THE HAZARDOUS KM-SIZED NEOs OF THE NEXT THOUSANDS OF YEARS. O. Fuentes-Muñoz[1], D. J. Scheeres[1], D. Farnocchia[2], and R.S. Park[2], [1]Smead Department of Aerospace Engineering Sciences, University of Colorado Boulder, 429 UCB, Boulder, CO 80305-0429 USA, corr: oscar.fuentesmunoz@colorado.edu, [2]Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Dr, Pasadena, CA, 91109, USA.

Operational impact monitoring systems such as JPL's Sentry rigorously assess the impact risk for known near-Earth objects (NEOs) for the next 100 years. These time scales allow reliable modeling of the trajectory of an asteroid and the evolution of the associated uncertainty [1]. Impact hazard analysis beyond the next century is limited after the position of the asteroid can become highly uncertain. We extend the impact hazard analysis to longer intervals using the fact that a very low Earth minimum orbit intersection distance (MOID) is a necessary condition for a collision[2], [3]. The main advantage is that the MOID uncertainty does not increase as fast as the orbital uncertainty, which is mostly in mean anomaly. For NEOs with well constrained orbits, the MOID can accurately be known for thousands of years. Using this method, the computational burden of the Monte Carlo simulations is greatly reduced as we need a smaller number of particles.

We propagate the orbits of all known km-sized NEOs for the next 1000 years and compute their Earth MOID. In turn, we compute the range of dates in which an Earth collision is possible and rule out potential collisions when the MOID remains greater than 0.01au for the next 1000 years. This is true for more than half of the km-sized NEO population, including some objects currently classified as Potentially Hazardous (current Earth MOID < 0.05 au and absolute magnitude <22). Figure 1 shows an example of the MOID propagation for 29075 (1950 DA). There are a few objects whose Earth MOID is likely to be smaller than 0.01 au during a significant part of the next centuries. We list these objects including the dates when their orbit stops being deterministic, which indicates candidates for further observation and characterization.

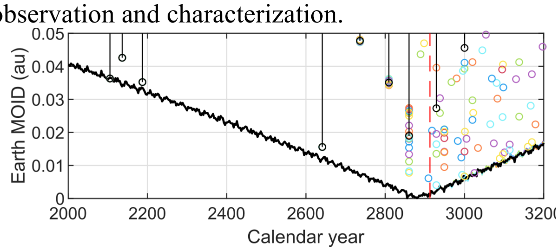

Figure 1: Earth MOID of 29075 (1950 DA) and close encounters found in the Monte Carlo propagation. The nominal orbit and encounters are shown in black. Red dashed line indicates when the uncertainty in mean anomaly becomes larger than 10 degrees.

When the MOID is sufficiently small and the position is unknown along the orbit, we use analytical estimates of the probability of collision[4]. This estimate allows us to rank NEOs in orbits corresponding to a higher intrinsic probability of collision in the future. In the next 1000 years, we find 28 km-sized NEOs with a future unknown mean anomaly period while MOID < 1 LD, out of the 852 objects considered. According to our ranking, the highest ranked objects in terms of impact hazard is 7482 (1994 PC1), for which we found a continuous presence of MOID < 0.01 au for all Monte Carlo runs. The 20 km-sized NEOs with higher probability of an encounter of closest approach distance < 1 LD (lunar distance) are shown in Figure 2. For each object we look for encounters in the deterministic phase of the trajectory, when the uncertainty in mean anomaly is still small. To further illustrate this long-term hazard characterization method, we show in detail the examples of 7482 (1994 PC1) and 66391 Moshup.

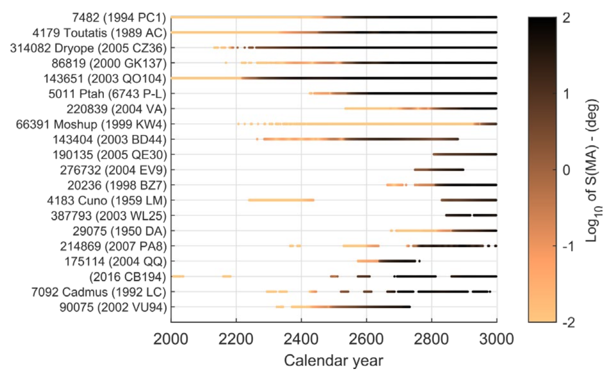

Figure 2: List of 20 km-sized NEOs with non-zero encounter < 1LD probability in the next 1000 years. The standard deviation of Mean Anomaly is shown in $\log_{10}$ in the dates in which the MOID < 0.01au.

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