MISSION TO EUROPA – LANDER AND ORBITER CAPABILITIES TO SUPPORT THE SEARCH FOR EXTANT LIFE.

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Introduction: The presence of a sub-ice ocean is reasonably established for the Jovian moon Europa [1, 2], with the liquid phase being present due to gravitational tidal heating from Jupiter. This sub-ice ocean has likely existed for at least hundreds of millions of years. Telescopic spectral studies and data from Galileo show the surface is rich in H_2O ice and hydrates [3]. Lineaments (lineae) in the ice surface (Fig. 1) likely represent faulted ruptures in the crust, analogous to terrestrial seafloor spreading at mid-ocean ridges, through which upwelling of salty slush has occurred. Solidification of this liquid to semi-liquid medium at the surface presents a *unique opportunity to sample the sub-ice ocean and evidence of possible extant life without the need for deep drilling.* Dynamic activity in the moon is ongoing based on plausible evidence of water vapor plumes provided by the Hubble space telescope.

Younger craters have bright ejecta, not yet darkened by long exposure at the surface. Dark deposits can be seen in Fig. 1 that may be detritus from millennia of ice sublimation. The deposits could include salts, as discussed by [2], and they may include organic carbon compounds. If life evolved in the sub-ice ocean, the dark detritus deposits would be prime targets for close-up observation, sampling, and chemical analysis**.**

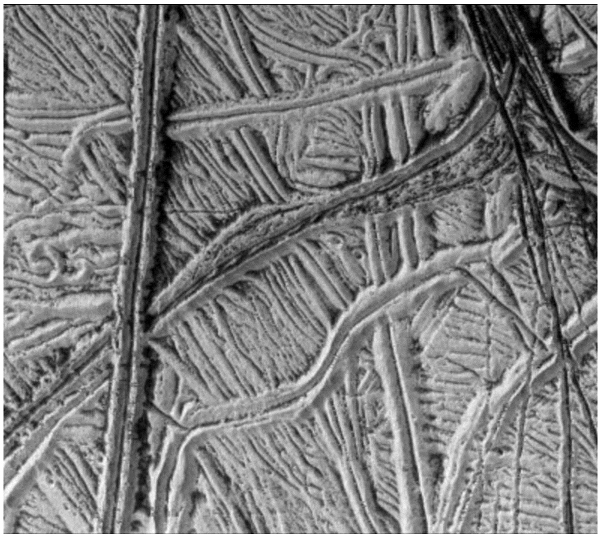

Fig. 1. Image from NASA's Galileo probe; ridged plains on Europa, reminiscent of mid-ocean spreading ridges on Earth. Note areas of dark surface deposits. More prominent ridges are ~1 km wide. Image taken at a range of 1300 km. North is up and surface is illuminated from upper left. Frame is 20 km wide, centered at 14°S, 194°W (26 m/pixel). Credit: NASA/JPL.

Orbiter Capabilities: An electromagnetic (EM) instrument for the orbiter would be valuable for deeply probing beneath the surface of Europa. EM data could help detect whether the youngest lineations on the surface correlate with shallower liquid layers. At Mars the MARSIS and SHARAD instruments “imaged” the entire thickness of the polar caps. However, that confirms the Martian ice caps contain relatively pure ice, low in salts. If the crust of Europa (especially the uppermost layer) contains significant salts [2, 3], that would significantly increase the ice conductivity, possibly reducing the EM skin depth as much as an order of magnitude.

For an ideal mission the lander should not be deployed until detailed investigation of the surface is carried out by an orbiter. This philosophy is similar to the Viking Mars missions, which released their landers after nearly a year in orbit. Radiation fields near Europa would place practical limits on surveillance time. Having the probe orbit Europa for purposes of pre-landing surveillance and relay communications would require more reaction mass for the craft but less for the lander, as it would be reduced to orbital speed before descent to the surface. One goal of the surveillance would be to locate recent ice ruptures that post-date features seen in images captured in 1996-97 by the Galileo mission. Such a location, if it exists, would provide the freshest possible samples of the sub-ice ocean. Stereo photogrammetry similar to that of the Mars Express HRSC instrument would enable topographic mapping of potential landing sites, as an alternative to laser or radar mapping. On Mars Express this was the lightest of 3 instruments. Fig. 1 shows a straight ridge pair (top to bottom of frame) that cross-cuts many other ridges in the image, and is probably the youngest feature in this view.

