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EUROPA CLIPPER IMPACT: TEMPERATURE ANALYSIS

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HIGHLIGHTS: Because of the potential habitability of Jupiter's moon Europa, it is safeguarded by strict planetary protection policies. Our study evaluated the impact of the *Europa Clipper* spacecraft onto Europa's icy surface. Results from 1D, 2D, and 3D simulations indicate that substantial temperature increase is expected in all parts of the spacecraft during impact, primarily due to self-impact of spacecraft components.

INTRODUCTION:

Europa, a prime candidate for the search for life beyond Earth [1], is the target of the *Europa Clipper* mission. However, if the spacecraft were to crash into Europa, would the heat of impact be enough to destroy any remaining Earth-based life, or would the search for life on Europa be forever marred by the potential forward contamination from Earth? The purpose of this work is to simulate such an event in order to determine the possible temperatures experienced by the spacecraft materials. The goal is to assess whether impact-induced heating is sufficient to sterilize [2] the *Europa Clipper* and ultimately protect Europa from forward-contamination.

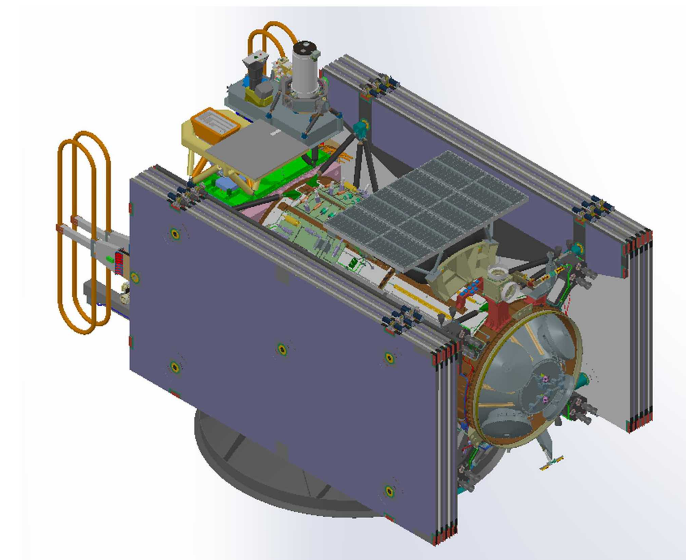

Fig. 1: *Europa Clipper*, stowed position

BACKGROUND AND METHODS:

The Sandia National Laboratories-developed code, CTH, is ideal for studying shock physics problems with multiple materials and high deformation [3]. Previous work with shaped-charge jets validated CTH temperature calculations with experiments [4-5]. This study simulated the *Europa Clipper* impact in multiple dimensions to probe different aspects of the event. For simplicity, we modeled the spacecraft as aluminum (with a SESAME equation of state, EOS) and assumed the solar panels were in their stowed position (**Fig 1**). We simulated the surface of Europa with a semi-infinite slab of ice (five-phase SESAME EOS [6]), with up to 75% porosity, which was attained with a P-Alpha model. We assumed the impact speed to be 4 km/s at both a vertical (90°) impact angle and at 15° from the horizontal. The initial temperature of all objects was 232 K (-40° C). Sterilization temperatures were taken from Clark [2] to be between 394 – 773 K (121 – 500 °C), depending on wet vs. dry heat stabilization and heat soak duration.

1D Simulations tested a) material models, b) effect of ice porosity on impactor temperatures, c) effect of subsequent aluminum-on-aluminum impacts (representing different spacecraft components impacting each other). **2D plane-strain simulations** tested temperature increases in components of a) the propulsion unit and b) the vault. **3D simulations** tested the effect of impact angle. Simulations tested: a) 90° and b) 15° impact angles.

