Modeling the Dynamic Response of an Asteroid or Comet to a Nuclear Deflection Burst

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There is much popular press about Potentially Hazardous Objects (PHOs) and how to mitigate their threat. The two mitigation options are destruction or deflection of the PHO. Presently, the most technically feasible method of deflection is a nuclear stand-off burst. However, many questions remain as to the response of an asteroid or comet to a nuclear burst. Recent increases in computing power and scientific understanding of the physical properties of asteroids and comets make it possible to numerically simulate the response of these porous and inhomogeneous bodies to strong shocks and radiation. Here we use the radiation-hydrocode RAGE to explore the coupling of the energy from a nuclear burst to a simplified PHO. We start with simple 1-D and 2-D models of material responses to variations in device yield, along the with composition and porosity of the PHO.

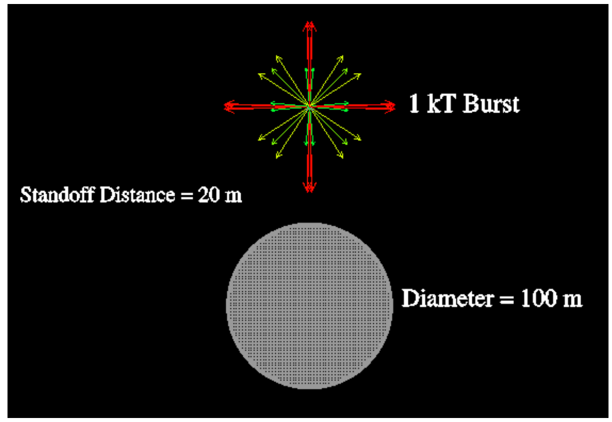

Figure 1: Initial configuration of the 100 meter target and nuclear munition (small dot)

Background

The NASA 2007 white paper "Near-Earth Object Survey and Deflection Analysis of Alternatives" [1] affirms deflection as the safest and most effective means of PHO impact prevention. It also calls for further studies of object deflection. In principle, deflection of a PHO may be accomplished using kinetic impactors, chemical explosives, gravity tractors, or nuclear munitions. Of these, nuclear munitions are by far the most efficient in terms of yield per unit mass launched and are technically mature. However, there are still significant questions about the response of a comet or asteroid to a nuclear burst. Previous calculations of deflection by nuclear munitions ([2], [3], [4], [5], and [6]) either do not assume a standoff burst and/or do not account for the substantial porosity or internal composition variations. These properties may substantially affect how a PHO responds to a standoff nuclear burst [7]. Several recent rendezvous and flyby missions to asteroids and comets showed their wide range of structure and composition, allowing us to model them better. In addition, we now have available computer codes that allow us to model the response of a simulated PHO to the energy from a nuclear burst.

Model Parameters

We use the RAGE radiation-hydrodynamics code [8] with radiation transport. For our initial studies, we use a fiducial 100 meter spherical target that is a uniform 50:50 mixture of basalt and water ice. We do not model the nuclear munition in detail. The energy is sourced into a 50 cm diameter aluminum sphere over an arbitrary, but short (5 μsec) time interval. This "device" is 20 meters away from the near surface of the target, which is the optimum standoff distance according to [2]. To simulate the nuclear burst, we source in the desired amount of energy Because RAGE is not set up to handle a true vacuum, we use a low density ($\sim 3 \times 10^{-8}$ g/cm^3) solar wind composition gas for the background. In figure 1, we show the initial configuration of the target and munition.

For our preliminary parameter study, we consider solid spheres of pure basalt, along with 05:95, 50:50, 95:05 basalt/ice, and pure ice compositions. All of these are simulated as 100 m diameter spheres. We also examine the response of a pure basalt sphere to different yields and consider 1 kt, 10 kt, 100 kt, and 1 Mt. At present, we consider these sources to be blackbodies, which means most of the energy will be X-rays. Finally, we will vary the standoff distance to determine which distance is optimal [7].

At the moment, we have run the calculations to 10^{-3} seconds to obtain initial estimates of the ablated material and the deflection velocity imparted to the target.

