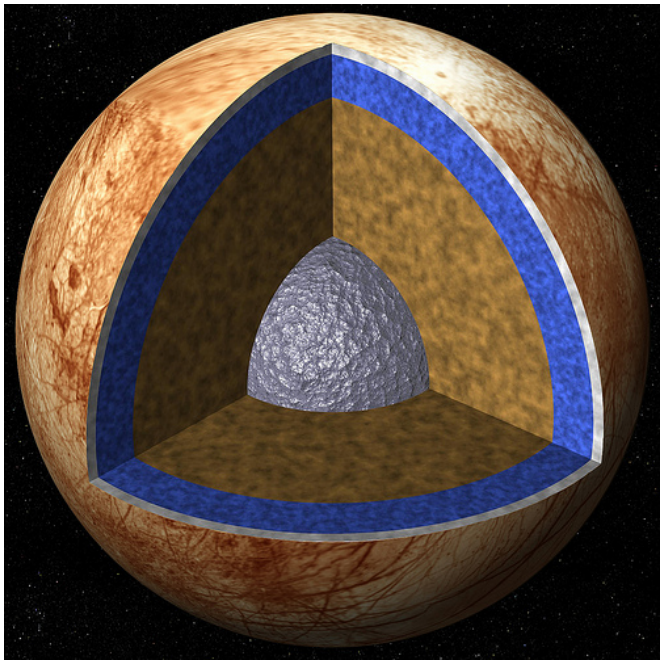
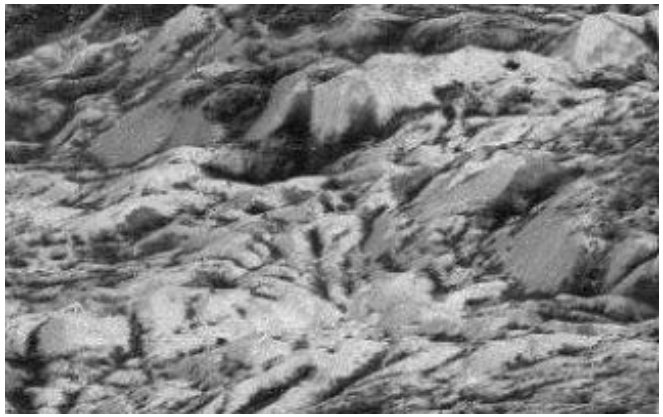
Deep Ice Probes

- Hot-water injection and melt probes have been used to explore ice for over 50 years.
- JPL has been researching approaches that scale to Ocean Worlds in terms of mass, power, comm, planetary protection, for over 15 years (JPL probe is the one pictured in the Wikipedia article on Cryobots).

Challenges for Ocean Worlds

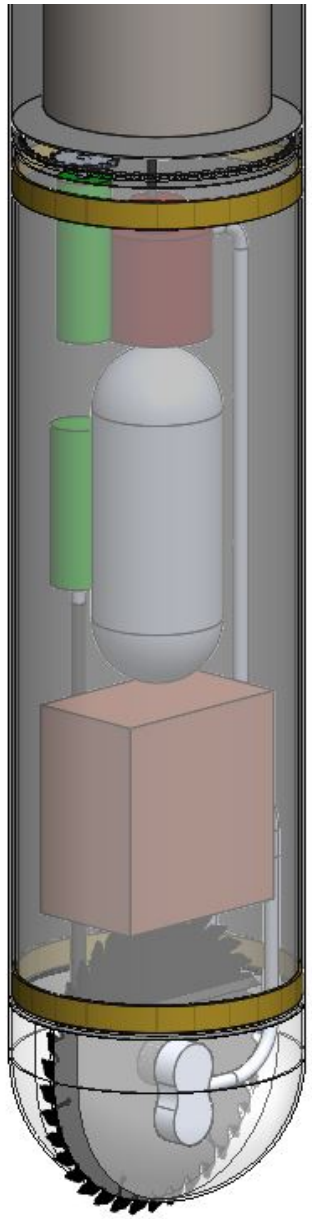
- 100 Kelvin ice at surface (-173°C) warming to 0°C at ocean boundary many kilometers deep.
- ~100 kg/100 Watt mass/power budgets.
- Planetary protection to avoid killing extant life with Earth organisms.
- Possible sediment particles or layers in ice - salts, sulfur, etc.
- Heat conduction away from melt probes is a major challenge.
- Sediment buildup in front of melt probes is a major challenge.
- Where to analyze samples - down the hole or at the surface?





