Tidally Induced Ice Shell Fracturing and Faulting at Europa & Implications for Future Subsurface Missions.

R. R. Lien[1,2], K. L. Craft[2], and M. Walker[3], [1]University of Oregon, Eugene, OR (rlien@uoregon.edu); [2]Johns Hopkins University Applied Physics Laboratory, Laurel, MD (Kate.Craft@jhuapl.edu); [3]Planetary Science Institute (mwalker@psi.edu).

Introduction: The Jovian moon Europa is an ideal candidate for future exploration, but the processes that maintain a potentially habitable subsurface ocean also result in geophysical hazards on the surface and within the ice shell. During Europa's elliptical orbit, the gravitational pull from Jupiter causes its ice shell to distort, triggering fractures and fault-like motion [1-2]. In order to explore Europa's subsurface ocean, it is necessary to understand the potential hazards that a tunneling probe and communication hardware, such as an optical tether extending from the surface or free space repeaters, could experience within the ice shell [3-4].

Model Set-up: Here, we used the 3D modeling software Ansys Mechanical to simulate fracture slip resulting from tidal forcing at periapse for two locations on Europa, the Subjovian and the Thera Macula chaos terrain (50°S, 180°E), which are challenging stress environments as well as regions of scientific interest [5]. The tidal stress components differ considerably for the selected locations, with vertical stress dominating at the Subjovian and lateral stress higher at Thera Macula. We designed a 3D geometry to represent a 3-km x 2-km x 2.5-km-deep section of Europa's ice shell. A fault plane representing a fracture down to 900 m depth was added to the geometry angled at 5, 20, or 45 degrees from vertical and oriented towards either east or north (Figure 1). We quantified the amount of slip at both locations for this range of fracture orientations as well as maximum/minimum values for the coefficient of friction of ice (0.1 to 0.55) to understand many possible hazard scenarios.

Results: At the Subjovian, results indicate the net fault displacement would range from ~0.2–4.3 cm, with minimal variation between the different fracture orientations. The fractures open rather than slip, so results were nearly independent of friction. At Thera Macula, the fracture motion resembles either strike-slip or reverse faulting with net fault displacements ranging from ~4.8 cm up to 81.5 cm. The net fault displacement results were used to calculate the range of strain values that could potentially be imposed on a communication tether crossing an active fault during a subsurface mission.

Ongoing Work: In addition to the static models described above, we are working to model fault motion at multiple time points during the tidal cycle in order to consider stick-slip motion. Tidal stress data for twelve time points (30-degree increments of Europa's orbital trajectory) at the Thera Macula location will be imported into the 5-degree fracture model. Net fault displacement results will be computed for the periapse and final apoapse position, and results will be compared to those from the static model. The total displacement at the final time point (apoapse) will indicate whether observable fault slip is accumulated during each tidal cycle (apoapse to apoapse). Differences between the results of the time-dependent and static models would suggest that the time-step analysis is more accurate and should be carried out for the other model conditions.

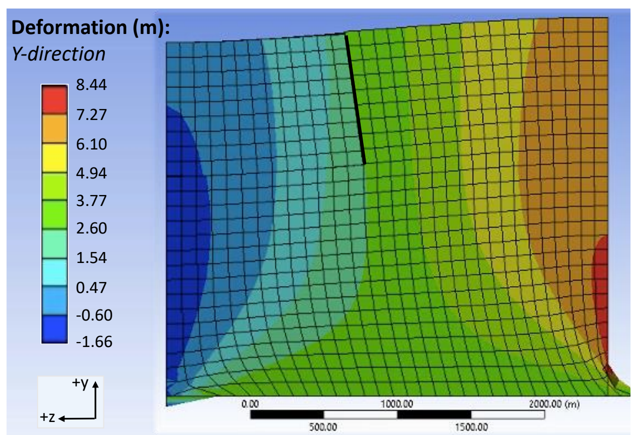

Figure 1. Vertical (Y) deformation result for the 5-degree fracture model at Thera Macula. Bold black line highlights the location of the fracture in the ice block. The +X-direction is east, Y-direction is vertical, and +Z-direction is south.

References: [1] Greenberg, R., et al. (1998) Icarus, 135, 64–78. [2] Lee, S., Pappalardo, R. T., and Makris, N. C. (2005) Icarus, 177, 367–379. [3] Craft et al. 2019, AbSciCon, Abs. 402-2. [4] Oleson, S., et al. (2019) NASA/TP–2019-220054. [5] Europa Lander Study 2016 Report: Europa Lander Mission. JPL D-97667.