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CHARACTERIZING THE EFFECT OF ASTEROID TOPOGRAPHY ON HAZARDOUS ASTEROID KINETIC IMPACT DEFLECTION

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ABSTRACT

This paper will probe the detailed effects that an asteroid's shape and topography have on the delivered impulse from a kinetic impactor deflection mitigation attempt. Previous analyses of kinetic impactor deflections often model the asteroid as a spherical body, meaning that the added impulse from the ejecta (characterized by the Beta factor) is added normal to the sphere's surface and through the objects center of mass. Additionally, as most delivery designs target the asteroid center of mass, the delivered momentum and the induced momentum from cratering nominally add and provide an ideal deflection result. In reality, the surface and shape of an asteroid deviate from spherical and can cause significant variations in the imparted impulse from the ejecta crater, thus adding a significant level of "noise" to the imparted change in velocity. Even if the asteroid shape is well known, targeting errors in delivering the impactor to the asteroid can cause the ejecta momentum to be oriented in significantly off-nominal directions.

We have embarked on a program to understand this effect using realistic asteroid shapes with simple analytical models for the transfer of momentum (Housen and Holsapple 2012) and testing and verifying these results using detailed numerical simulations of impacts with Spheral, an open source, adaptive SPH code computational tool (Owen 2010; Owen 2014). Comparisons will be made both to verify the utility of the analytical models and to validate initial computations that show a significant non-Gaussian uncertain component in the delivered impulse that arises from naturally occuring topography variations across an asteroid's surface.

Figure 1 shows the effect of asteroid topography on the delivered impulse to an asteroid. The variation seen in these histograms arises from convolving a

conservative ~50 meter diameter Gaussian 3-sigma targeting error ellipse onto the surface of asteroid Golevka (Figure 2), and modeling the beta enhancement as occuring normal to the local impact point. From this simple effect we see that a significantly non-Gaussian distribution in the delivered Delta V occurs, implying that the prediction of an asteroid's deflection will be strongly influenced by detailed surface morphology. Such systematic control errors will either require an over-designed mitigation or monitoring and reapplication of impacts to appropriately "steer" the hazardous asteroid.

The paper will focus on the physics of this effect, show verifications of the simple model using precise numerical simulations, and discuss the development of tools to represent the stochastic properties of delivered impulse as a function of surface topography.

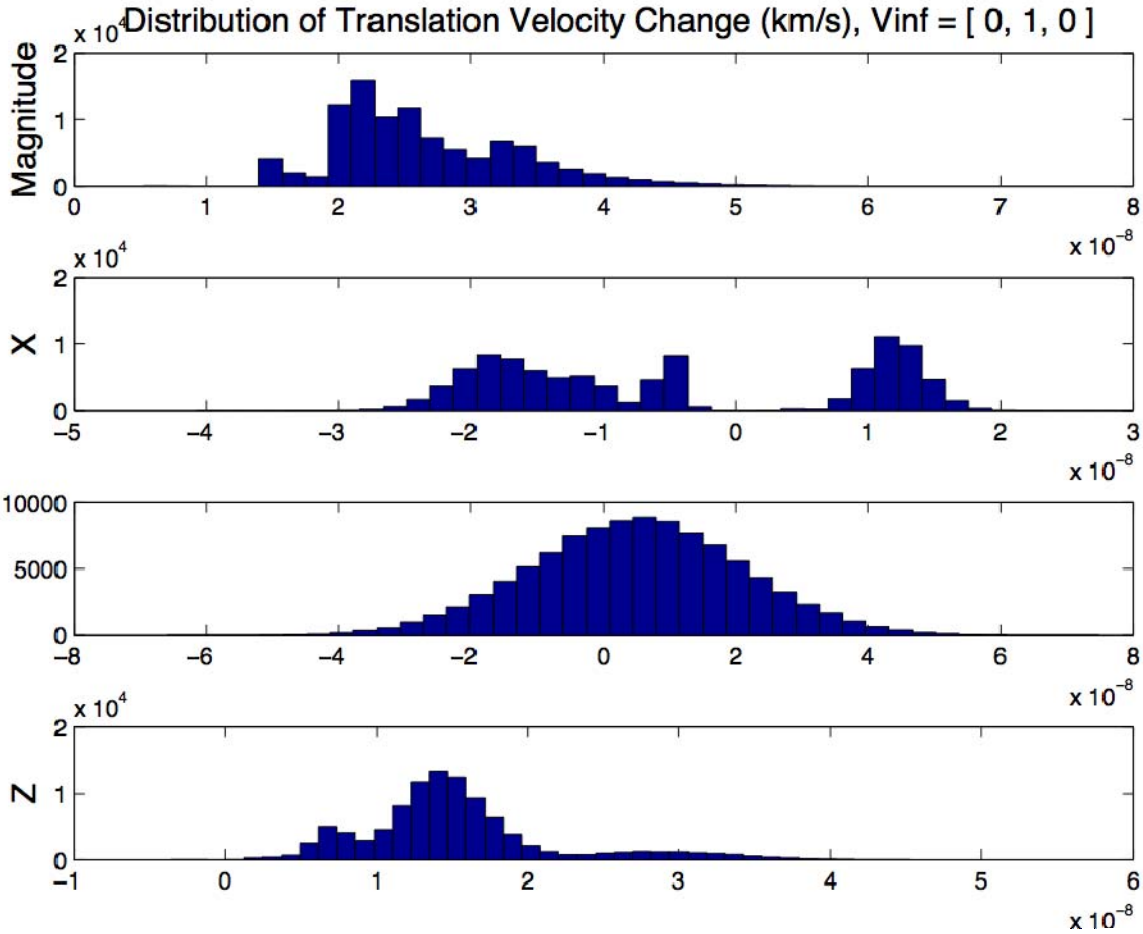

Figure 1: Histogram of delivered change in velocity to asteroid Golevka from a 1500 kg impactor striking the surface at 10 km/s with a 3-sigma targeting uncertainty of 25 meters (an accuracy of 0.1 asteroid radii).

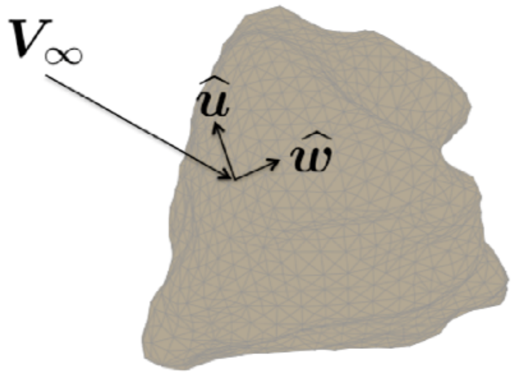

Figure 2: Shape model of asteroid Golevka showing the nominal impact point.

References
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