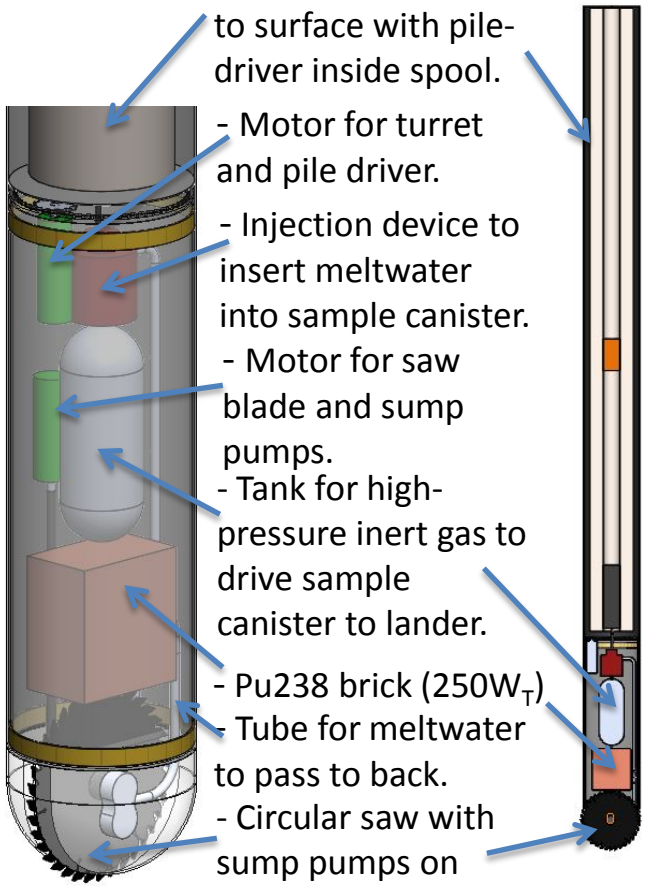
Scaling to Ocean Worlds Exploration

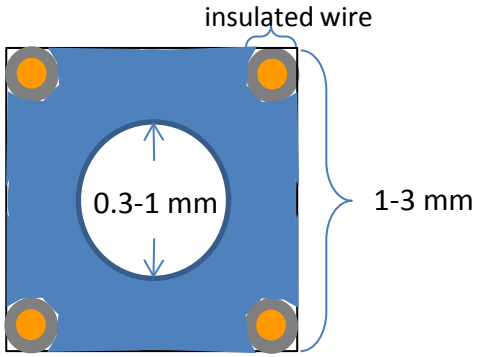
- To solve the problem of loss of heat through conduction, put the heat source in a vacuum bottle
  - so the outside of the probe stays cold and no heat is conducted away through the ice.
- A circular saw blade sticks through a slit in a turret dome in the vacuum bottle, throwing ice chips (including cuttings from sediment) inside where the Pu238 heat source can melt them, they can be sampled, and then pumped out the back to re-freeze.
- The only ice that is heated is that directly in front of the probe.



Deep Subsurface Ice Probe capable of multi-km penetration of Europa Ice

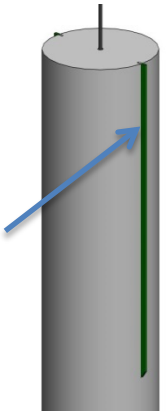
- **Deep Subsurface Ice Probe has Pu238 block (250 Watts) which melts ice chips cut by circular saw protruding through turret slit in "vacuum bottle" housing.**
- **Kilometers of custom-extruded aluminum tube with embedded high-temperature wires operate 3 motors in probe: saw blade, turret-swivel/pile-driver, and sample transfer into pneumatic canisters exchanged with lander via tube.**
- **Entire assembly can be heat sterilized at ~500C indefinitely (e.g. during cruise), using Pu238 as heat source.**





Detail of custom-extruded square OD tubing with embedded electrical conductors for controlling the 3 motors without electronics in probe (e.g. for heat sterilization).

Spring-loaded "fins" keep body from spinning when saw turret is rotated



Cutting Ice in Cryo-Vac Conditions