TO LAND ON EUROPA. James H. Shirley, Robert W. Carlson, Wayne F. Zimmerman, Tommaso P. Rivellini, and Dara Sabahi, California Institute of Technology-Jet Propulsion Laboratory, 4800 Oak Grove Drive, Pasadena CA 91109. (James.H.Shirley@jpl.nasa.gov).

Introduction: The Science Definition Team (SDT) for NASA's Jupiter Icy Moons Orbiter (JIMO) Mission recommends including a lander as an integral part of the science payload of the JIMO Mission [1]. The Europa Surface Science Package (ESSP) could comprise up to 25% of science payload resources. We have identified several key scientific and technical issues for such a lander, including 1) the potential effects of propellant contamination of the landng site, 2) the likely macroscopic surface roughness of potential landing sites, and 3) the desire to sample materials from depths of ~1 m beneath the surface. Discussion and consensus building on these issues within the science community is a prerequisite for establishing design requirements.

Landing Site Selection: Considerations of the potential for biosignature preservation have led to the identification of certain geologic feature classes as being of higher potential interest for sampling [2]. Criteria for this selection included youthfulness, presence of non-ice materials, and the likelihood of material exchange with the subsurface. High priority feature classes include low albedo plains, smooth plains, smooth bands, and chaos. Candidate landing sites have already been identified on the basis of Galileo images [3], but it seems clear that some flexibility in landing site selection should be retained, in order to take advantage of the newest information.

Mission Scenario: The following scenario represents one hypothetical but possible sequence of events. Following an extended cruise, and orbital sojurns at Callisto and Ganymede, the JIMO spacecraft will spend approximately two months spiraling in to reach a mapping orbit of ~100 km elevation above Europa. Imaging and other observations of Europa during that period will provide late-breaking information relevant to final landing site selection. It is conceivable that early high-resolution JIMO observations may identify locations showing evidence of post-Galileo or even current geologic activity. Such locations may then be assigned high priority for in-situ exploration.

Following the selection of an accessible landing site of high scientific interest, the Europa lander subsystem will separate from JIMO. It will propulsively counter the substantial horizontal velocity of the orbital motion and descend to the surface. Prior investigations have established that it should be possible to deliver a lander of mass up to perhaps 150 kg to the surface of Europa, given the stated JIMO SDT constraint of a maximum total lander system mass of 375 kg.

Pre-Touchdown Issues: We have identified two pressing questions linked with the final descent phase of the lander mission. Both of these carry certain implications for science. First is the question of the required targeting accuracy and the associated sophistication of the velocity sensing and control system. Pinpoint accuracy and small scale hazard avoidance capability are attainable but only at significant costs. To flight-qualify a highly sophisticated velocity sensing and control system for the hostile radiation environment of Europa would require a significant investment; its inclusion would have implications for power resources and would reduce the amount of mass available for science instruments. We have tentatively concluded that velocity estimation via IMU propagation and altitude knowledge from a simple radar altimeter represents an acceptable solution, given the mass constraints.

A second issue derives from the science desire to perform geochemical and astrobiological experiments with ppm resolution on surface and subsurface materials [1]. Pristine samples of surface materials are desired, but soft lander systems typically contaminate the landing site with propellant by-products. A significant by-product of hydrazine is ammonia. The in-situ concentrations and compositions of Europan nitrogen-bearing species are of scientific interest, and the possible reactions of propellant by-products with ambient materials may be difficult to categorize in advance. This question requires further investigation. We have initiated plume dynamics and compositon studies, and we welcome input from parties interested in this question.

