**Introduction:** Harboring potentially habitable environments, Jupiter’s moon Europa has risen to the forefront of planetary exploration [1]. There is a general consensus in the community that under Europa’s geologically young ice shell exists a subsurface ocean, probably in contact with a silicate seafloor -- which may lead to an ocean rich in the elements and energy needed for the existence of life. Landforms on the surface additionally suggest recent or ongoing geologic activity.

As NASA moves forward with the exploration of Europa through the upcoming Europa Clipper flagship fly-by mission, efforts are also underway to mature the technologies required for a potential future mission to land on the icy surface [2]. We consider lessons learned from successful landings on Mars, the Moon, comets, and asteroids [4-6]. Additionally, reconnaissance data collected by Europa Clipper will be critical for the identification of potential landing sites that satisfy criteria for engineering safety and maximize science value for a future landed mission to Europa [6-7]. However, current data from the Galileo spacecraft resolves the surface only to length scales of 10s of meters at best, and future reconnaissance from the Europa Clipper spacecraft will resolve the surface to the ~meter-scale.

Thus, technology development efforts are focusing on a robust landing system capable of navigating unknown lander-scale terrains to safely deliver a payload to the surface. To inform this development effort, the Europa Lander mission concept team is developing a comprehensive Terrain Specification Document (TSD, JPL D-97648) that summarizes current knowledge regarding surface characteristics such as optical, thermal, and mechanical properties; chemical composition; topography; and environmental context. This information is used to explore the design space and requirements for lander technologies, including capabilities of the autonomous landing system, interaction with the lander workspace, and sampling architecture on the surface. Here we summarize the dual science-engineering approach used to develop the structure and content of the TSD, as well as lessons learned for future development of TSDs for Europa and other bodies.

**Approach to Content Generation:** Once a topic is identified, the science team and the relevant engineering sub-systems work together to iterate on the types of questions, bounding conditions, and other specifications that the engineering team may need to consider in their design and/or modeling efforts. Subject matter experts are then involved to begin literature review and documentation with a science-driven focus. In addition, engineers from a group dedicated to developing, characterizing, and producing extraterrestrial simulants begin prototyping and testing relevant earth analogues. Frequent conversations between team members (both scientists and engineers from different sub-systems) are encouraged to ensure material may be successfully integrated, is germane, and is appropriately referenced with up to date literature. While a science manuscript style text is common and appropriate during content generation, accessible and approachable “quick-look” products, like summary tables, ensure the content will
be digestible and useful to a non-expert. Where possible, scientists and engineers work together to try to identify and place bounds on:

(1) representative characteristics of each science topic: For example, ice composition, grain size, albedo, roughness are examples of aspects of the Europan surface that are studied.

(2) the maturity of assessment: For example, is the information a well-characterized and constrained tenet in planetary science, a recently developed hypothesis, or an observation with a paucity of data? Additionally, if we are unable to bound a characteristic to the fidelity needed for an engineering subsystem, an effort is made to note what future developments and studies would help (e.g., lab ice testing, data from Europa Clipper, etc.).

(3) likelihood, potential consequence, and locationSCALE as part of risk assessment: Here, “consequence” is considered something that may affect or prove a hazard to an engineering system, or have an overall implication for mission success. For example, a particular species of ice may contain radiolytic products that might be corrosive to a tool bit interacting with the surface at shallow depths.

**Exploring Key Science Topics:** Below is a sample of the topics and potential stakeholders that are currently explored in the TSD. **Topics:** Geologic units and terrain evolution; analogues (terrestrial, testbed, lab); surface processes (impact gardening, ion radiation, high-energy electron radiation, solar radiation, sintering); surface chemistry; mechanical, thermal, electrical, and optical properties. **Potential Stakeholders:** Sampling arm and tool development teams; vision perception team; landing gear team; instrument teams; thermal management team; deorbit, descent, and landing (DDL) architecture team.

**Conclusions:** Development of a Terrain Specification Document (TSD, JPL D-97648) by the Europa Lander mission concept team works to summarize the current understanding of Europan surface characteristics, processes, and properties, with a focus on science-driven content in order to provide guidance for subsystem and systems engineering teams in their design and validation testing efforts. An important outcome of this effort is the identification of specific areas of knowledge that are insufficiently mature and require further study. Focusing future efforts on these topics will help ensure mission success. These efforts help maximize science value for a future landed mission to Europa especially when coupled with engineering safety and science criteria for landing site selection, use of data from upcoming missions (in particular Europa Clipper) for landing site reconnaissance, and technological advancements. For more information see [https://www.jpl.nasa.gov/missions/europa-lander](https://www.jpl.nasa.gov/missions/europa-lander) and [https://www.europa-insitu.caltech.edu](https://www.europa-insitu.caltech.edu).

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**References:**

[5] Scully +, this LPSC.