1D SIMULATIONS

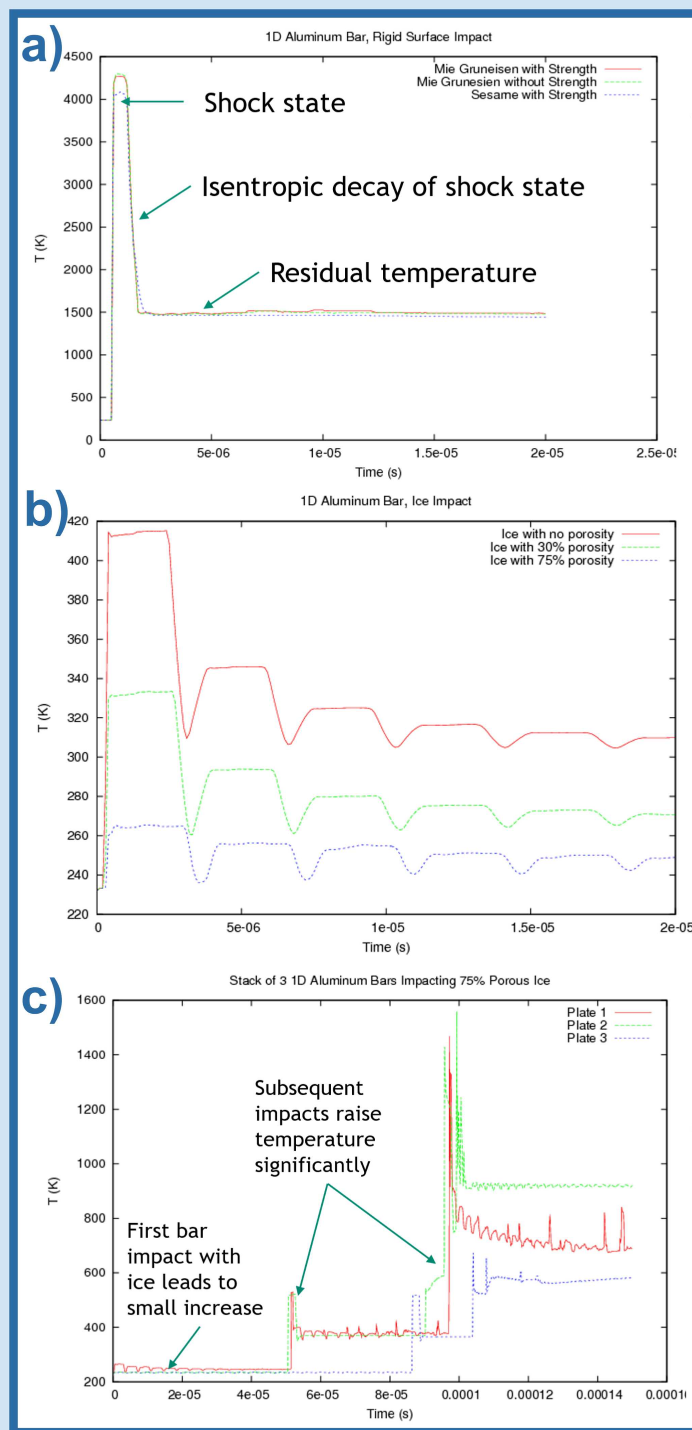

Fig. 2: a) Simulation results from varying EOS material models and strength models. b) Temperature of aluminum during impact of 1-cm aluminum bar into ice with varying porosity. c) Temperature of aluminum during impact of 1-cm aluminum bar into ice with subsequent Al-on-Al impacts.

RESULTS: a) All material inputs produced similar results. b) Impacts into ice resulted in minor temperature rise in the impactor. Temperature rise became less substantial with increasing ice porosity. c) Subsequent hits with additional aluminum pieces resulted in drastic temperature increases in impactor.

