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Size Scaling of Momentum Enhancement during Hypervelocity Impact of Porous and Consolidated Rock

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ABSTRACT

During the past decade, researchers at Southwest Research Institute have investigated the momentum enhancement caused by crater ejecta during hypervelocity impacts. Experimental, computational, and theoretical work has been performed. With the exception of a 70% porosity pumice, an extremely important effect that has been observed in these studies is that the size of the impactor matters, alternately referred to as the scale size of the impact event. As the size of the impactor increases, the momentum enhancement increases at an even faster rate – i.e.,, the momentum enhancement is nonlinear in the size scaling. We will present data we have collected on aluminum sphere impacts into pumice, sandstone, concrete, and granite. Large scale size tests were performed at SwRI where the impacting spheres ranged in size from 2.54 cm in diameter to 4.45 cm in diameter with impact speeds on the order of 2 km/s. Smaller size scale tests have been performed at the Ames Vertical Gun Range at higher speeds. The different rock materials display various scaling exponents. As expected, the highly porous pumice material has the least momentum enhancement but it also shows the most scatter. Also presented will be the analysis of the impact event using large scale

numerical simulations. These calculations are challenging and do not show the size-scale behavior with standard constitutive and damage models used for these materials, leading to concerns about their applicability in extrapolation to larger size scale events. Analysis of the impact test data leads to extrapolation formulas for the various materials to larger impactors such as would be envisioned for a planetary defense scenario, such as the impactor being a 1 meter diameter aluminum sphere. As larger size impactors lead to larger momentum enhancement, it argues for an impactor to be as large as possible with a single-strike scenario to deflect a small asteroid or comet nucleus.