MODELING MICROMETEORITE BOMBARDMENT INTO METAL TARGETS USING THE FLAG HYDROCODE. M. C. Holmes, W. K. Caldwell, J. L. Budzien, Los Alamos National Laboratory, Los Alamos, NM 87505, matthewh@lanl.gov, wkcaldwell@lanl.gov, jbudzien@lanl.gov.

Introduction: Microcratering is the dominant process causing erosion of surfaces exposed to the lunar environment such as satellite bodies [1]. Micrometeorite impacts occur at velocities on the order of kilometers per second causing material strength to be negligible during the contact and compression stage [2]. However, material strength can no longer be neglected in the excavation stage, and in the case of microcraters, dominates the process [2].

We model such impacts to understand the effects of the high strain rates and shock conditions that these impacts produce within target materials. Thus, it is necessary to use a hydrocode that incorporates a constitutive model to capture material mechanical behavior. We use FLAG: a hydrocode developed at the Los Alamos National Laboratory which models solid materials as fluids with extra features like strength and damage [3] [4]. Importantly, FLAG has undergone verification and validation processes in the context of impact cratering [5].

Research Plan: Our focus is on projectiles with diameters on the order of 100 µm made of carbon, ceramics, concrete, or silicates striking targets made of aluminum, copper, tin, glass, or borosilicate glass (Pyrex) at velocities of 5 km/s. Our goal is to model repeated oblique impacts in order to simulate space weathering effects, and to predict how target materials will be damaged over time.

Results: We present 2D axisymmetric vertical impacts involving aluminum, copper, and tin materials. Additionally, we discuss preliminary results of 3D oblique impacts as a foundation for future simulations of multi-impact bombardment scenarios.

Our simulations employ adaptive mesh refinement, use LANL's SESAME database [6] for tabular equation of state, melt curve, and cold shear modulus, and include the analytic Preston-Tonks-Wallace strength model, Johnson-Cook ductile fracture model, and simple minimum pressure spall model [3] [4].

2D Al Impact. We first modeled Al-6061 for both projectile (100 µm diameter sphere) and target (50 cm diameter cylinder, 25 cm in length), with ambient material modeled as void. Figure 1 displays the progression of pressure and density in this simulation. Note that the color bar ranges and units in Figure 1 change with time; for scale, a 200 µm ruler is included in each frame.

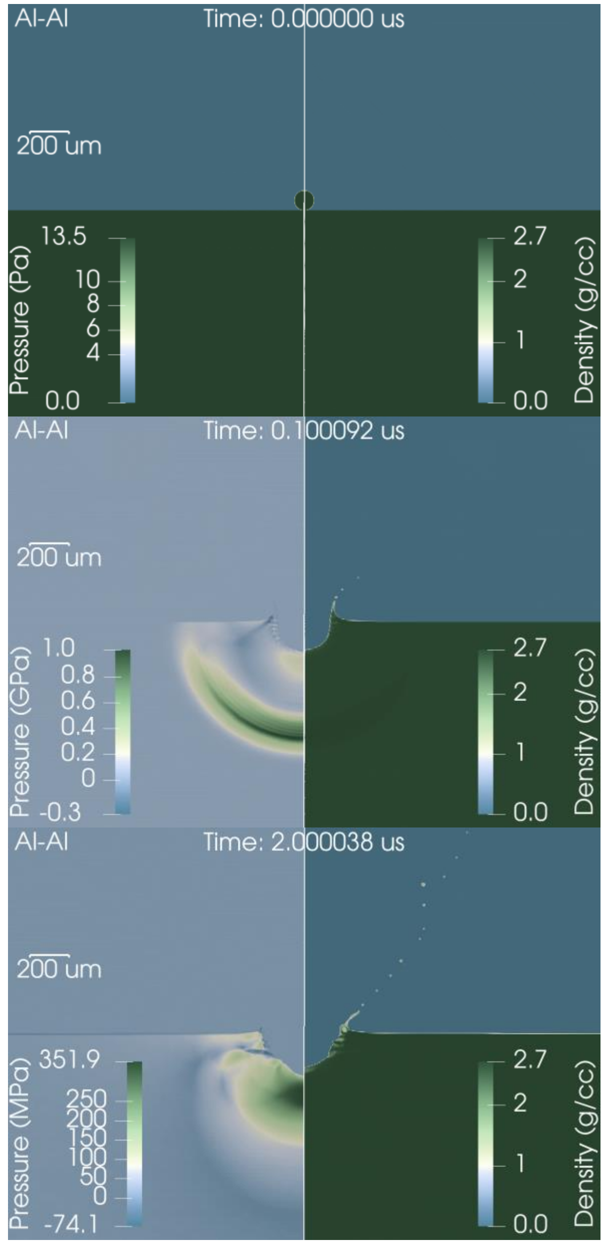

Figure 1: Progression of an Al-Al impact simulation colored by pressure (left) and density (right).

2D Cu and Sn Impacts. The impacts in this section are identical to the aluminum impact presented above, but use different material models. Figures 2 and 3 introduce results involving Cu and Sn materials. We note that the Sn material does not include the Johnson-Cook fracture model. Thus, the apparent smoothness of the Sn-Sn crater is likely a result of not having a fracture model, but we do not expect a significant difference in crater morphology.

