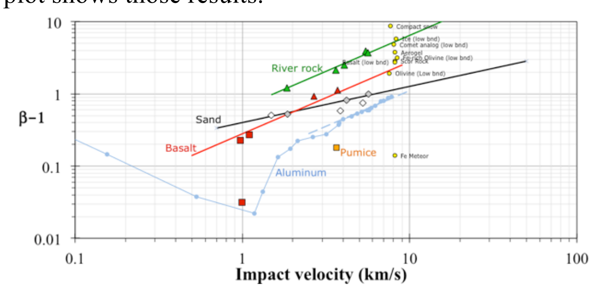
STUDIES OF IMPACTS: EXPERIMENTAL AND NUMERICAL SIMULATIONS OF CRATERING, DISRUPTIONS, AND ASTEROID DEFLECTIONS.. K. A. Holsapple[1] and K. R. Housen[2], [1]University of Washington 352400, Seattle, WA 98195, holsapple@aa.washington.edu, [2]Applied Physics, MS 2T-50, The Boeing Co, P.O. Box 3999, Seattle WA 98124 kevin.r.housen@boeing.com

Introduction: There are three serious barriers in our attempts to understand the outcomes of impacts between solar system bodies: 1) because they are rare we are unlikely to observe them in real-time; 2) because of experimental size and velocity constraints we cannot directly simulate them in the lab, and 3) because the material responses are so complex we only crudely model them in numerical code methods. Nonetheless, the literature is replete with our efforts, and, since those efforts are often described as "state of the art" (which they are) they form the basis for many applications to studies of the solar system history. Recently there has arisen interest in those impacts for another reason: the suggested use of an impact of a spacecraft into an asteroid as a means to change its path so as to miss the Earth [1]. That application has motivated a study involving experimental and numerical simulations of impacts into asteroid bodies.

So what is the fidelity of our understanding? How can we make progress? With a focus on that deflection issue, we discuss recent experiments, scaling and numerical models.

Experiments: Recent experiments [2] have been made at the Boeing impact facility and at the NASA Ames Vertical Gun Range. The target materials included dry sand and two rock types: one non-porous and one highly porous. The impacts occurred vertically and normal to the target surface, with the impact velocity from 0.5 to 5.7 km/s. The primary goal was to measure the "beta" momentum multiplication factor (the ratio of delivered projectile momentum to that imparted to the target). To do so, the target was suspended by springs, and the resulting oscillations allowed the momentum transfer to be determined. High speed cameras recorded the oscillations as well as the cratering and/or disruption processes. The following plot shows those results.



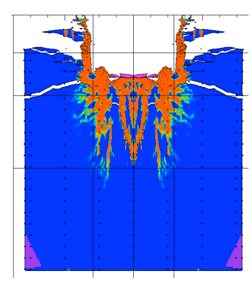
Scaling: To overcome the experimental limits, we need scaling theories to address the extension to large sizes and high velocities. We presented in [1] some scaling ideas that add features not considerred before. Those begin with the standard point-source arguments [3] that form the basis for all hypervocity phenomena, but are further honed to apply to the momentum transfer feature. In this case, we derived a simple predicted form for the β momentum multiplication factor given as:

$$\beta = 1 + K\left(U / \mathrm{v}_{esc}\right)^{3\mu-1} \quad (1)$$

where K is a material constant that may differ for the strength and gravity regimes, and v_{esc} is the escape speed of a target asteroid. Plots in this form will be presented and discussed.

Code Simulations: And finally, we will present numerical code calculations designed to match the experiment outcomes. We systematically find that certain features in the material modeling [4] are essential to reproduce the outcomes. We look in detail at not only the crater, but also the ejecta, damage patterns and disrupted shape, and compare to experiments. Examples will be given of calculations using different models, and references will be made to existing models that are lacking some essential features.

An example of the type of calculation we study is given below as a comparison of an experiment and a numerical simulation of a 2 km/s impact into a basalt cylindrical target [5]. It is seen that the match is excellent.



References: [1] "Near-Earth Object Surveys and Hazard Mitigation Strategies", The National Academies Press, 2011. [2] Housen, K. R., Holsapple. K. A., LPSC 2012. [3] Holsapple K. and Schmidt R. (1987) *JGR*, 92, 6350-6376. [4] Holsapple, K. A., Planet Space Sci, 2009. [5] Housen, K. R., LPSC 2009.

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