



Prioritized Technology: Ice Penetration

Technical Goal

System-level ice penetration and sampling capability to penetrate a water body on Europa. Within 2 years, reach:

- Depths of 15 km to reach the ocean
- Depth of 4 km to reach a lake of melted accreted ice
- Must operate on existing power technologies (e.g. 5 MMRTGs)
- Mobility system must be less than 200 kg, excl. MMRTGs
- Must start up in a vacuum at the surface
- Must penetrate “dirty” ice, for example:
 - Salt/Sediment/Sulfur layers, Sulfuric acids, Embedded gases
 - Must be able to get unstuck or avoid getting stuck
- Must make forward progress
- Must restart after unexpected, extended (>2 days) stop
- Must retain command authority for the life of the mission, including after entry into liquid (ocean or lake)
- Surface systems, if any, must survive radiation environment (reference environment info)
- Tethers, if used, must be resilient; the amount of instantaneous shear displacement caused by faults unknown.

Environment/Mission

- Targeted launch in 2032 (TRL6 by 2026)
- MMRTG decay starts 2 years before launch, 5 year transit, 2 years to explore ice
- Target: Entire system powered by 40 GPHS bricks configured as up to 5 MMRTGs (for each: 45 kg, ~1750 Wth and ~90 We @ EOM) or 40 GPHS bricks (for each: 1.44 kg, 250 Wth BOL)
- Target: Entire landed mass 1000 kg dry, including:
 - Up to 5 MMRTGs
 - 445 kg for surface comm, deployment, descent/lander
- Probability of forward-contamination of the ocean must be less than 10^{-4} .
 - 110 C sterilization as needed to prevent forward-contamination.
- Ice thickness estimates range from 5 to 30+ km, ~90 K, vacuum at the surface and ~270 K, 20 MPa at the ice/ocean boundary.
- Ice properties range from a brittle ice layer at the surface to a ductile layer. Ice includes hydrated salts, porosity, entrained lakes (sills), possible voids
- Ice shell thickness is estimated as up to 30 km thick, may include outer brittle layer and inner ductile layer
- Surface fractures ~100 m deep; 3.5 day diurnal cycle
- Fractures expected throughout at least the top several hundred meters, during each diurnal cycle

Mission Goals

- Discovery of evidence of life can be sought in the liquid water ocean, or sub-surface environment.
- Depths > 10 m enables sampling of pristine material, e.g. almost entirely unaffected by the radiation environment of Europa.
- Enables sampling/analysis concentrated biomarkers from past lakes (sills)
- Enables sampling/analysis of liquid water from oceans covered by the shallowest ice thickness, or in ice that has been in contact with the liquid oceans in the relatively recent past