NEAR-EARTH ASTEROID SURVEY PRECURSOR TO HUMAN EXPLORATION. A. F. Cheng[1], A. S. Rivkin[1], K. Hibbard[1], R. Mink[2], B. Barbee[2], J. Garvin[2], P. Abell[3], D. Mazanek[4] and R. Landis[5], [1]Johns Hopkins Applied Physics Laboratory (andrew.cheng@jhuapl.edu), [2]NASA GSFC, [3]NASA JSC, [4]NASA LaRC, [5]NASA ARC.

Introduction: The nation has embarked upon a flexible path for expansion of human space flight beyond low Earth orbit to sites never visited before, with an announced goal of sending a human mission to a Near-Earth Asteroid (NEA) by 2025. As human exploration progresses, the flexible path would include a return to the Moon and a visit to Mars, but the path leads first to an NEA. To maintain the support of the public and key stakeholders, significant accomplishments are needed in the near term, not only after decades of investment, and they must be affordable within constrained NASA budgets. Hence studies have been undertaken to identify potential NEA targets for the first human missions outside the Earth-Moon system, with accessibility constraints. That is, roundtrips are feasible in the desired time frame, given propulsion capabilities likely to be available and anticipated maximum allowed flight times for the crew. To date, such studies have identified only a handful of potential NEA targets, all of which are small (under 30 m diameter).

Hence the most urgent knowledge need to prepare for human spaceflight to a NEA is the need to discover a sufficient number of suitable candidate targets. This knowledge need will not be met in a timely manner by existing or planned ground-based surveys. The suitable target NEAs occupy Earth-like orbits and can be discovered quickly and affordably by a space-based telescopic survey. Initial simulations of space-based NEA surveys show roughly similar discovery rates for searching from near the Earth, specifically at the Sun-Earth L2 Lagrangian point (SEL2), and from a trailing Venus-like orbit (0.7AU), although search efficiency for the former case is higher for larger size targets assuming a particular pair of point designs for the survey telescopes. Either approach also significantly advances NEO science and understanding of the impact hazard.

Near-Earth Object Populations: The known population (as of December 7, 2010 from the Minor Planet Center) comprises 7497 Near-Earth objects (NEOs), of which 1016 have absolute magnitude $H \leq 18$ (0.9 km size or larger, for an average albedo of 0.14 [1]). The known population is over 90% complete to km size, but it becomes progressively less complete at smaller sizes. For instance, the known population to $H \leq 24$ (about 60 m size, for the same albedo) is 5885 objects, but the actual population number at this size may be under 9×10^4 or may exceed 5×10^5. This current survey status is summarized in a recent NRC report [2].

The known population is subject to severe observational biases [e.g., 3-4]. In the absolute magnitude range $18 \leq H \leq 24$, the range of estimates for the debiased NEO population can be bounded below by

$$N_{low}(< H) = 10^{-2.8018+0.32262H}$$

for the cumulative number of NEOs brighter than *H*, and the estimates can be bounded above by

$$N_{high}(< H) = 10^{-5.1848+0.45571H}$$

Not only is the total population uncertain, but so is the distribution in orbital elemental space. The uncertainties are particularly large for NEOs in the most Earth-like orbits, which are also the most accessible NEOs. This is because these objects are exceptionally difficult to observe from ground-based telescopes, so the observational biases are strong, and moreover they are difficult to treat in numerical models of NEO orbital evolution because of strong planetary interactions.

NEO Survey Missions: Mission design studies have been undertaken for the first human-crewed missions to a NEA, searching the known NEO population and imposing accessibility constraints based on launch time frames, Δv requirements and mission flight time. In support of these studies, the results of space-based NEO surveys have been simulated, using both the low and high population bounds given above for the debiased NEO population, and using orbital element distributions following the numerical models of [4].

NEO Survey Simulation Results. Two survey strategies were considered: 1. telescope in trailing Venus orbit (~0.7AU), searching near opposition, and 2. telescope in SEL2, searching two sweet spots [5] each of which is from 40° to 70° longitude off the Sun and within ±20° latitude of the eclptic. Both strategies assume optical telescopes with 0.9m apertures and state-of-the-art CCD cameras. Either strategy can be implemented as a low cost mission (less than Discovery mission cost) for launch by 2015. The overall discovery rates are similar for the two strategies, and either strategy is likely to discover tens of NEOs suitable for human exploration within two years of operation. For the SEL2 case, the survey would reach roughly 40% completeness for NEOs >140 m size, within two years.

References: [1] Stuart J. S. and R. P. Binzel, (2004) *Icarus, 170,295-311*. [2] Committee to Review Near Earth Object Surveys and Hazard Mitigation Strategies (2010) *Defending Planet Earth*, Space Studies Board, NRC. [3] Stuart J. S. (2001) *Science* 294, 1691. [4] Bottke W. F. et al. (2002) *Icarus, 156, 399-433*. [5] Veres P. et al. (2009) *Icarus, 203,472-485*.