Impact probabilities and lead times

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The most important requirement, scientific or otherwise, for any impact mitigation is the recognition of the hazard, since, in the absence of a perceived impact risk, there is neither the incentive nor the capability to address the threat. Therefore, the success of any potential mitigation effort will rely heavily upon our ability to discover, track and analyze threatening objects. In this presentation we will consider the effectiveness of the present surveying and monitoring capabilities by bombarding the Earth with a large set of simulated asteroids that is statistically similar to the impacting population. Our aim is to see how many of these impactors might be recognized as threatening, and what is the reliability and expected lead time for such recognition.

To begin, we form a large set of "typical" impactors. For this purpose we use the debiased NEA population model developed by Bottke et al. (2000, Science 288, 2190). Starting with a very large population of NEAs we derive a set of 1000 impactors by first reducing the population to those for which the minimum orbital separation, or MOID, is low enough to permit an impact. Impactors are sampled from this low MOID set according to the fraction of their orbital period that they spend within the Earth-capture cross-section of the Earth's orbit, a value that can range from as much as a few percent for Earth-like orbits down to 10^-9 for low-MOID cometary orbits. This sampling approach allows for the more hazardous orbital classes, such as low inclination, Earth-like or tangential orbits, to have appropriately increased prominence among the simulated impactors. The orbital characteristics of the impacting population are important from a mitigation perspective in terms of both discovery and deflection efforts and these issues will be addressed.

Given a set of impactors one can ask whether and when they would be discovered by various NEO surveys with differing sky coverages and brightness limits. To approach these questions we run survey simulations, recording detections for various object sizes. This allows us to infer the distribution of warning times as a function of size. If there is a warning before an impact, the warning time will generally be measured either in years or else in weeks. In the former case mitigation by disruption or deflection of the object may be feasible, while in the latter case mitigation will be limited to evacuation of the impact region, etc. Detectability at the final apparition is often very challenging since the objects will tend to have rather slow sky-plane motion and will generally be located far from the heavily-searched opposition region. This means that in many cases, especially for the smaller objects, if a last-minute detection does occur it is not likely to be until the object is close enough for the parallactic motion to be detectable, generally a few weeks before impact.

The detection lead time is important in determining the time available for mitigation, but it is not the only factor. There is some delay between the discovery of the asteroid and the recognition that it poses a threat worthy of mitigation. The idea of continually monitoring the ever-evolving asteroid orbit catalog for possibilities of impact is fairly new, and the first automatic collision monitoring system was fielded less than three years ago. Today there are two independent and parallel systems, at JPL and the Univ. of Pisa, that are operating continuously to scan for potential impacts. These efforts have been very successful at detecting potentially hazardous future encounters for newly discovered asteroids and reporting the results to the NEO community. Follow-up observers have responded enthusiastically with observations that permit the hazard assessment to be refined and usually eliminated. We will consider a few impact case studies to understand how rapidly after discovery the probability of an impending impact can be expected to increase as time passes, and in particular to understand how this affects the lead time for mitigation.