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DISRUPTION LIMITS OF KINETIC-IMPACTOR MITIGATION SCENARIOS

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ABSTRACT

Deflection and successful mitigation of modest-sized (<300 m) near Earth objects may be achieved by the momentum impulse from a kinetic impactor, given sufficient warning time [1]. The applicability of this approach is limited by current launch vehicle mass capabilities and achievable encounter velocities for a given hazardous object's orbit, along with the risk of disruption. Recent work highlights the delicate cohesive forces binding fast-rotating asteroids together and questions whether impulsive deflection strategies may pose serious disruption risk [2]. While disruption criteria for asteroids has been well-studied for the low-velocity (<5 km/s) impacts typifying natural collisions within the asteroid belt [3,4], prior studies have not systematically examined small-body disruption risk at a range of higher velocities. Additionally, the potentially destabilizing effects of rapid rotation have not yet been included in impact disruption calculations. Here we assess disruption risk at the upper end of physically plausible impactor masses (1000 and 10,000 kg) and encounter velocities (up to 30 km/s), using Spheral, an open source, Adaptive Smooth Particle Hydrodynamics (ASPH) code [5]. Key features of the code, including accurate modeling of anisotropic strain fields through adaptive node sampling, well-benchmarked damage models, self-gravity, an array of built-in equations of state and constitutive models, and user-extendibility to new physics packages, make Spheral particularly well-suited to probing the disruption/deflection limit for impulsive asteroid mitigation scenarios. While this study focuses on kinetic approaches, future contributions will examine the disruption limits for ablation by a standoff nuclear burst.

We investigate the effects of internal structure, macro- and micro-porosity, strength, composition, and rotation rate on total momentum impulse and disruption risk for spherical asteroid targets ranging from 50 to 300 m in diameter. A recent parametric study of momentum impulses from kinetic impactors used a planar target geometry, modest impactor masses (300 kg), and focused on near-crater effects [6]. Our approach considers full-body response to more massive (1000 and 10,000 kg)

impactors, to assess the safety limits of the kinetic impactor approach for a range of asteroid initial conditions.

Consistent with previous work, we find that the shock-attenuating effects of porosity provide protection from fragmentation while lowering the total momentum impulse [6]. Inclusion of a dynamic fracture model also decreases the total delivered impulse. For smaller asteroids, many of which rotate rapidly, disruption avoidance becomes a greater challenge. Results from this work have implications for decisions on mitigation. In particular, for cases when imparting the necessary velocity change from a kinetic impactor will risk accidental disruption, other methods (e.g., robust dispersal by a standoff nuclear device) may be advisable. We include example calculations of robust asteroid disruption and dispersal for completeness.

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