Abstract
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. Here, we explore the effect of neutrons and photons on various asteroid- and comet-like materials.

Analytic Approximation
We develop a simple analytic approximation to model how energy couples to a material. We assume that the probability of a mono-energetic photon or neutron interacting within a homogenous material decreases exponentially with path length (Beer-Lambert Law). Using this assumption, we can characterize the energy deposition profile as a function of depth \( z \):

\[
 f(z) = \frac{\eta_Y}{\delta} \exp\left[\frac{z}{\delta}\right]
\]

where the skin depth \( \delta \) is the depth at which 1-1/e fraction of the energy has been deposited and the yield coupling efficiency \( \eta_Y \) is the fraction of incident energy deposited. The goal of this approximation is to construct analytic deposition equations that can be applied to a variety of 2D and 3D geometries (see posters by Joe Wasem & Rob Managan).

Energy Coupling
Using the N-particle transport codes MCNP and Mercury, energy deposition profiles for photons and neutrons are determined as a function of energy type, angle of incidence and target material.

Melted/Vaporized Material as a Metric for Deflection
Predicting the response of a particular object is difficult, since ejecta size and velocity distributions rely heavily on the unknown, complicated internal structure of the body. However, lower bounds on the blow-off momentum can be estimated using the melted/vaporized surface material. At identical yields \( Y_{source} \) sufficient to melt a given material the blow-off momentum scales as,

\[
 p \propto \delta \eta_Y Y_{source}
\]

Above: Illustration of how deflection using a nuclear device works. (1) A nuclear device intercepts a body at some standoff distance. The device goes off depositing energy into the object in the form of neutrons and photons. (2) The material heats up and blows off. Because of conservation of momentum, the blow-off imparts momentum to the remaining mass resulting in a deflection event.

Above: Combining \( \delta \) and \( \eta_Y \) gives an estimate of the melt depth for different energy sources in SiO\(_2\) as a function of source yield and stand-off distance. The more material melted/vaporized, the larger the push from the initial blow-off.

Above: Schematic phase diagram in the pressure-entropy plane illustrating the isentropic expansion of bolide material that has been melted/vaporized as a result of isochoric heating. Material that is melted/vaporized will ultimately be lost from the parent body. Credit: Richard Kraus