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When an Impactor is Not Enough: The Realistic Nuclear Option for Standoff Deflection

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ABSTRACT

When discovered sufficiently far in advance, impactors are the preferred deflection option for the more common, smaller asteroids. However, nuclear-explosive deflection may be essential for responding to the less common but more catastrophic large asteroids, or when the time to impact is short. Any nuclear response, particularly when time is short, will likely depend on a currently existing or active system. A detailed understanding of the energy output of such devices is a central part of estimating their deflection potential.

As a measure of the deflection possible from this option, we report the prompt speed change induced by surface material vaporized by a nearby nuclear explosion. The use of the vaporized material as the metric of deflection avoids uncertainty associated with additional ejecta (and impulse) that are affected by porosity. As such, our results represent a lower limit to the expected speed change. We then examine the prompt speed changes achieved by standoff bursts (between 50 m and 1 km), using a realistic description of the x rays, gammas, and neutrons resulting from a nuclear explosion that is representative of existing devices. It is shown that the impulse depends significantly on the x-ray spectrum, and less so on the yield. This is a consequence of differences in energy penetration depth, and the fraction of energy reradiated (lost).

To begin defining those asteroid characteristics that are important for mitigation, we examine the impulse differences seen with changes of composition, densities, and size on the prompt speed changes achieved, and scaling relationships ware examined. We

find that the impulse produced by an available spectrum is little affected for minerals composed of elements with atomic numbers below 20. Enhanced impulses are found when water or ices are present as volatiles (not bound in a high temperature hydrate). Alternatively, the presence of substantial iron reduces x-ray penetration and the resulting input.

Finally, with a realistic measure of the minimum speed change expected from nuclear explosives, we examine deflection options as a function the range of sizes and times-to-impact. Available yields are sufficient for kilometer-sized objects; the height of burst can be increased to appropriately tune the deflection magnitude for smaller (<1 km) bodies.

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