Preliminary Results

Here, we present results for a 100 meter sphere of 50:50 basalt/ice for yields of 1 kt, 100 kt, and 171 Mt (the latter is an example of the response to a yield which will vaporize the body). In figure 2 we show a plot of the radiation temperature about $2\mu s$ after the start of energy being sourced into the problem. The 1 kt source problem has an ablation velocity of about 40 m/s, while the 100 kt source problem has material ablating at over 8 km/s. We will show additional results on the ablation of material and the deflection velocity at the meeting. In addition to running parameter studies, we will also come up with problems that will allow us to validate the RAGE results for asteroid deflection.

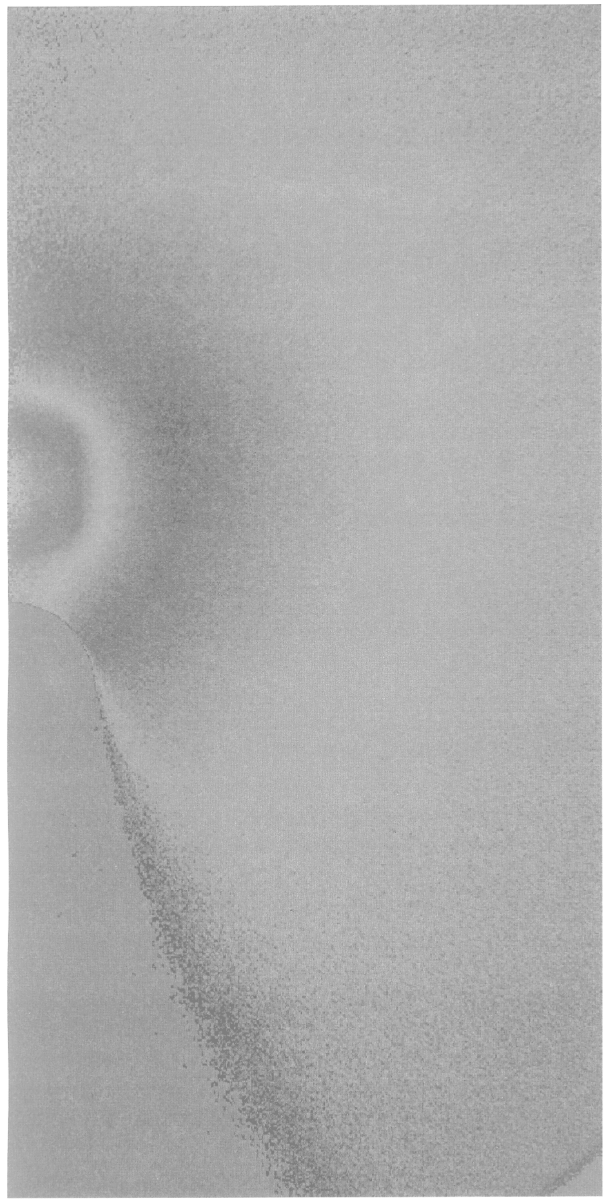

Figure 2: Radiation temperature plot at $2\mu s$ after the start of sourcing energy into problem. The burst is centered in the "ring" near the top. Note the "shadowing" of the radiation by the asteroid. The temperature range is 0.018 to over 300 eV.

References

[1] NASA. Technical report, NASA Office of Program Analysis and Evaluation, (2007). [2] Ahrens, T. J. and Harris, A. W. In *Hazards Due to Comets and Asteroids,* Gehrels, T., Matthews, M. S., and Schumann, A. M., editors, (1994). [3] Schafer, B. P. e. a. In *Hazards Due to Comets and Asteroids,* Gehrels, T., Matthews, M. S., and Schumann, A. M., editors, (1994). [4] Simonenko, V. A. e. a. In *Hazards Due to Comets and Asteroids,* Gehrels, T., Matthews, M. S., and Schumann, A. M., editors, (1994). [5] C., S. J. and Snell, C. M. In *Hazards Due to Comets and Asteroids,* Gehrels, T., Matthews, M. S., and Schumann, A. M., editors, (1994). [6] S., D. D., Patenaude, S., and Managan, R. A. In *Proc. Planetary Defense Conference*. [7] Holsapple, K. A. In *Mitigation of Hazardous Comets and Asteroids,* Belton, M. J. S., Morgan, T. H., Samarasinha, N. H., and Yeomans, D. K., editors, 113–+, (2004). [8] Gittings, M., Weaver, R., Clover, M., Betlach, T., Byrne, N., Coker, R., Dendy, E., Hueckstaedt, R., New, K., Oakes, W., Ranta, D., and Stefan, R. *Computational Science and Discovery* **1**, 015005 December (2008).