PDC2023
Vienna, Austria

Deflection / Disruption Modeling & Testing

INITIATIING NUCLEAR MITIGATION MISSION SIMULATIONS WITH A SIMPLIFIED X-RAY ENERGY DEPOSITION MODEL

Mary T. Burkey[(1)], Robert A. Managan[(1)], Nicholas A. Gentile[(1)], J. Michael Owen[(1)], and Megan Bruck Syal[1)]

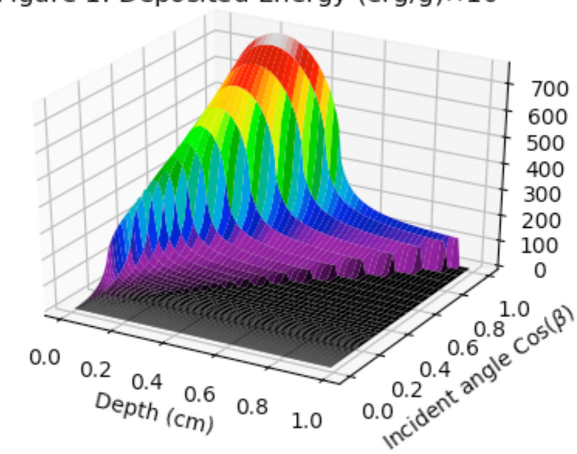
[(1)] *Lawrence Livermore National Laboratory, 7000 East Ave, Livermore, CA 94550, corresponding email: burkey1@llnl.gov*

Keywords: *Nuclear Deflection/Disruption, X-ray Deposition, Spheral*

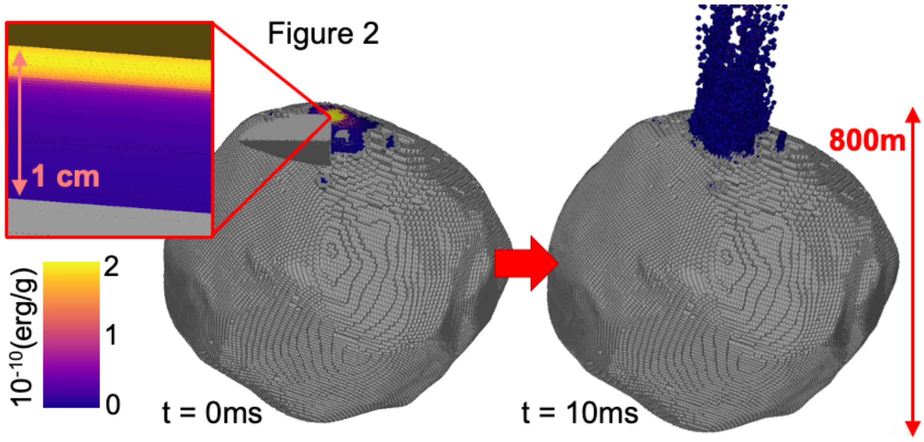
ABSTRACT

Though the DART Mission demonstrated the effectiveness of kinetic impact technology for altering an asteroid’s orbit, there remain many scenarios, including this PDC exercise, where a kinetic impactor would not be sufficient to prevent an Earth impact. In these instances, utilizing a nuclear device is a versatile, alternative mission option. With almost 100,000 times more output energy per launch mass than a kinetic impactor and post-launch energy tuning capabilities via the standoff distance, the nuclear device remains a powerful option for planetary defense. Predicting the efficacy of a potential nuclear deflection or disruption mission depends on accurate multiphysics simulations of energy deposition, ablation, and blowoff. Especially in cases where short warning times prevent a rendezvous mission to constrain a Near-Earth Object’s (NEO’s) physical properties, having a reliable simulation to gauge the uncertainties’ influence on mission success is invaluable. However, modeling the complete response of an NEO to the radiation from a nuclear device is scientifically complex and computationally expensive. The main type of radiation from a nuclear device is soft x rays, which penetrate less than a centimeter into NEO surface material and require a full radiation-hydrodynamics code to properly simulate. The shockwave that develops after enough material is vaporized and ejected may travel through the entire NEO in the case of a disruption and would require a hydrocode with accurate strength and damage models, such as Spheral, to model. Thus, the problem is best approached by initializing a hydrocode with results from an early-time rad-hydro simulation. We present a completed energy deposition model for initiating a nuclear mitigation mission hydrocode simulation that accurately reflect the results of a full simulation. Development was completed using the Kull Multiphysics code, which is a fully-coupled radiation

Figure 1: Deposited Energy (erg/g)×10^{-10}



hydrodynamics simulation with Implicit Monte Carlo (IMC) transport. The model encompasses four different NEO-like materials (Silicon Dioxide, Forsterite, Ice, and Iron) at porosities ranging from 0 to 80%, with radiation source fluences of 1 to 1e-4 kt/m^2 using either a 1 or 2 keV black body spectra. An example of what the energy deposition profile looks like as a function of depth and incident angle for an 800m Silicon Dioxide NEO with 21% porosity (an approximation of the exercise asteroid) can be seen in Figure 1. An example of the initial and late-time results of a Spheral simulation of the same asteroid using a Bennu shape model can be seen in Figure 2. With the completion of this model, and combined with the ever-increasing capabilities in Spheral, the vast model-space of an NEO's physical properties can be explored for mission effectiveness.



Prepared by LLNL under Contract DE-AC52-07NA27344. LLNL-ABS-843109

****

Comments:

If possible, an oral presentation would be great. Thank you!