2D SIMULATIONS

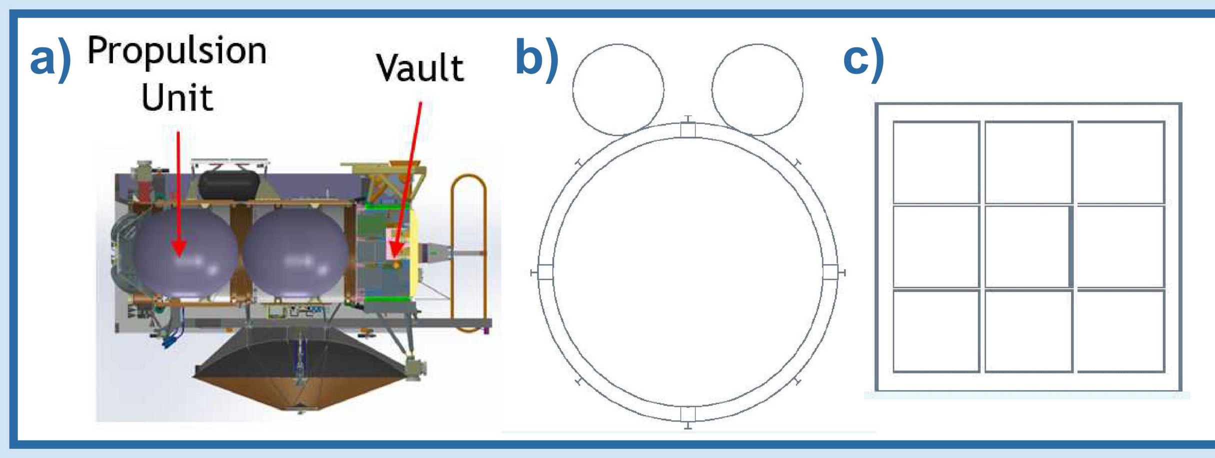

Fig. 3: a) Cutaway of the *Europa Clipper* CAD model. b) Simplified propulsion unit and c) vault. Simplifications allow for running sims at high resolution.