Using the data from Figures 1 and 2 we measured the depth-to-diameter ratios at 2 μs after impact to be 0.4861 for Al-Al, 0.6458 for Cu-Cu, and 0.625 for Sn-Sn, which are consistent with expectations [7].

The preliminary results of Figure 3 indicate that projectile density correlates with deeper craters, which is expected [7]. We plan to further explore this hypothesis with additional material models.

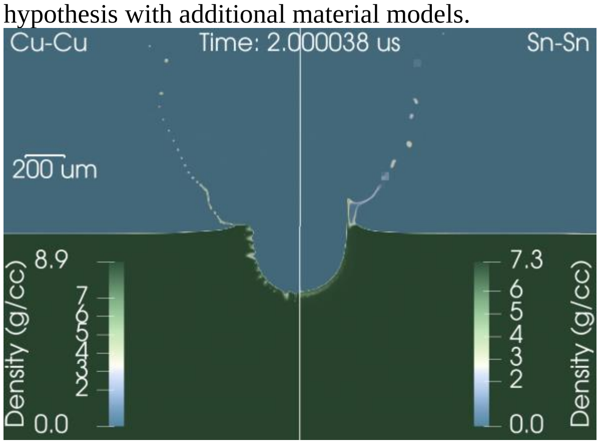

Figure 2: Symmetric Cu-Cu and Sn-Sn impacts at t = 2 μs colored by density.

3D Al Impact. Finally, we present a 3D 45° Al-Al impact using a symmetry plane, which is shown in Figure 4. We are developing a fully 3D bombardment simulation involving many projectiles, each initialized with diameter, velocity, and impact angle, location, and time according to appropriate random distributions. With such a setup, we can straightforwardly model various bombardment scenarios using empirical data.

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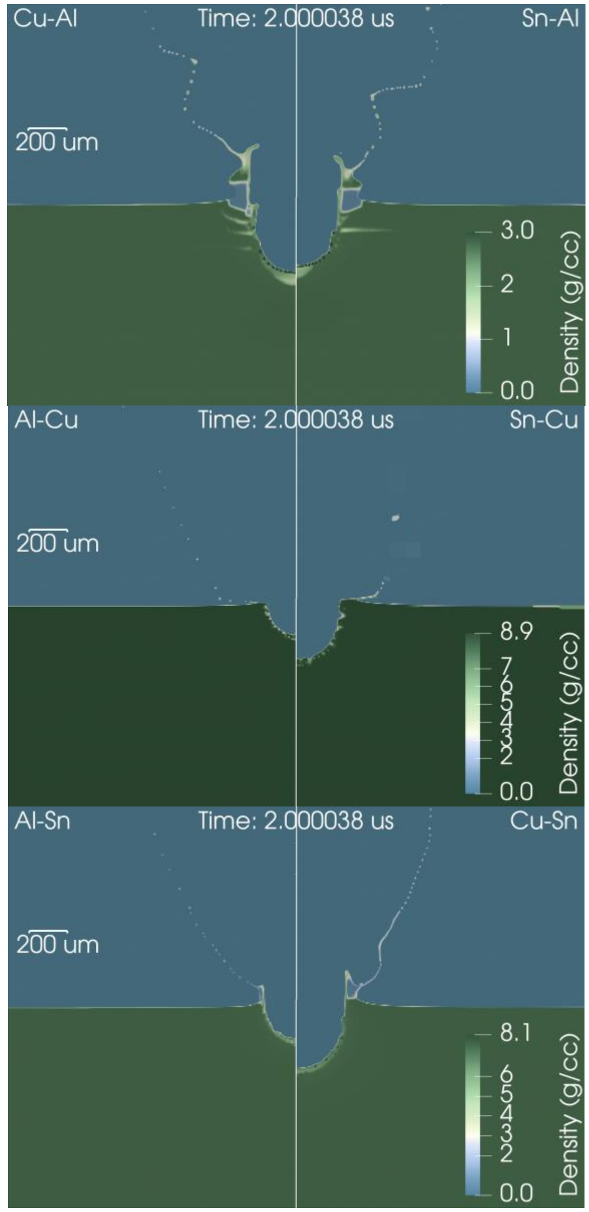

Figure 3: The six possible asymmetric impacts involving Al, Cu, and Sn at t = 2 μs colored by density.

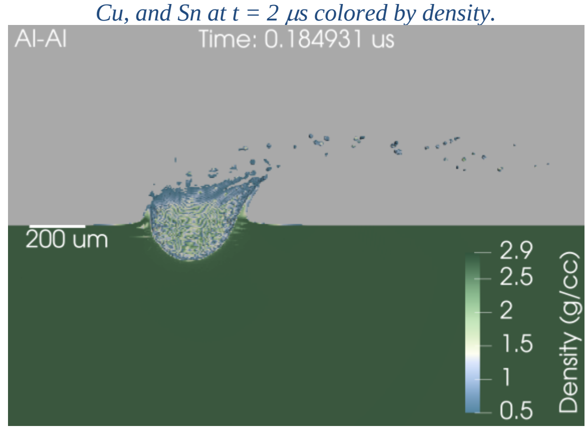

Figure 4: Symmetric 45° Al-Al impact at t = 0.185 μs modeled in 3D and colored by density.