SCIENCE GOALS AND MISSION ARCHITECTURE OF THE EUROPA LANDER MISSION CONCEPT.

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1 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]. Critically, Europa's subsurface ocean has likely persisted for much of the history of the solar system [2, 3], potentially providing a stable environment in which a second, independent origin of life may have arisen [4, 5]. The discovery of signs of extant life is critical if we are to understand biology as a universal process [6]. In addition, Europa presents an important target for comparative oceanography, *i.e.*, the opportunity to study liquid water oceans as a widespread planetary process [7, 8].

In 2016 NASA convened a Science Definition Team (SDT) to develop the science, and mission concept, for a landed spacecraft that could achieve civilization-scale biosignature science, while also answering questions about the surface and subsurface environment [9, 10]. The high-level science goals of the Europa Lander Mission Concept (ELMC) are to:

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, and their associated objectives, investigations, and measurements [9], are achieved by employing a lander on the surface of Europa that collects and processes a minimum of three separate samples, each of at least seven cubic centimeters in volume, and acquired from a depth of at least 10 cm. Instruments in the model payload include an organic compositional analyzer (e.g., a gas chromatograph-mass spectrometer), a high resolution microscope (e.g., an atomic force microscope), a vibrational spectrometer (e.g., a raman spectrometer), a context remote sensing imager (e.g., Mastcam-Z), and a geophysical sounding system for detecting Europa 'quakes' and other acoustic signals in the ice.

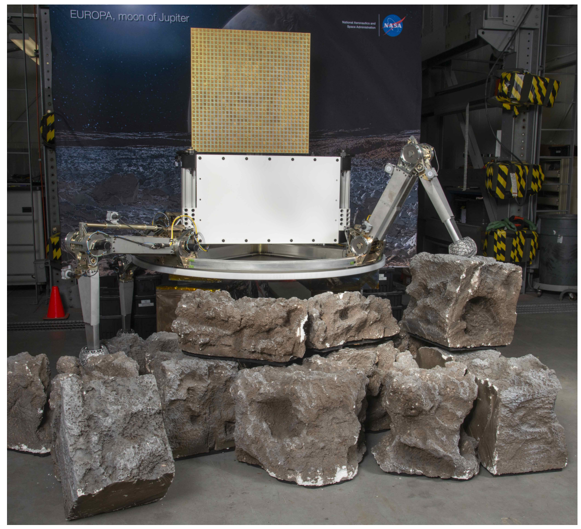

Figure 1: One of the full-scale Europa Lander mechanical testbed vehicles built at JPL is shown here with its stabilizer legs configured to show adaptation to hazardous terrain with significant relief. Once the bottom of the lander contacts the surface with sufficient force, the legs are locked into place to prepare the vehicle for sampling and surface operations. Mounted on top of the testbed is a prototype of the high-gain antenna.

Mission Architecture: The scientific and technical approach of the mission concept provides a robust, and in many ways conservative, strategy for the first landed mission to the surface of Europa [10]. No high-risk roving or melting capabilities are included, nor are any radio-isotope power sources used that could complicate planetary protection considerations. Independent of any biosignature results, the scope of the science is such that high science return is nearly guaranteed, by merit of being the first landed mission on the surface of an airless ice-covered ocean world. Many of the technologies employed have high heritage from Mars surface missions, and other in situ surface science exploration (*e.g.*, the Huygens probe). For more details on the science objectives and investigations, as well as the full science traceability matrix, we refer the reader to the 2016 Science Definition Team Report [9].

In July of 2017 the mission concept detailed here

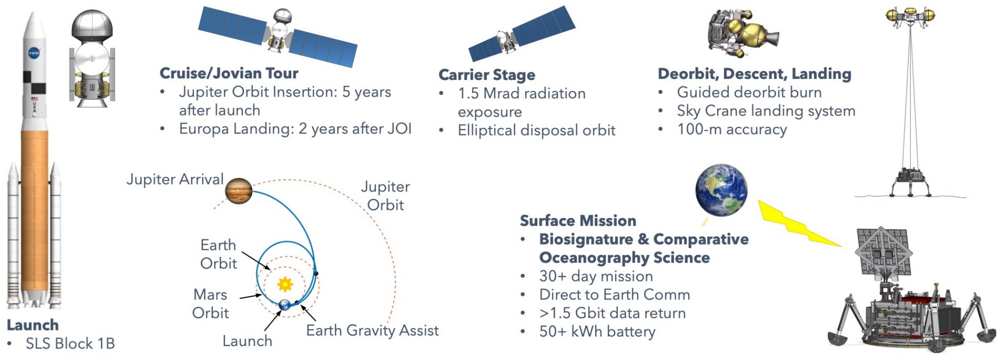

Figure 2: Overview of the Europa Lander mission concept architecture. The baseline mission would potentially launch on a Space Launch System (SLS) rocket, followed by a ∼5 year cruise to Jupiter Orbit Insertion (JOI), after which, the carrier stage then conducts flybys of Ganymede and Callisto to position the spacecraft for deorbit, descent, and landing on Europa, using terrain relative navigation, hazard avoidance, and the sky crane landing system. The surface science mission is focused on the search for biosignatures and the science of comparative oceanography.

passed through a Mission Concept Review (MCR), with direction to reformulate the architecture from one in which a communication relay stage is in orbit around Europa, to one in which the communication from the lander occurs Direct-to-Earth (DTE) from the lander, and Direct-from-Earth (DFE) to the lander. In November 2018, the DTE Europa Lander successfully passed through a delta-Mission Concept Review (dMCR). Figure 2 shows key stages of the mission: cruise, deorbit, descent, and surface operations. As part of the mission development effort, NASA has invested in technology developments to retire science, technology, cost, and schedule risks associated with the mission concept [10].

The mission concept uses primary batteries and is designed to survive, with margin, for at least 30 days on the surface; it could survive for ∼60 days or more with a number of low risk modifications to the power subsystem. The choice of primary batteries was, in part, to save on cost and complexity. A longer-lived mission with a radioisotope power system was studied, but planetary protection, thermal management, and increases in mass contributed to increased cost and technical risk. The MCR and dMCR review boards both determined that the surface lifetime from primary batteries was acceptable, and helped to limit planetary protection and cost risks.

The dMCR DTE concept was costed at $2.8B, in real-year dollars, for phases A-D. This includes 32% for unallocated future expenses (UFE), which is in addition to reserves held by the pre-project at the subsystem level. The $2.8B estimate is from an Independent Cost Estimate (ICE) at the 50% confidence level in the S-curve, compliant with a NASA headquarters-level 7120.5E requirement. We note that the cost information is of a budgetary and planning nature and is intended for informational purposes only. It does not constitute a commitment on the part of JPL and/or Caltech.

Importantly, the mission would build 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 landing site selection. Also significant, data from *Clipper* would be unlikely to dramatically change our approach to deorbit, descent, and landing; 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.

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