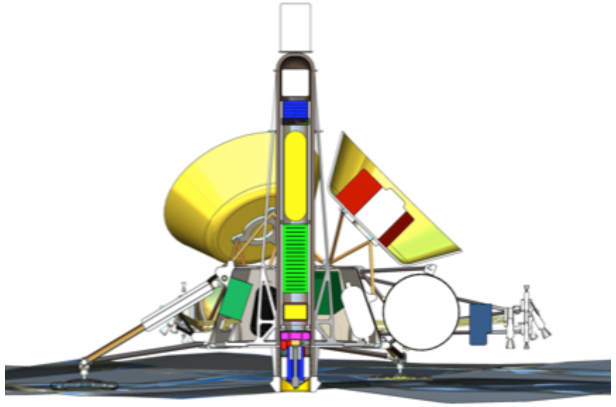
Communication

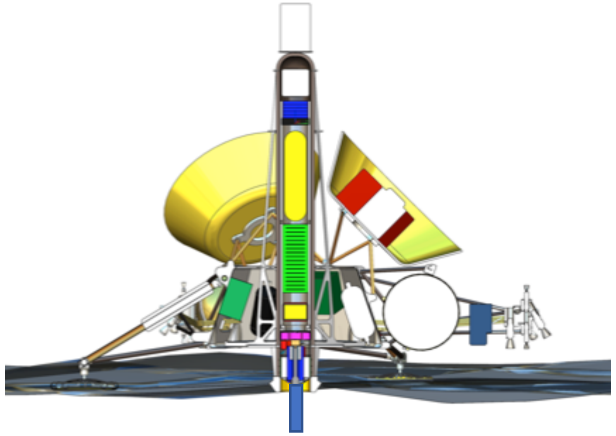
- Direct to Earth or through Orbiter
- To and from Europan ice probe

