PDC2019
Washington, DC, USA

Please send your abstract to iaapdc (at) iaamail.org

You may visit www.pdc.iaaweb.org

(please choose one box to be checked)
(you may also add a general comment - see end of the page)

- ☐ **Key International and Political Developments**
- ☐ **Advancements and Progress in NEO Discovery**
- ☐ **NEO Characterization Results**
- ☒ **Deflection and Disruption Models & Testing**
- ☐ **Mission & Campaign Designs**
- ☐ **Impact Consequences**
- ☐ **Disaster Response**
- ☐ **Decision to Act**
- ☐ **Public Education & Communication**

Gravitational Dynamics of Fragments in Nuclear Disruption Scenarios

Patrick King(1)(2), Megan Bruck Syal(3), J. Michael Owen(4), and Cody Raskin(5)
(1) *Department of Astronomy, University of Virginia, 530 McCormick Road, Charlottesville, VA 22904 (540)-905-9770 pkk4hu@virginia.edu*
(2) *Lawrence Livermore National Laboratory (LLNL), 7000 East Avenue, Livermore, CA, 94550 (925)-423-0309 king97@llnl.gov*
(3) *LLNL, (925)-423-0435 syal1@llnl.gov*
(4) *LLNL, (925)-423-7160 owen8@llnl.gov*
(5) *LLNL, (925)-422-8796 raskin1@llnl.gov*

Keywords: *Disruption, Fragmentation, Numerical Simulation, Gravity, Nuclear Explosives*

ABSTRACT

While kinetic impacts can effectively deflect small asteroids in scenarios with long warning times, situations may arise in which a kinetic impactor cannot move the asteroid off an Earth-impacting orbit [1]. In these cases, nuclear explosives may provide a sufficient impulse to achieve successfully deflection (keeping the target bulk intact) or disruption (thoroughly fragmenting and dispersing the target). Disruption may be the only effective strategy for scenarios with short warning times. Modeling these scenarios require calculations that span a large range of time and distance scales. To that end, we present two concurrent efforts: the first designed to constrain both the fragmentation processes occurring during a nuclear explosive scenario, and the second, to follow the fragments along realistic gravitational trajectories to determine how many fragments still hit Earth. Together these efforts provide insight into the expected consequences of the nuclear option.

We present modeling efforts aimed at high-fidelity determination of the fragments using 3D Adaptive Smoothed-Particle Hydrodynamics (ASPH) simulations performed using Spheral++, which incorporates material strength, fracture, and porosity. We use a semi-analytic energy deposition scheme assuming the device is a prompt point source of soft x-rays; the target body is constructed using a shape model for the near-Earth asteroid Bennu. Ablative processes are initiated, leading to the production of an inward-moving shock and outward-moving ejecta, which initiates fragmentation. An example calculation is shown in Figure 1. Cohesive fragments are identified using a friends-of-friends algorithm, which in turn provides a list of fragment characteristics.

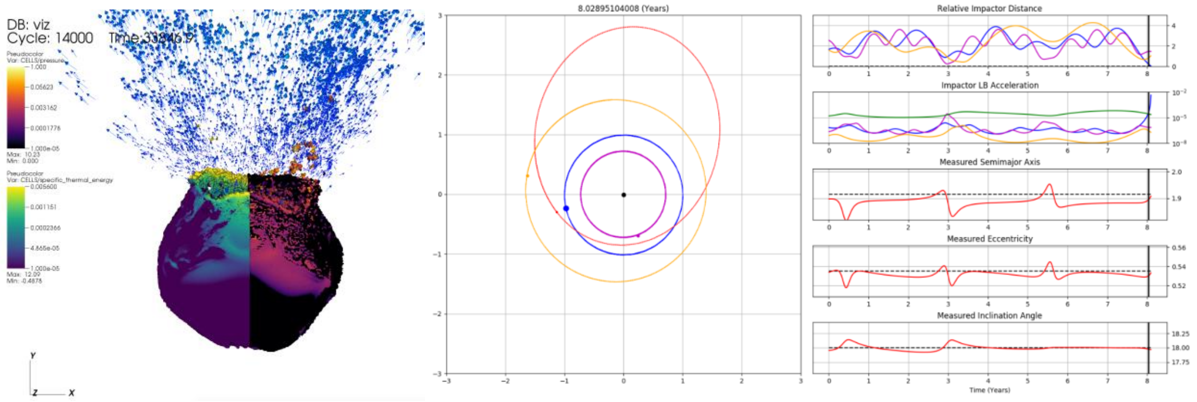

Figure 1. *Left: An example simulation, 33.846 milliseconds after a nuclear explosive was set off 60 meters above the 100-meter diameter target. Shown is a cross-sectional view of the target, with specific thermal energy on the left and pressure on the right; arrows indicate velocities of ejecta. Middle: positions/trajectories of Earth (blue), Mars (orange), Venus (purple), and the hazardous asteroid from the PDC-2019 exercise, shown shortly before impact. Right: relative distances between the planets and the hazardous asteroid (top); gravitational accelerations (including Jupiter in green); and the instantaneous semimajor axis, eccentricity, and inclination, relative to nominal, demonstrating the influence of the planets.*

We also present gravitational N-body calculations that follow fragment orbits after a disruption event. An orbit is constructed using desired orbital parameters for the hazardous body. The body is then replaced with fragments and the system integrated forward. An example hazardous orbit, along with some relevant quantities, are presented in Figure 1. Impact events are logged along with important characteristics such as relative impact velocity. We study both simplified scenarios (such as pure disruption or deflection scenarios) as well as realistic scenarios derived from our fragmentation modeling efforts. We consider both late- and early-time interventions to better quantify the evolution of the fragment distributions.

This work was performed under the auspices of the Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344. LLNL-ABST-763207-DRAFT.

[1] Barbee, B. W. et al. Options and uncertainties in planetary defense: Mission planning and vehicle design for flexible response. Acta Astronautica 143 (2018), 37-61.

****