Analysis of ejecta fate from proposed man-made impactors into near-Earth objects — a NEOShield study

S. Schwartz[1], P. Michel[1], and M. Jutzi[2]

[1]Lagrange Laboratory, University of Nice-Sophia Antipolis, CNRS, Observatoire de la Côte d'Azur, France
[2]University of Bern, Center for Space and Habitablity, Physics Institute, Sidlerstrasse 5, 3012 Bern, Switzerland

Asteroids measuring 100 meters across tend to impact the Earth once every 5,000 years on average [1]. Smaller bodies enter into the Earth's atmosphere more frequently, but may detonate before reaching the surface. Conversely, impacts from larger bodies are more rare [2], but can come with devastating global consequences to living species. In 2005, a United States Congressional mandate called for NASA to detect, by 2020, 90 percent of near-Earth objects (NEOs) having diameters of 140 meters or greater [3]. One year prior, ESA's Near-Earth Object Mission Advisory Panel (NEOMAP) recommended the study of a kinetic impactor mission as a priority in the framework of NEO risk assessment [4]. A "Phase-A" study of such a mission, Don Quixote, took place at ESA until 2007.

In accordance with NEOMAP and with the Target NEO Global Community's recommendations in 2011 [5], the NEOShield Project is being funded for 3.5 years by the European Commission in its FP7 program. NEOShield began in 2012 and is primarily, but not exclusively, a European consortium of research institutions and engineering industries that aims to analyze promising mitigation options and provide solutions to the critical scientific and technical obstacles involved in confronting threats posed by the small bodies in the neighborhood of the Earth's orbit [6]. To further explore the NEO threat mitigation via the strategy of kinetic impact, building upon the Don Quixote study, the idea is to target a specific NEO for impact and attempt to quantify the response. How long do ejecta remain aloft and where do they end up? Fragments that are ejected at high speeds escape, but what about material moving at or near the escape speed of the NEO or that suffer energy-dissipating collisions after being ejected? Where would be a "safe" location for an observing spacecraft during and subsequent to the impact? Here, we outline the early phases of an ongoing numerical investigation of the fate of the material ejected from a targeted spacecraft impact, part of a specific work package of NEOShield.

To compute the initial, hypervelocity, phase of the impact (0.3 s), we use a Smoothed Particle Hydrodynamics (SPH) impact code, specially written to model geologic materials [7], using the Tillotson equation of state, a standard Drucker-Prager yield criterion for rocky materials, and a modified Grady-Kip tensile fracture model relying on a Weibull distribution of incipient flaws [8]. To determine the fate of the ejecta, the output is then ported into the N-Body code, PKDGRAV, originally developed for cosmological modeling of large-scale structure at the University of Washington [9]; the code was then outfitted to handle collisions and adapted for planetary-science applications [10]. We take advantage of PKDGRAV's sophisticated neighbor-finding tree to run its gravity solver and search for contacts as part of a soft-sphere collisional routine [11]. Simulating the evolution of the ejecta cloud is complex, involving a lot of material moving at a wide range of speeds. The fastest-moving ejecta easily escape the weak pull of the asteroid's gravity, but the trajectories of material sent aloft at or near escape speed must be followed for weeks in order to determine their fate. Slow-moving material lingers in the weak gravitational field, potentially posing a risk to nearby spacecraft (e.g., the "orbiter" in the Don Quixote study), and obscuring data collection, by ground- and/or space-based detectors, in the aftermath of the impact. Results of the study will be furnished.

Acknowledgements: The research leading to these results has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement №282703-NEOShield.

References: [1] Collins G.S. et al. (2005) Meteorites & Planet. Sci. 40, Nr 6, 817–840. [2] Harris, A.W. (2009) AGU Fall Meeting, Abstract #PP33B-05. [3] National Research Council (2009) Near-Earth Object Surveys and Hazard Mitigation Strategies: Interim Report. The National Academies Press. [4] Gonzalez, J.A., et al. (2004) Don Quijote: An ESA mission for the assessment of the NEO threat. 55th International Astronautical Congress. [5] Barbee, B. W. (2011) Target NEO: Open Global Community NEO Workshop Report. George Washington University. http://www.lpi.usra.edu/sbag/documents/NEOfinalReport.pdf [6] Harris A.W. et al. (2013) Acta Astronautica 90, 80–84. [7] Benz, W., and Asphaug, E. (1995) Computer Physics Communications 87, 253–265. [8] Jutzi, M., Michel, P. (2014) Icarus 229, 247. [9] Stadel, J. (2001) University ofWashington, PhD Thesis. [10] Richardson, D.C., et al. (2000) Icarus 143, 45–59. [11] Schwartz, S.R., et al. (2012) Granular Matter 14, 363.