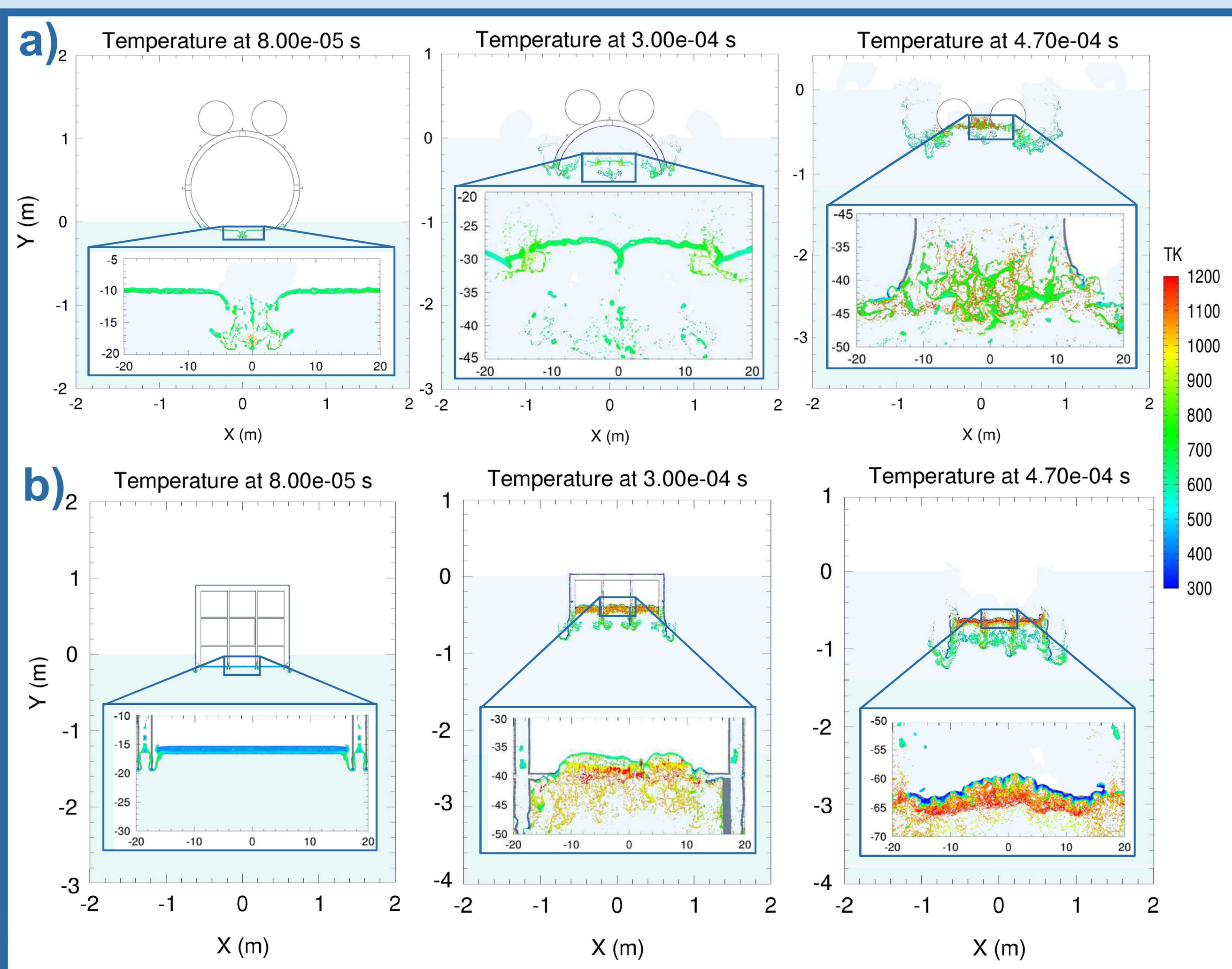

Fig. 4: CTH Temperature plots for a) the propulsion unit and b) the vault. Plots taken at different times demonstrate the effect of multiple Al-on-Al impacts. Subsequent impacts of pieces of the spacecraft result in increased temperatures. Zoomed-in insets are in cm.

RESULTS: a) The propulsion unit sim ran to 800 μs. At this time, most of the mass was 565 – 978 K (min 482 K; max 2135 K from aluminum-on-aluminum impact). b) The vault sim ran to 1870 μs. At this time, most mass was 486 – 1076 K (min 486 K; max 2171 K).

3D SIMULATIONS

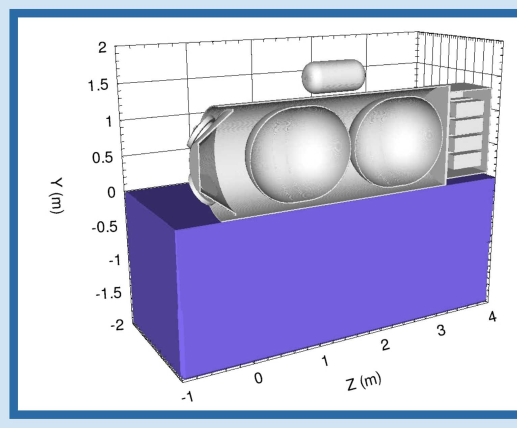

Fig. 5: Full 3D simulations with CAD would be prohibitively expensive; the detail in the CAD model is such that it requires more memory than is available per core on Sandia's parallel computers. A simplified 3D model with key geometry was used for initial testing.

