LOS ALAMOS RAGE HYDROCODE SIMULATIONS OF EFFECTIVE MITIGATION OF POROUS PHO OBJECTS.
R. P. Weaver[1], C.S. Plesko[1] and W.R. Dearholt[1], [1]Los Alamos National Laboratory, MS T087, Los Alamos, NM 87545 (rpw@lanl.gov, plesko@lanl.gov, and wrd@lanl.gov)

Introduction: Disruption of a potentially hazardous object (PHO) by an energetic surface or subsurface burst is considered as one possible method of impact-hazard mitigation. This technique of employing surface or subsurface explosions has been popularized in the media but is probably one of the lower priority deflection/disruption methods, unless the warning time is short. In all of our current simulation we use realistic RADAR shape models for the initial geometry, not merely spherical objects. The non-sphericity of the geometry is very important in the resultant shock hydrodynamic evolution. We use the Ostro et al. (2004) [1] shape model of Asteroid 25143 Itokawa obtained from Goldstone radio telescope data with 20 m resolution.

There are two potential scenario's for the use of interior explosions to mitigate PHOs. First, is where the source explosion is emplaced at or near the surface of the object. An explosion energy of ~500 kt then results in strong shocks that will preferentially eject material from the surface near the explosion and by conservation of momentum the remainder to the body as a significant force in the opposite direction. Any porosity of the object will reduce the momentum imparted. The goal of this type of intercept would be to impart a large enough velocity to the remaining object/fragments so that they would miss the earth orbit by a significant margin. The second subsurface method of mitigation would be to emplace the explosive source below the surface of the object and independent of the composition of the PHO the explosion would have enough power to significantly disrupt the entire body, leading to ejection velocities well above the escape velocity. Given a large enough explosion [here we consider energies of 100 kilotons (kt) – 10 megatons (Mt) TNT equivalent] the PHO would be fractured into smaller fragments with sufficient velocity to again miss the Earth's orbit by a significant margin. First we considered the second option – a centrally located explosion, where we used the RAGE hydrocode to simulate the imparted momentum as a function of depth-of-burial (DOB). Note that the RAGE code has been extensively verified and validated for these types of shock physics applications [2] - [7]. Next, we built our computational models from simple to more complex by first considering uniform composition non-spherical objects and then non-uniform, or "rubble pile" initial geometries. These rubble piles can have a very large range of actual internal compositions for which we have no actual data. We consider various rubble pile geometries. In this work we do not consider any political nor engineering issues with obtaining the initial conditions assumed in these model hydrocode simulations. An example of a surface 500 kt explosion on a 25% porous object in the shape of Asteroid 25143 Itokawa is shown in Figure 1.

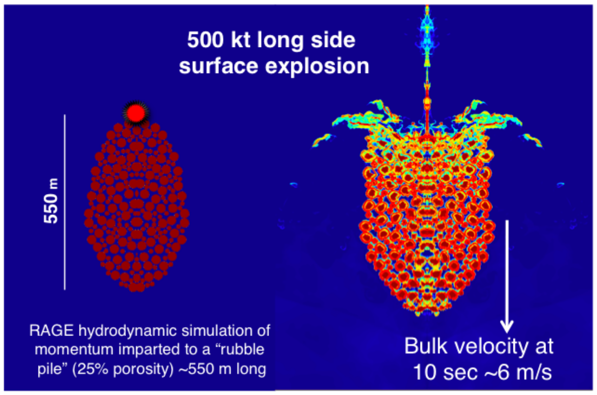

Figure 1. An example of a RAGE hydrocode simulation of a 500 kt surface explosion at the long side resulting in mass jection velocities of ~6 m/s after 10 seconds.

References: [1] Ostro, S. J., L. A. M. Benner, et al. (2004). "Radar observations of asteroid 25143 Itokawa (1998 SF36)." Meteoritics and Planetary Science **39**: 407-424. [2] Gittings, M.L., et al., "The RAGE radiation-hydrodynamic code," *Comput. Sci. Discovery*, **1** (1), (2008). [3] Gisler, G. R., "Two-Dimensional Convergence Study of the Noh and Sedov Problems with RAGE: Uniform and Adaptive Grids," Los Alamos National Laboratory report LA- UR-05-2809 (2005); [4] Kamm, J. R., W. J. Rider, et al., "Space and Time Convergence Analysis of a Crestone Project Hydrodynamics Algorithm," Los Alamos National Laboratory report LA-UR-02- 5962 (2002); [5] Kamm, J. R., "Investigation of the Reinicke and Meyer-ter-Vehn Equations: 1. The Strong Conduction Case," Los Alamos National Laboratory report LA-UR-00-4304 (2000); [6] Baltrusaitis, R. M., M. L. Gittings, et al. (1996). "Simulation of shock-generated instabilities," *Physics of Fluids*, **8** (9), 2471–2483 (1996); [7] Zoldi, C. A. (2002). "A numerical and experimental study of a shock-accelerated heavy gas cylinder," Ph.D. thesis, SUNY Stony Brook (2002).