Lander Capabilities: A half-scale version of the Mars Curiosity Rover (Fig. 2) could be deployed to Europa with sufficient capabilities to search for evidence of life. Its power supply would be a version of the Multi-Mission Radioisotope Thermoelectric Generator, similar to that on Curiosity, with auxiliary heater units for key components. Shielding of electronic components would be needed, given the enhanced radiation belts around Jupiter. The very thin atmosphere prevents the use of aeroshell friction/parachute descent and would require a rocket descent motor, analogous to landing on Earth’s moon. Less reaction mass would be needed to land on Europa because the surface gravity is 1.3 m s^{-2}, 18% less than on Earth's moon and only ~1/3 that of Mars. Wheels on Curiosity specifically designed for Mars may require design modification to navigate icy surfaces. Valuable experience was gained with the Spirit Rover on Mars where rearward movement was still possible even after one of its 6 wheels froze. The rugged terrain in Fig. 1 is of great scientific interest, and would likely present challenges for a lander. However, the much lower surface gravity would enhance rover mobility in varied terrain. Access to any ridges like those in Fig. 1 could support a search for extant life.

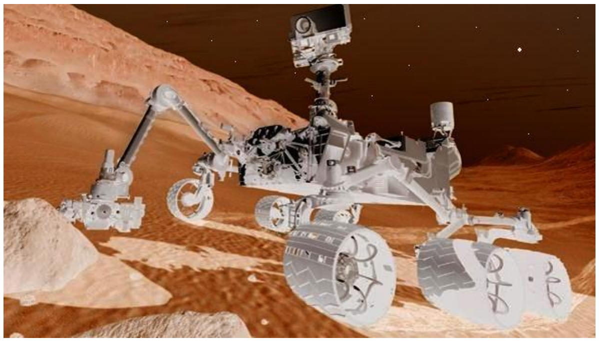

Fig. 2. Futuristic view of lander conducting in situ studies and gathering samples for biochemical analyses.

Seismic Investigation: Europa may have significant seismic activity, given the extensive and extraordinary ice fracture and upwelling patterns seen in surface images, the effects of Jovian tidal forces 3 orders of magnitude greater than lunar tides on Earth, and observations of atmospheric plumes. Seismic activity is also a plausible energy source for creating the pattern of dark deposits seen in Fig. 1, which appear to be concentrated in low areas. With no atmosphere or wind on Europa, seismicity could move dark surface material downslope over time. Light-weight detectors, analogous to cell phone accelerometers, could be carried by the lander to record seismic events.

Cameras: A camera array equivalent to that on Mars Curiosity (MastCam; MAHLI; MARDI) would provide adequate coverage of surrounding terrain and close-up views of the surface materials. The ability to acquire 3-D color panoramas would be useful to help guide rover movements given the very long 2-way radio communication times. An equivalent of MARDI could image the critical lander descent.

Sample Analysis: The SAM instrument package onboard the Curiosity Rover, with appropriate radiation shielding and thermal protection, would provide the main capabilities needed for a lander mission to Europa. SAM consists of three instruments, including a gas chromatograph, mass spectrometer, and a laser spectrometer. These instruments permit analysis of the abundance of light elements associated with life, including carbon, hydrogen, oxygen, nitrogen, and their various isotopes. The abundance of these elements is key to exploring whether life exists or has existed at Europa. The hardware will also permit detection of carbon compounds including methane. Sample handling would significantly differ from the Martian case in that icy material would be the likely medium added to the inlet tubes, rather than soil. An abrasion or shallow drilling tool rather than scoop may be needed to gather samples.

Although Europa has little atmosphere, we suspect that the slush that rose from below carried entrained gas bubbles produced in the subsurface, of inorganic or possibly biogenic origin. Consideration should be given to sampling methods that can preserve and "capture" such bubbles to allow analysis of their composition.

Planetary Protection: Galileo data show that near-surface radiation is high and variable, dominated by energetic electrons, on the order of 5 gray d^{-1}. However, even though Europa has no permanent magnetic field, significant reductions in electron flux occur near the moon and would be further reduced on its surface along the leading hemisphere [4]. Radiation levels would still be in the sterilizing range, with the consequence that planetary protection from Earth microbes should be of reduced concern in preparing a lander.

Discussion: Europa's surface age (from cratering) has been estimated at a youthful 30-70 myr [5], with superposition of linear features revealing a span of relative ages. The surface composition of older surfaces on Europa would have been altered by slow sublimation effects that would concentrate salts and other non-volatiles, along with changes caused by the solar wind, Jovian radiation, cosmic ray exposure, and exogenic sulfur from Io. Therefore, the assumption that any surface sample would accurately represent the composition of a sub-ice ocean would be questionable. If relatively youthful upwelling zones or active plumes can be identified from orbit and targeted for landing, the judicious collection of surface samples would lead to more accurate analysis of the composition of Europa's sub-ice ocean, i.e., relative percentages of water, methane (and other carbon compounds), ammonia, and various salts. If microscopic or larger organisms dwell in the sub-ice ocean, their remains should be preserved in the solidified upwelling zones where they can be detected.

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