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PHYSICS OF NUCLEAR ENERGY DEPOSITION FOR THE DEFLECTION OF ASTEROID AND COMETS

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ABSTRACT

Nuclear explosions are a potential method for diverting an object on a collision course with Earth. This approach is especially effective when the object is large and/or the time to impact is short. Deflection using a stand-off nuclear explosion works by heating surface material such that it is ejected, which provides thrust to the remaining mass. Since the magnitude of the deflection achieved scales with the amount of mass ejected, it is desirable to heat larger masses to a lower temperature rather than smaller masses to a higher temperature. In both cases, energy densities sufficient to melt material must be reached in order to achieve deflection.

In a stand-off nuclear explosion, a significant fraction of the energy deposited consists of thermal x-rays and neutrons. In this talk, we explore the energy coupling efficiencies from these sources in a variety of asteroid and comet-like compositions using the particle transport codes MCNP6 and Mercury. We explore monochromatic x-rays from 1-100 keV, mono-energetic neutrons at 2.45 MeV and 14.1 MeV, and fission and thermonuclear weapon neutron spectra into ice (H_2O), silicon dioxide (SiO_2), forsterite (Mg_2SiO_4) and iron-nickel (α-[Fe,Ni]). We find that at energy densities sufficient to melt material, neutrons and hard x-rays are most effective at affecting mass. Soft x-rays, on the other hand, are able to melt material at fluences for which neutrons and hard x-rays won't melt any material. However, as the energy of the soft x-rays is decreased and/or the fluence is increased, a significant fraction of the energy deposited is re-radiated away before material can respond, thereby decreasing the amount of momentum available for transfer. These results demonstrate the importance of the nuclear explosion spectrum on the energy deposition profile, and consequently on the magnitude of the deflection acheived.

Using the results from MCNP6 and Mercury, we develop analytic approximations for the x-ray and neutron energy deposition profiles into the asteroid and comet-like

materials at varying angles of incidence. The talk by Robert Managan titled “1D to 3D Mapping for Nuclear Energy Deposition” discusses the details of mapping the tablular and analytic 1D profiles onto arbitrary 3D geometries. The talk by Joseph Wasem titled “Differences in Nuclear Deflection Scenarios with Oddly Shaped Asteroids” uses the 1D to 3D mapping framework to look in detail at how the shape and features of a target affect the deflection outcome. The talk by David Dearborn titled “Standoff Deflection of Asteroids: The Realistic Nuclear Option” explores the asteroid deflection speeds achieved for x-ray spectra representative of some stockpile systems.

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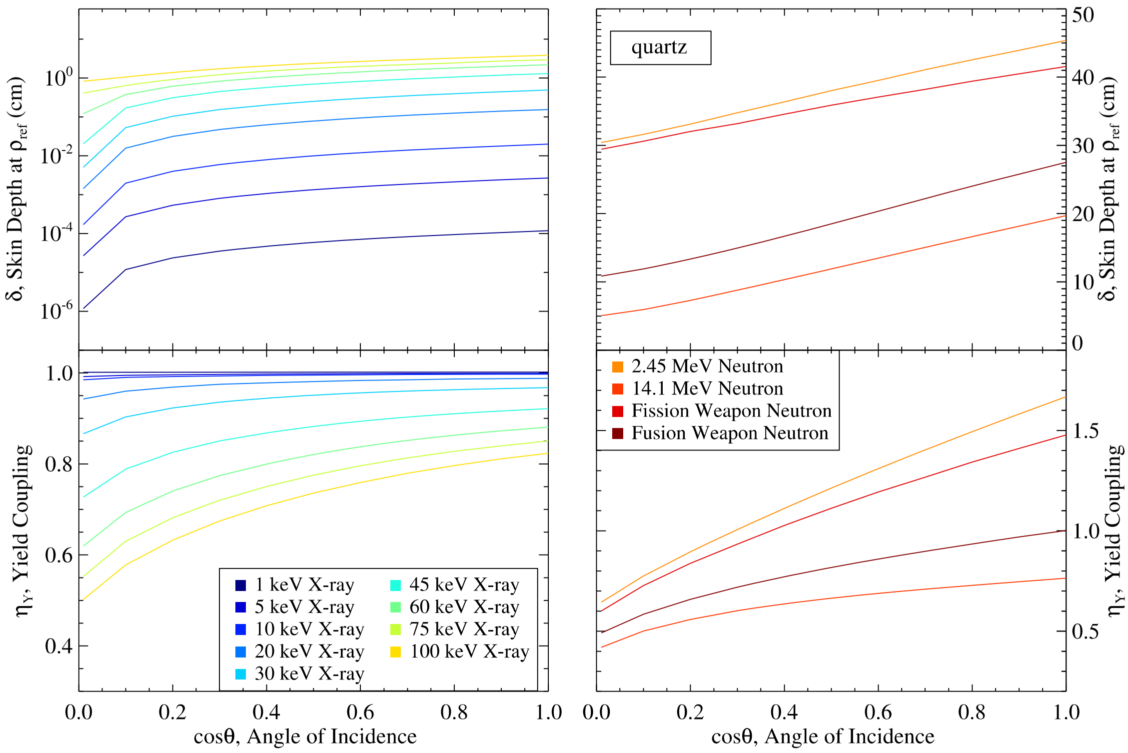

Approximate skin depth and energy coupling efficiencies for various energy types as a function of angle of incidence into silicon dioxide. Clockwise from top left: Depth at which x-rays deposit (1-1/e) fraction of their energy, depth at which neutrons deposit (1-1/e) fraction of their energy, fraction of incident neutron energy deposited, fraction of incident x-ray energy deposited.

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