TIME-RESOLVED STUDIES OF HYPERVELOCITY VERTICAL IMPACTS INTO POROUS PARTICULATE TARGETS: EFFECTS OF PROJECTILE DENSITY ON EARLY-TIME COUPLING AND CRATER GROWTH.

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Introduction: The depth and duration of energy and momentum coupling in an impact shape the formation of the crater and distribution of ejected material. Metrics for crater growth (e.g., crater diameter and depth) and ejecta velocity are usually approached from late-stage parameters [1,2]. Implicit in most of these studies is a reliance on the point-source approximation, which collapses the initial details of energy and momentum coupling into a single parameter [3]. This approximation breaks down at early-times while the projectile is still transfering its energy and momentum to the target, however [4]. The flow-field inside the transient crater is reflected in the ejecta velocity distribution.

In this study, we present new experimental measurements of the ejecta distribution and crater growth from early- to main-stage flow to examine the role of impactor density on the depth and duration of coupling. The technique employed allows expression of the ejecta velocities as a function of both time and launch position for the first time, as well as direct comparison to and benchmarking of hydrocodes.

Experimental Methodology: A suite of hypervelocity vertical impact experiments into Ottowa quartz sand was performed at the NASA Ames Vertical Gun Range using a variety of different projectile materials ranging in density from 0.9g/cc to 7.8g/cc. A non-intrusive, high-speed (15,000fps) imaging technique (particle tracking velocimetry or PTV) tracks the motion of individual sand grains during excavation and allows temporally and spatially resolved mesurements of the ejecta velocities.

Results and Analysis: The earliest stages of excavation result in high-speed ejecta derived from the upper surface near the impact point. Dense projectiles penetrate deeper and couple later in the target, whereas under-dense projectiles couple quickly relatively closer to the surface. Crater growth metrics for both the depth and diameter of the crater demonstrate non-proportional crater growth, where the crater first exhibits more relatively downward growth before transitioning to relatively outward expansion. This flow-field center evolution manifests in migrating ejection angles for much of crater formation. The temporal nature of the data also enables validation of computational parameters (e.g., EOS) using the CTH hydrocode.

Conclusions: The effect of projectile density on both the depth and duration of coupling has implications for planetary impacts, affecting models of ballistic ejecta emplacement and source depths of ejecta from primary craters (e.g., Apollo samples). Temporal (rather than spatial) description of the ejecta dynamics allows a physical understanding for ejecta produced by artificial impacts, such as the Deep Impact mission and the recent LCROSS impact. Investigation of the time-resolved growth of the crater is essential for comparison to the azimuthally-varying ejecta velocities from oblique impact events.

References: [1] Housen, et al,. 1983. *Journal of Geophysical Research* 88:2485-2499. [2] Barnouin-Jha, et al., 2007. Icarus, 188(2):506-521. [3] Holsapple and Schmidt, 1987. *Journal of Geophysical Research* 92:6350-6376 [4] Hermalyn and Schultz, 2010. Icarus, 209(2):866-870.