

Science of the Europa Lander Mission Concept. K. P. Hand¹, C. B. Phillips¹, A. Murray², J. Garvin³, E. Maize¹, G. Reeves¹, G. Tan-Wang¹, A. San Martin¹, R. Crum¹, B. Kennedy¹, and the Europa Lander Science Definition Team, the Project Science Team, and the Project Engineering Team. ¹Jet Propulsion Laboratory, Caltech, ²University of Nevada, Reno & the Desert Research Institute, ³Goddard Space Flight Center.

Introduction: Jupiter's moon Europa is a prime target in our exploration of potentially habitable worlds beyond Earth, and of oceans that likely exist beneath the icy shells of numerous worlds in the outer solar system. **Europa may hold the clues to one of NASA's long-standing goals – to search for life elsewhere and determine whether or not we are alone in the universe [1].**

The exploration of Europa presents an important target for both astrobiology and comparative oceanography, i.e., the opportunity to study liquid water oceans as a planetary process. Europa's icy shell also offers the opportunity to study tectonics and geologic cycles across a range of mechanisms (e.g., Earth's cooling versus Europa's tidal dissipation) and compositions (silicate in the case of the Earth, versus ice in the case of Europa). **Europa is a scientifically important and strategic target for both planetary science and astrobiology.**

Critically, Europa's subsurface ocean has likely existed for much of the history of the solar system, potentially **providing a persistent, stable environment in which a second, independent origin of life may have arisen.** Observations and models indicate that the ocean is likely in contact with a rocky, silicate seafloor, and the ice shell may have tectonic activity that could allow reductant-oxidant cycling. This scenario could lead to an ocean rich in the elements and energy needed for the emergence of life, and for potentially sustaining life through time. The persistence of Europa's ocean means that life could be alive there today – i.e., signs of extant life could be found within the ice and ocean of Europa. **The discovery of signs of extant life is critical if we are to understand biology as a universal process:** Does it contain DNA or does it function on some other large biomolecules for information storage, replication, and repair? Are there many separate 'trees of life' within our solar system, or is the tree of life on Earth the only one? The search for past life on worlds like Mars is very important, but the search for extant life is how we will truly revolutionize biology (if life exists beyond Earth).

Lander concepts for Europa have been studied for over two decades (JPL concept studies go back to 1997). In 2016 NASA convened a Science Definition Team (SDT) to develop the science, and mission concept, for a landed spacecraft that would achieve civilization-scale biosignature science, while also

answering questions about the surface and subsurface environment. **Figure 1** shows the mechanical configuration of the lander during surface operations.

The high-level science goals of the Europa Lander Mission Concept are:

1. **Search for evidence of biosignatures on Europa.**
2. **Assess the habitability of Europa via in situ techniques uniquely available to a lander mission.**
3. **Characterize surface and subsurface properties at the scale of the lander to support future exploration.**

These goals are achieved by employing a lander on the surface that collects and processes a minimum of three separate samples, each of at least seven cubic centimeter in volume, and acquired from a depth of at least 10 cm.

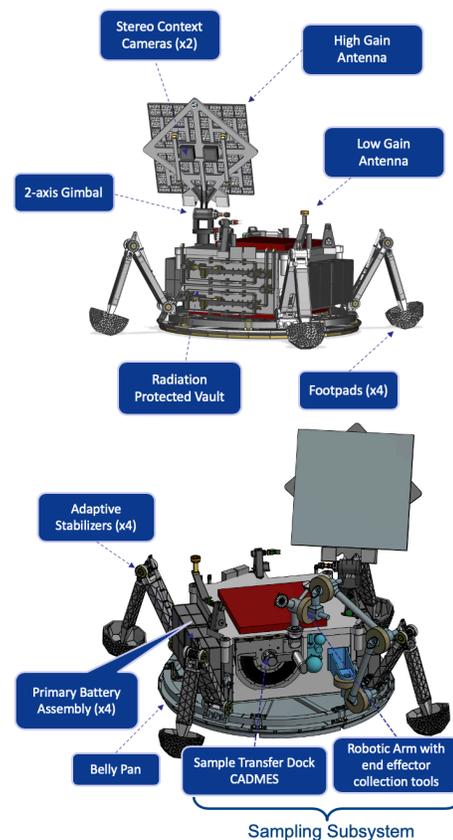


Figure 2. The Europa Lander concept (shown here in surface operations configuration) is mature and ready to move into Phase A.