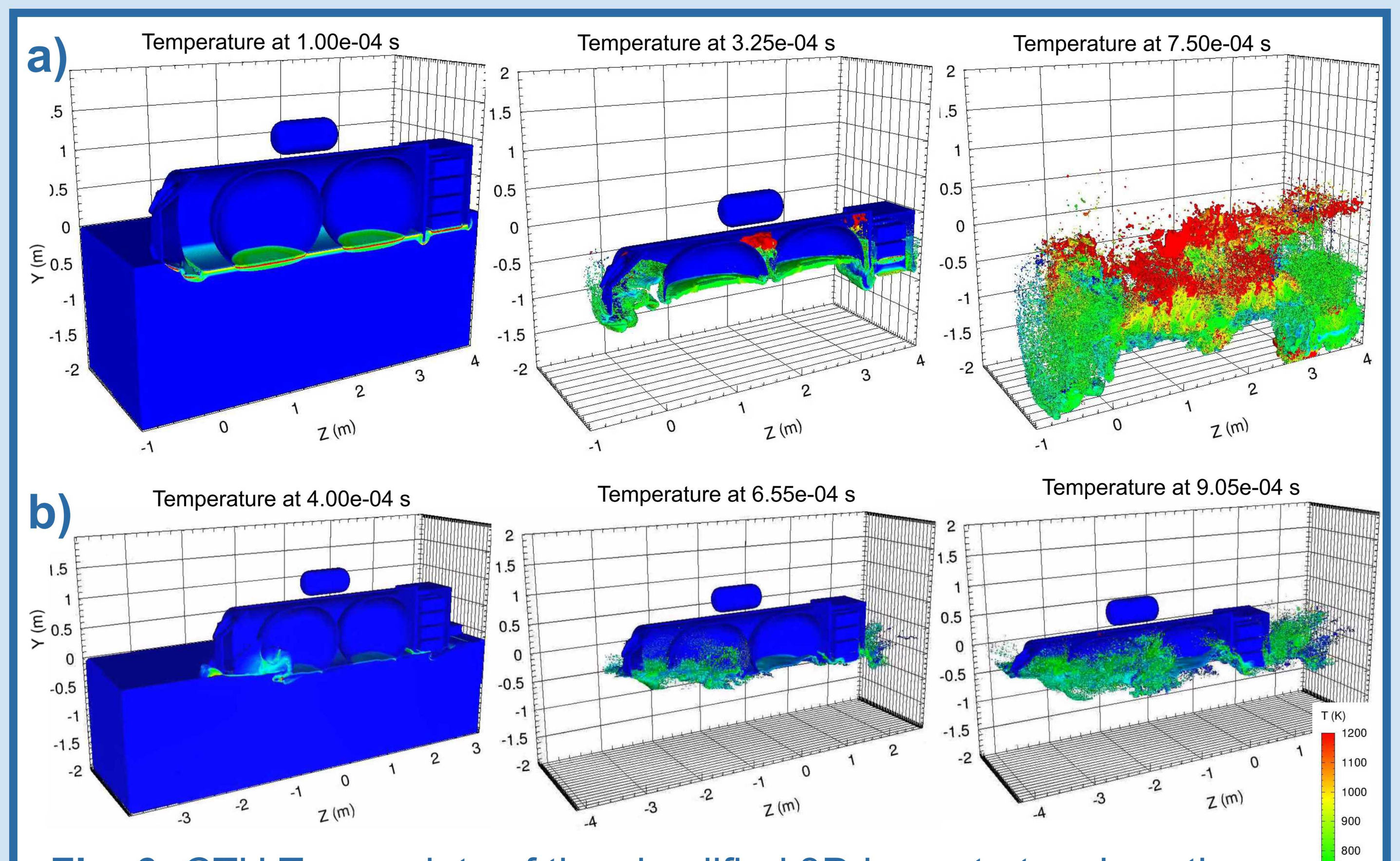

Fig. 6: CTH Temp. plots of the simplified 3D impact at various times for a) 90° and b) 15° impact angles. The spacecraft + ice slab are shown in the first panel, subsequent panels show only the spacecraft temperatures.

RESULTS: a) At 90°, the simulation ran to 740 μs. The majority of aluminum was 209 – 906 K (min 100 K; max 1900 K). b) At 15°, the simulation ran to 900 μs, but was not fully impacted yet. At this time, most temperatures were 209 – 707 K (max 906 K). Lower temperatures are due to the model being either not fully impacted (b) or parts still having significant motion (a). Longer runtimes are needed, and higher temperatures are expected to result.

CONCLUSIONS:

The 1D, 2D, and 3D simulations in this study indicate that substantial temperature increase is expected in all parts of the spacecraft during an impact. Even though the high porosity of ice expected at Europa should reduce impact-related temperatures in the spacecraft, subsequent self-impact of different pieces of the spacecraft onto itself is the main driver for temperature increase. From the 2D and 3D simulations, most material spacecraft components appeared to reach temperatures of 450-1050 K, with peak temperatures ranging from 500 K to over 2000 K. These temperatures are above many of the dry-heat and wet-heat sterilization temperatures cited for planetary protection. However, the CTH studies here only model the temperatures of the materials upon impact; subsequent cooling of the material is not considered. More detailed final conditions and cooling timeframes should be considered using a heat flux code.

REFERENCES:

[1] National Research Council (2011) Natl. Acad. Press. [2] Clark B.C. (2004) Advances in Space Research 34 (11), 2314-2319. [3] McGlaun J.M., Thompson S.L., Elrick M.G. (1990) Int. J. Impact Eng 10(1-4), 351-360. [4] Helminiak N.S., et al. (2017) Procedia Engineering 204, 178-185. [5] Sable P., et al. (2017) Procedia Engineering 204, 375-382. [6] Senft L.E. and Stewart S.T. (2008) MAPS, 43 (12), 1993-2013.

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