Touchdown Issues and the Terrain Problem: The highest-priority landing site identified during the spiral-in phase of the JIMO Europa encounter may lie in chaos terrain; atop a smooth gray band; or atop some extensive cryovolcanic flow feature, among other possibilities. To allow access to high scientific interest locations the lander must be capable of surviving a landing on surfaces that are not level and smooth. It must also be capable of communicating with the orbiter, regardless of the topographic slope or structural complexity of the landing site. The topographic variability of Europa is significant [4,5]; preliminary estimates of mean topographic slopes over baseline distances < 100 m for a variety of Europan terrain types range upwards from ~7º to > 15º [6]. In some locations the available data suggests that tectonic or other processes have produced pervasive fracturing and crevassing on a variety of scales (see Figure 1). Whether or not fracturing and crevassing is ubiquitous on geologically youthful surfaces at lander-relevant scales is presently unknown. We have very little information on macroscopic surface roughness or surface properties on scales from 0.05 – 10 m.

The mechanical properties of surface materials are highly relevant but imperfectly known. The hardness of non-porous surface ice at 80-130 K is comparable to that of concrete; but we are more likely to encounter a regolith [7], whose depth and porosity may vary from place to place [8]. Prior work on the physics of water volcanism [9, 10] suggests that the surfaces of youthful cryovolcanic flow features are likely to be rough and blocky on the scales of interest to us here.

Landing on Europa is evidently more difficult and more hazardous than landing on the Moon or Mars. There is a need for additional studies that may be able to more adequately constrain the likely lander-scale structural and physical properties of the various Europan terrains. Better information is needed on the likely size and frequency distribution of landing hazards such as crevasses, ridges, and boulder-like features. Nontheless we are confident that engineering solutions may be found for landing safely in these hazardous terrains.

Post Touchdown Issues: Sampling. Europa's intense radiation environment modifies the chemistry of surface layers. Cooper et al. [11] found that "significant elemental modifications are produced on unshielded surfaces to approximately centimeter depths in times of ≤ 10^6 years, whereas micrometer depths on Europa are fully processed in ~ 10 years." Modification by energetic electrons may dominate at depths from 5-10 cm [12]. These interactions may destroy evidence of the existence of life, in the form of nonequilibrium chemistry or nonrandom distribution of organic species, if it exists. "Gardening" of the surface [7] by micrometeoroid impacts may bury and preserve such signatures, thus facilitating their detection. These considerations dictate that the ESSP should include a capability to sample materials from beneath the surface.

The JIMO SDT report [1] calls for a capability to sample to a depth of ~ 1 m. Our preliminary work suggests that it is unlikely that this will be accomplished under the present constraints. Innovative, light weight systems for active sampling to depths of several cm have been evaluated; a lander including such a system could weigh in at less than the allocated 375 kg. However, if the science community strongly desires sampling to depths of ~ 1 m, we believe it will be necessary to significantly increase the lander total mass allocation from its present level.

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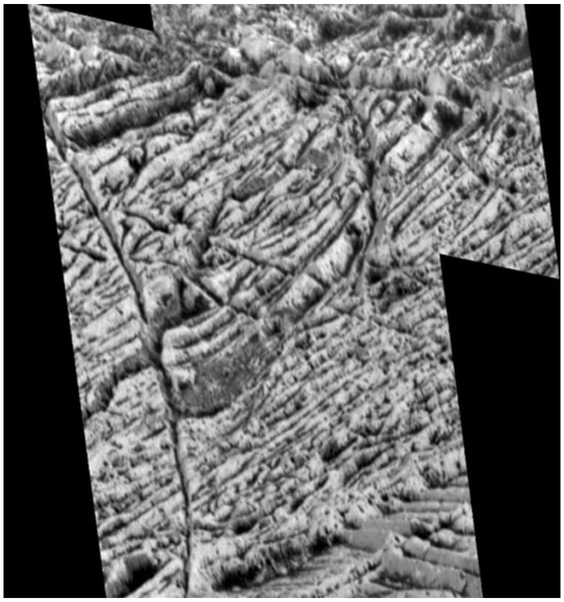

Figure 1. A portion of a mosaic of Galileo SSI close approach imagery of Europa from the E12 encounter (courtesy of L. Prockter). Scale is < 10 m / pixel.