Overview of Mission Concept: Here we detail the science of the Europa Lander Mission Concept, but first we provide an overview of significant milestones and developments that may be of interest.

1. **The mission concept passed its delta Mission Concept Review (dMCR) in November of 2018.** The original Mission Concept Review (MCR) was held in June of 2017, and key feedback from the MCR board, and NASA HQ, was to reduce the mission cost by removing the carrier relay stage and instead use a Direct-to-Earth (DTE) communications link from the surface of Europa. The dMCR DTE concept was costed at \$2.8B, in real-year dollars, for phases A-D. This was an Independent Cost Estimate, the details of which can be shared with the committee upon request. **This mission is ready to move into Phase A.**

2. **The dMCR mission concept achieves high value science without requiring an excessive number of engineering ‘miracles’;** this mission aims to be the right ‘first’ mission to the surface of Europa and balances technical risk with science return and cost. Over the past decade, JPL and APL have examined a range of mission architectures – from minimal science ballistic probes and impactors, to highly capable melt probes. Ballistic probes initially appear ‘simple’ but detailed analyses reveal significant complexity for comparatively low science return. Melt probes and deep drills, meanwhile, achieve high-value science but require too many ‘miracles’, leading to high technical and cost risk. In addition, we have also examined options for lander missions that might fit into a Discovery or New Frontiers budget, but no viable options emerged.

3. **The technology and instrumentation investments made to date (which exceed \$300M) could enable a new era of planetary exploration.** Many of the technologies that have, or are, being developed for the Europa Lander Mission Concept can be utilized for landing on the unknown surfaces of many ocean worlds, and airless bodies in our solar system.

4. The Europa Lander builds on the investment in Europa Clipper, using data from that mission for landing site selection. There would be at least five years of time between the end of Clipper’s prime mission and the landing site selection date. Importantly, data from Clipper would be unlikely to dramatically change our approach to de-orbit, descent, and landing (DDL). **The mission concept team examined a variety of mechanical configurations and concluded that even after the acquisition of the Clipper data, the DDL and mechanical architectures would not significantly change.** Uncertainty about parameters such as porosity and

structure at the sub-meter scale would still require the intelligent landing system, with terrain relative navigation and hazard avoidance. Furthermore, the lander would still need to employ the ‘snowshoe belly pan’ and ‘grasshopper’ adaptive stabilizer legs to accommodate soft and variable surfaces at the sub-meter scale.

5. The Lander concept uses primary batteries and could survive for many weeks to >60 days on the surface, depending on sampling and idle power usage assumptions. The choice of primary batteries was, in part, to save on cost and complexity. A longer-lived mission concept with a radioisotope power system was studied, but planetary protection, thermal management, and mass were found to contribute to increasing cost and technical risk. **The MCR and dMCR boards both determined that the surface lifetime from primary batteries was acceptable and helped limit planetary protection and cost risks.**

6. In 2019, NASA selected 14 teams for development of instrumentation relevant to the Europa Lander model payload. **The NASA ROSES “Instrument Concepts for Europa Exploration 2” (ICEE-2) program has helped advance many of the types of instruments needed for the in situ exploration of Europa and other ocean worlds.** The ColdTech, SESAME, PICASSO, and MatISSE programs have also funded numerous technology and instrument developments to build a strong foundation for ocean worlds science investigations.

7. Below are links to several online resources related to this mission concept:

- A full description of the science, including a full traceability matrix and traceability to past Decadal Surveys, can be found in the Science Definition Team report: <https://europa.nasa.gov/resources/58/europa-lander-study-2016-report/>
- A video of the mission concept, which is based on a detailed trajectory, avionics, and mechanical framework, can be found here: <https://www.youtube.com/watch?v=pxin9qJVw48>
- A recording of our 2-hour virtual workshop, in which the mission concept, model payload, and sampling strategies were presented in detail, can be found here: <https://www.europa-insitu.caltech.edu/>

References:[1] NASA (2020)

<https://science.nasa.gov/about-us/science-strategy>.