IMPACT HAZARD MITIGATION RESEARCH AT LOS ALAMOS NATIONAL LABORATORY: CURRENT STATUS AND WHAT WE COULD LEARN FROM SPACECRAFT RECONNAISSANCE. C. S. Plesko¹, Jim M. Ferguson², Galen R. Gisler², Robert P. Weaver², ¹Los Alamos National Laboratory, XTD-NTA (plesko@lanl.gov), ²Los Alamos National Laboratory, XTD-PRI

Introduction: Los Alamos National Laboratory (LANL) has been tasked by the National Nuclear Security Agency (NNSA) to study the mitigation of the impact hazard of asteroids and comets on the Earth. We are modeling two possible methods of hazard mitigation; deflection or disruption of a hazardous object by kinetic impactor or nuclear burst. Kinetic impactors transfer momentum directly through impact and through a target-dependent momentum enhancement by ejected target material. Nuclear devices impart momentum to the target object by vaporizing target material and lofting it, and in some cases entrained solid material, away from the body. The implementation of these mitigation methods would be a multivariate function of the geometry of the situation, the yield or mass of the device, and the composition of the object.

Methods: We use several numerical methods to model energy deposition and predict target response.

Hydrocode Models of Impacts. We use the RAGE hydrocode [1] with several strength and porosity models to simulate the impact of different impactors into target asteroids of varying shape and composition, including both sub-mesh scale and macro-scale voids.

Hydrocode Models of X-ray Energy Deposition. Approximately 97% of the energy emitted by a nuclear device is in the form of kinetic energy (debris) and thermal radiation (x-rays). We model this portion of the energy using the RAGE hydrocode’s gray diffusion radiation transport model that simulates the flow of wavelike light in a problem in combination with the SESAME equation of state and opacity tables [2]. Gray diffusion is similar to a black body model except the bodies absorb and radiate with an inefficiency, σ < 1.

Particle Transport Code Models of Neutron Energy Deposition. The remaining energy is released as nuclear radiation (neutrons and gamma rays), which deposit their energy much deeper in the target than x-rays do, so they may have a significant effect on the amount of debris and momentum ejected from the surface. We model the nuclear radiation energy deposition using the MCNP particle transport code [3].

Model Results to Date: We have conducted a series of verification and validation models previously [4][5]. Currently, we are modeling a simplified analog of asteroid Bennu, the Osiris-REX mission target, in collaboration with Lawrence Livermore National Laboratory [6], who are modeling the same target. Impact models conducted by Gisler use a 64-cm-diameter impactor striking the target at 20 km/s. He is exploring the effects of target properties on momentum enhancement (Fig. 1). X-ray deposition models by Weaver, Plesko, and Ferguson, explore the dynamic response of both solid objects and those with macro-scale porosity, and the energy required to disrupt km-scale bodies (Fig. 2). MCNP models by Ferguson and Plesko explore the dependence of neutron energy deposition on object composition (Fig. 3).

Model Constraints from Spacecraft Reconnaissance: We cannot assume that spacecraft reconnaissance data will be available for a specific PHO prior to a mitigation attempt. The deflection mission would likely be the first spacecraft rendezvous. Spacecraft reconnaissance data is most valuable to us as aggregate information about the diversity of objects we might encounter, particularly information about possible internal structure and composition, macro- and micro-porosity, and the heterogeneity of structure and composition observed for a given object and across dynamical families and spectral types.


Fig. 1 (left): Ejecta v< 1m/s at t=0.1s, 64 cm impactor at 20 km/s into a 500 m solid quartz sphere.
Fig. 2 (below, middle): 1 Mt X-ray energy burst deposited into a 1 km x 0.5 km aggregate of spherical basalt boulders.
Fig. 3 (bottom): MCNP model of neutron deposition into CI Chondrite, mean free path 2.9 cm.