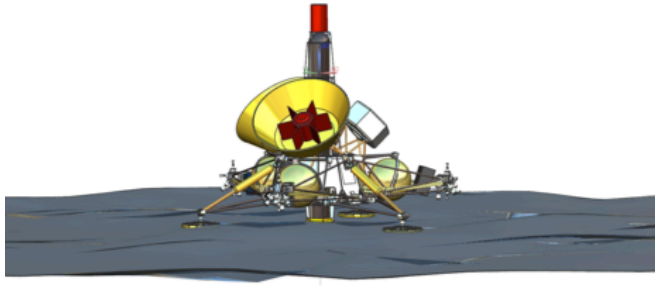




Surface Phase: Initial Access into Ice







SOL 0

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

SOL 1

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

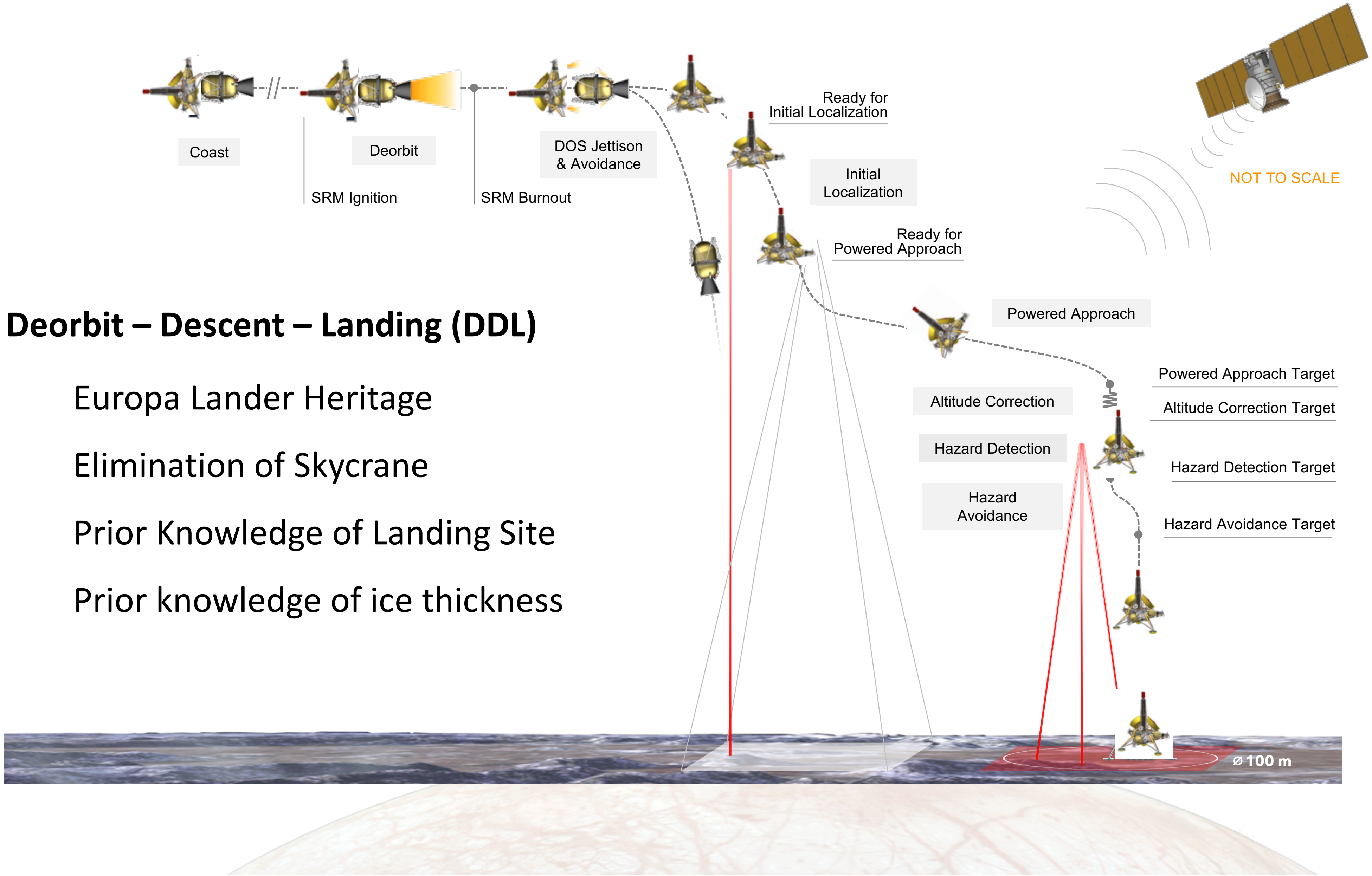
SOL 2

- 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)

