ASTEROID THREAT MITIGATION: AN IN-DEPTH LOOK AT WHAT CAN BE DONE IN THREE REAL-OBJECT SCENARIOS.

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Introduction: Nuclear explosions and kinetic impactors are two possible methods for diverting objects on a collision course with Earth. These two methods mitigate a potential impact by delivering an impulse that either deflects or disrupts a body. Our project at Lawrence Livermore National Laboratory (LLNL) investigates issues important to the nuclear approach, including the development of scenarios of impact objects, modeling energy coupling to asteroids, response to the energy deposition, orbital dispersion, and quantifying the effectiveness of the nuclear approach relative to other methods. Here, we apply the nuclear method to a select few objects and quantify the outcome. We select 2008 EV5, Apophis and 1998 KY26 as our test cases to coarsely span the range of potential threats. We then reposition these objects to create a certain future impact, and model the response of these bodies to a fission weapon and a thermonuclear weapon spectrum [1]. For comparison, we also model the response of these bodies to 1 ton and 10 ton kinetic impactors with impacting velocities of 10 km/s and 20 km/s. Special attention will be paid in the kinetic impactor simulations to the effect of material, object shape, and impact direction and position on the beta value obtained from the impact, where a beta of greater than one indicates that more than just the impactor momentum was transferred to the target body. The range of practically achievable beta values will significantly affect the parameters under which objects can be successfully diverted using a kinetic impactor with current launch lift capability.

Case Studies :

2008 EV5. We select the near-Earth asteroid 2008 EV5 as our first case study. This object is a 400 +/- 50 meter diameter oblate spheroid with shape data [2]. It has a large ridge parallel to the equator that is thought to be a rubble pile. On the ridge, there is a concavity that is likely the result of an impact. This object is hypothesized to be a rocky or stony-iron C-class object. It has a spectrum that best matches the CI carbonaceoius chondrite Orgueil [3], which we model the composition after. The bulk density has been estimated at 3.0 +/- 1.0 g/cc [4]. We use 2.0 g/cc, the lower bound of this range estimate, as the bulk density in our simulations.

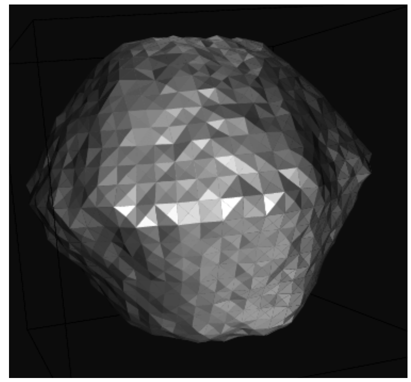

Figure 1: Surface shape model for 2008 EV5 used to generate initial conditions for our modeling.

Apophis. We select the near-Earth asteroid Apophis as our second case study. This object is a 324 +/- 25 meter diameter object [5] that was original thought to have a high probability of impacting Earth in 2029 [6]. We choose this object for study because it was a real threat with limited shape data available. In a real threat scenario, we may know very little about our potential impactor, including the size, shape and composition.

1998 KY26. We select the near-Earth object 1998 KY26 as our third case study. This object is a roughly spherical, 30 meter diameter, fast rotating object with shape data [7]. It rotates at a speed of 10.7 minutes, which has led to the belief that it is not a rubble pile [7]. Color and radar information suggests that this body is a water-rich carbonaceous chondrite [7].

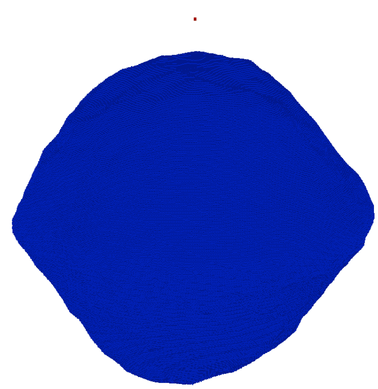

Figure 2: 2008 EV5 as modeled with ASPH points. A kinetic impactor is approaching from above the object in this scenario, shown in red.

Simulation tools: We are utilizing a range of simulation capabilities to explore the response of these bodies to nuclear explosions and kinetic impactors. For the nuclear approach, we begin by studying how the energy from our devices couples to the bodies using MCNP, a Monte Carlo N-particle transport code developed by Los Alamos Laboratory [8]. Next, in order to model the late time evolution of these scenarios we emply the ASPH (Adapative Smoothed Particle Hydrodynamics [9,10]) code Spheral++, which follows the evolution of the hydrodynamics with strength and porosity, gravity, damage evolution, fracture and failure. In one example we use the radar shape information for 2008 EV5 provided in [2] to generate a surface model shown in Fig. 1. This is used to generate the intial ASPH material model in Fig. 2, which in this case employs 10^7 ASPH points to represent the asteroid. In this case a 2m long aluminum kinetic impactor is set approaching from the pole of the asteroid at 10 km/sec. The initial conditions shown here are only one scenario considered: we similarly model the response of each of our case study bodies to thermonuclear energy deposition and several kinetic impactors, allowing the self-consistent comparison of the response of each object to each of these mitigation techniques.

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