THE FUTURE OF PLANETARY DEFENSE. A. Mainzer[1], J. Bauer[1,3], T. Grav[2], J. Masiero[1], C. Nugent[3], V. Reddy[4], [1]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA (amainzer@jpl.nasa.gov), [2]Planetary Science Institute, Tucson AZ, [3]Infrared Processing and Analysis Center, California Institute of Technology, Pasadena CA, [4]Lunar and Planetary Laboratory, University of Arizona, Tucson AZ.

Small bodies have interacted with Earth in the past and are certain to do so in the future. NASA and the worldwide community of astronomers, both amateur and professional, have made great strides in discovering, tracking, and characterizing potentially hazardous objects. In 2011, the community achieved the so-called "Spaceguard" goal of discovering more than 90% of near-Earth asteroids (NEAs) larger than 1 km in diameter [1][2][3][4]. Now, attention has turned to finding at least 90% of NEAs larger than 140 m, since objects of this size and above are thought to be capable of causing severe regional damage and to represent the bulk of the remaining risk of an unpredicted impact [5][6]. Significant progress has been made to date: At present, approximately 25% of NEAs larger than 140 m have been discovered [1]. The existing suite of near-Earth object (NEO) surveys primarily consists of 1- to 2-m class telescopes operating at visible wavelengths (e.g. PanSTARRS [7] and the Catalina Sky Survey[8]), with the exception of the 0.4 m space-based infrared (IR) NEOWISE survey [9][10][11][12].

However, by 2050, it is likely that efforts to identify more than 90% of NEAs larger than 140 m in diameter will have been achieved through advanced ground- and space-based surveys [5][6]. This will have clearly quantified the risk of an Earth impact from a body large enough to cause severe regional damage. In the process of carrying out such surveys such as LSST and the proposed Near-Earth Object Camera [13][14][15], a substantial fraction of smaller objects is likely to have been discovered, on the order of 50% or more of NEOs larger than ~75 m. Moreover, the statistical chance of an impact from NEOs smaller than 75 m will be well-determined, owing to the large number of objects in this size range that will have been discovered. Survey debiasing techniques can be used with this large sample to compute a statistically meaningful probability of impact from the ensemble of objects smaller than 75 m, as well as the remaining undiscovered population of larger objects.

To achieve >90% survey completeness for NEOs >140 m, the advanced surveys will necessarily have had to survey large areas with great sensitivity, covering a large fraction of the entire sky. Thus, they are likely to have discovered a large number of long-period comets (LPCs), since these have orbits with a roughly uniform distribution of inclinations and consequently declinations. Thousands of new LPCs are likely to have been discovered by 2050, supporting future missions to these objects as well as thoroughly characterizing the population as a whole and setting strong limits on the statistical chance of impact. Unlike NEAs, LPCs spend most of their orbits in the very outer solar system, and cannot be surveyed until they approach their perihelia.

By 2050, the focus of planetary defense might be expected to shift to improving knowledge of orbits for known objects on Earth-approaching trajectories, continuing to discover small NEOs that cannot be detected until they are very nearby, continuing to discover LPCs as they enter the inner solar system, and planning any mitigation campaigns that may be necessary. In particular, the Yarkovsky effect acts more strongly on smaller objects, causing their orbits to change by more than the 0.05 AU/century typical of larger NEOs. Continued monitoring of small NEOs in the 2050 timeframe and beyond will be required to characterize their orbital drift due to non-gravitational forces, and the resulting impact hazard they pose. This orbital characterization will in turn provide measurements of the mass of the asteroid, which constrains density when combined with infrared- or radar-measured diameters [16]. Thus the sample of objects with well-measured densities will grow significantly as part of the planetary defense campaigns occurring in the coming decades.

Since those objects that make close approaches to Earth are also those most likely to require the least Δv to reach, the process of surveying for potentially hazardous objects will also provide a wealth of small body targets that are energetically easier to reach, some easier than the Moon [17][18]. The targets discovered by surveys undertaken in the 2020-2030 timeframe should pave the way for low-cost missions to a slew of small bodies. In the 2050 timeframe, it is possible to envision a set of small spacecraft that explore a large number of NEOs spanning a diverse range of sizes, shapes, and taxonomic classifications to explore their detailed individual physical properties. Moreover, the large number of close-approaching NEOs that will be known will make a rich target set that can be explored for decades with large-aperture facilities such as ground-based radars and next-generation UV/optical/IR telescopes.

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