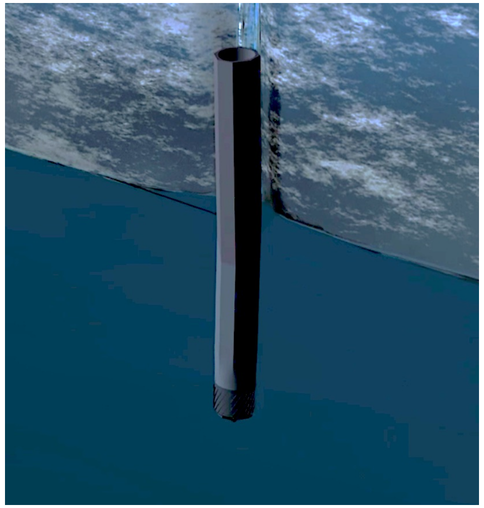
Europa Lander Heritage

Elimination of Skycrane

Prior Knowledge of Landing Site

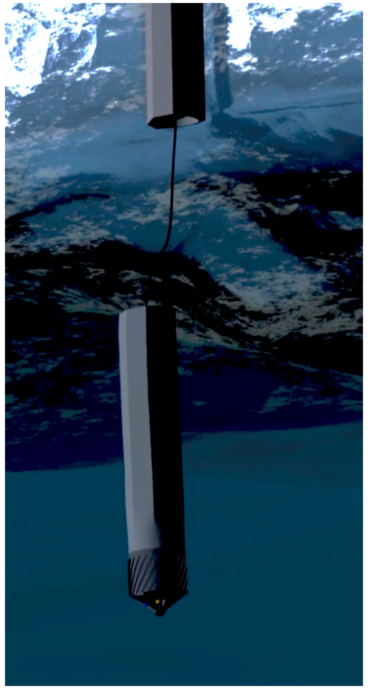
Prior knowledge of ice thickness

Ocean Access and Mobility: Four Science Segments



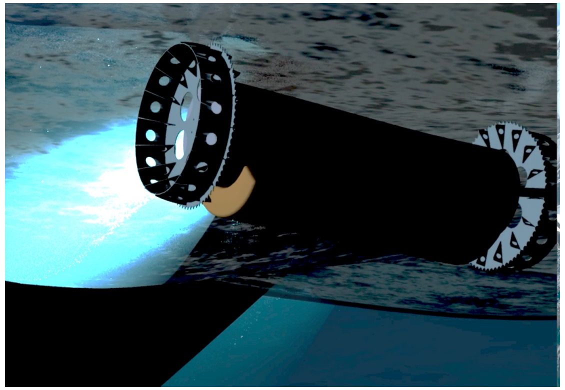
1 - Probe Nose In

Anchor
Image ocean
Sample water



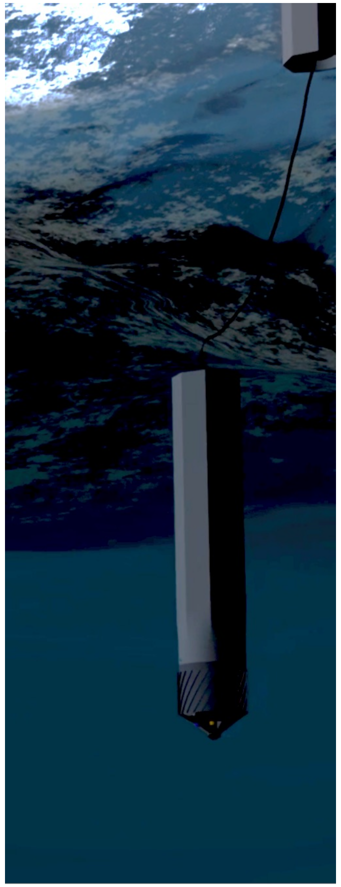
2 - Probe Fully Submersed

Deploy ocean probe
Tethered Ops



3 - Underwater Vehicle Ops

Buoyant operation
Science Ops
Mobility Ops



4 - Free Fall & End Of Mission

Cut Tether

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)

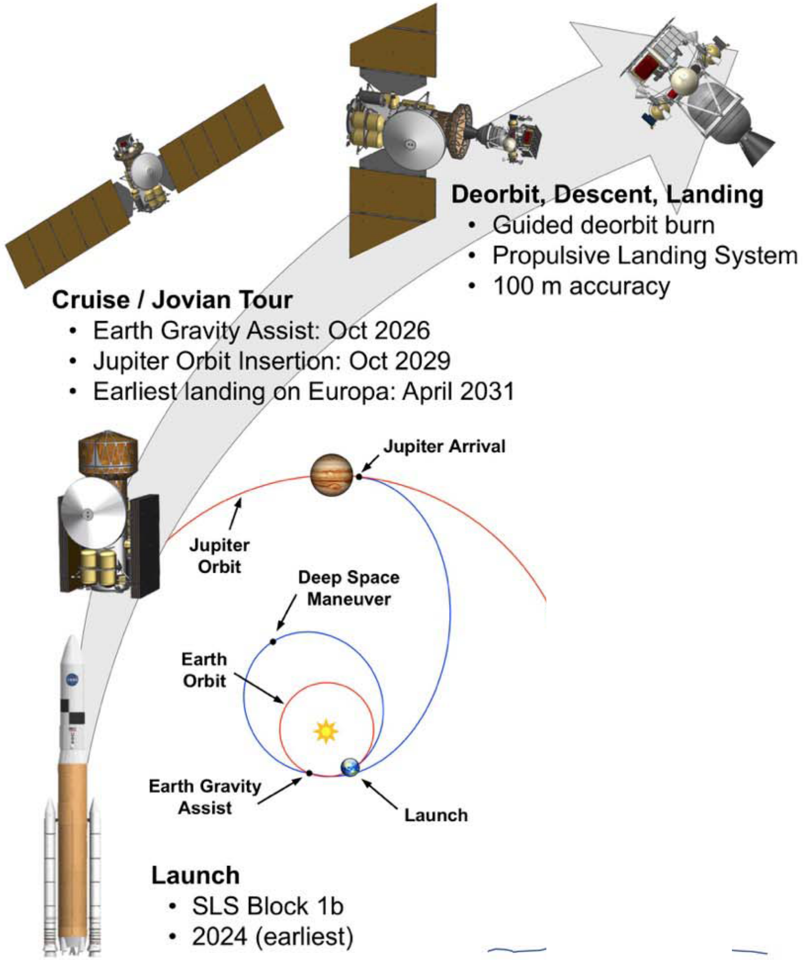
Begin with known power sources (radioisotope)

- What advances can we make?

