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**Probing Nuclear-Initiated Robust Disruption in Mesh-Based Simulations**

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**Keywords:** *Robust Nuclear Disruption, Mission-design analytic model*

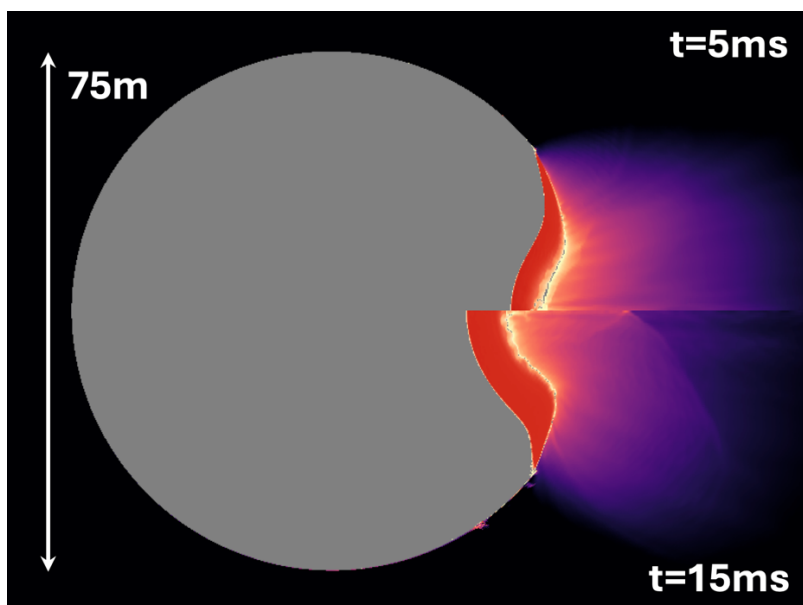
In the event of a potential asteroid impact on Earth, if an attempt can be made to prevent it, time will be of the essence. Simple models for determining what mission types are best-suited to deploy based on the circumstances are invaluable tools for facilitating a swift response. When NASA mission designers are exploring the mission space and uncertainties for exercises, such as the one aligned with this conference, they often rely on one such analytic model that estimates the deflection velocity ( $\Delta V$ ) a nuclear explosive device (NED) can impart to an asteroid.

The original analytic model delivered to NASA about a decade ago by LLNL researchers was based on 16 simulations covering various NED yields and heights of burst (HOBs) [1]. This model has since been updated with more simulations and higher fluence ranges [2,3] using new modeling capabilities [4] and the mesh-based code ARES. Development of an even more thorough update is underway, incorporating additional material options and properties, fitted with a larger set of simulation data. However, all these analytic fits are informed by deflection scenarios, with little chance of accidental disruption.

Mission designers often use this analytic model alongside generally accepted “rules-of-thumb” that compare the mission-imparted  $\Delta V$  against the asteroid’s escape velocity ( $V_{\text{esc}}$ ) to assess the feasibility of accidental weak disruption ( $0.1 \cdot V_{\text{esc}}$ )[5] or intentional robust disruption ( $10 \cdot V_{\text{esc}}$ ). The physics involved during a disruption includes shockwave propagation and the material’s strength and damage. In contrast, the deflection simulations are primarily influenced by the vaporization of surface material due to the NED’s x-ray photons, with minimal contribution from a shockwave. Therefore, the analytic model is ill-suited for informing disruption scenarios, especially robust or intentional ones.

Though disruption scenarios are best simulated using a high-fidelity, multi-physics code that is well benchmarked to experimental strength and damage (such as Spherical), the authors recognize that these simulations are costly in terms of time and computing resources with current capabilities. Therefore, alongside the updated analytic model, we present results from a suite of simulations in ARES (such as in the figure below) to better inform mission designers about the likelihood and nature of disruption for various scenarios to discourage over-extrapolation of the analytic model.

Prepared by LLNL under Contract DE-AC52-07NA27344. LLNL-ABS-871403.



[1] R. A. Managan, J. V. Wasem, K. M. Howley. “Near Earth Object Deflection Formulae.” 7th IAA Planetary Defense Conference – PDC 2021. 26–30 April 2021, Virtually hosted. IAA-PDC21-0X-YY.

[2] R. A. Managan, M. T. Burkey. “Extending NEO Deflection Formulae to High Fluences.” 8th IAA Planetary Defense Conference – PDC 2023. 3–7 April 2023, Vienna, Austria.

[3] Managan, R. A. & Burkey, M. T. 2023, LLNL/Analytic\_Deflection\_of\_Asteroids\_by\_NEDs, [https://github.com/LLNL/Analytic\\_Deflection\\_of\\_Asteroids\\_by\\_NEDs](https://github.com/LLNL/Analytic_Deflection_of_Asteroids_by_NEDs).

[4] M. T. Burkey *et al.* "X-Ray Energy Deposition Model for Simulating Asteroid Response to a Nuclear Planetary Defense Mitigation Mission," *The Planetary Science Journal*, 2023.

[5] D. P. S. Dearborn and P. L. Miller, "Defending Against Asteroids and Comets," in *Handbook of Cosmic Hazards and Planetary Defense*. Cham: Springer International Publishing, 2015, pp. 733-754.

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