Baseline 10Km ice thickness

- Baseline Ice temperature profile, salt content

Set approximately two-year time for ice travel



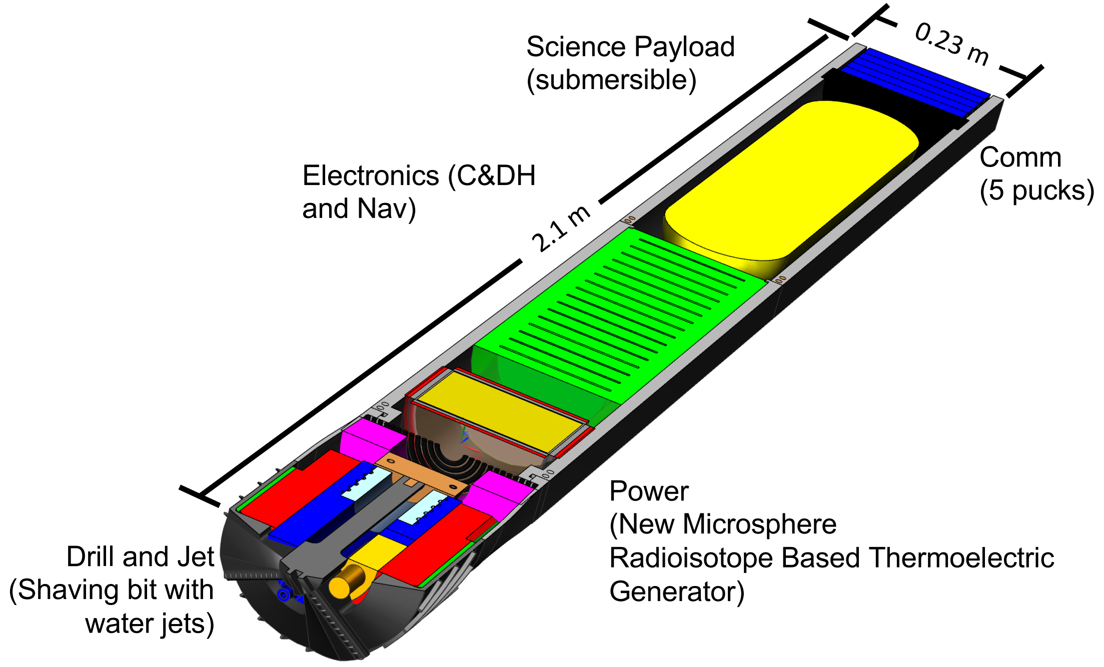
Europa Lander Mission Design

Conceptual Design

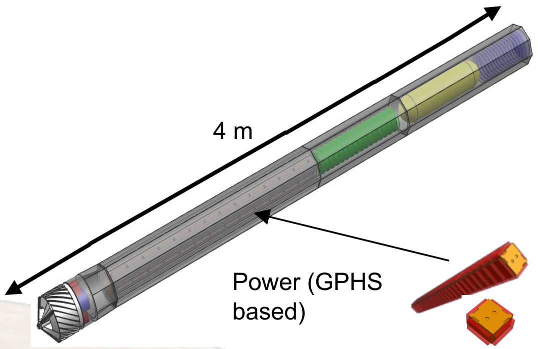
7 KW_{th} Main + 1 KW_{th} Nose Power Sources

Ice Probe	CBE Mass (Kg)	CBE Power (W_e)
Total Probe	**210.8**	**597.6**
Navigation	4.59	11.4
C&DH	1.50	10.0
Power	33.26	4.0
Telecommunication	5.55	30.0
Drilling / Water Jet	16.00	400.0
Submarine payload	26.70	27.2
Structure	112.00	5.0
Thermal	11.20	110.0
Margin (%)*	**41**	**29**

**Mass margin calculated against 335 Kg landed mass allocation for Europa Lander Class DDL*
**Power margin based on 836 W EOL (9 years)*



With newly developed pellet thermal source



With existing GPHS thermal source

Looking ahead: What we will know and have shown

Ice shell structure by RADAR

- Resolution of +/-10m @3km depth and +/-100m @30km depth

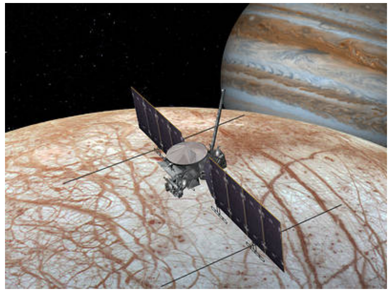
Detailed topographic surface map

- 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



Europa Clipper

Powered landing to 100m accuracy

- Terrain relative navigation
- Hazard detection LIDAR

High resolution descent/surface imaging

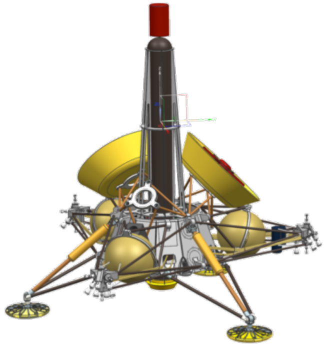
Surface operations

- Cutting and handling of ice and salts at temperature

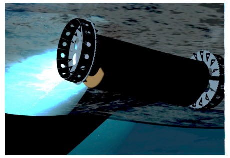
Organic/inorganic quantification at surface

Seismometer sensing of crustal motion

Europa Lander Concept



Europa Ocean Exploration



A Potential for Life

Energy Source

Biologically Essential Elements

Liquid Water