THE NEAR EARTH OBJECT SURVEILLANCE SATELLITE (NEOSSAT) MISSION ENABLES AN EFFICIENT SPACE-BASED SURVEY (NESS PROJECT) OF INTERIOR-TO-EARTH-ORBIT (IEO) ASTEROIDS. Hildebrand A.R.,[1] Tedesco E.F.,[2] Carroll K.A.,[3] Cardinal R.D.,[1] Matthews J.M.,[4] Kuschnig R.,[4] Walker G.A.H.,[4] Gladman, B.,[4] Kaiser, N.R.,[1] Brown P.G.,[5] Larson S.M.,[6] Worden, S.P.,[7] Wallace, B.J.,[8] Chodas P.W.,[9] Muinonen K.,[10] Cheng A.[11], Gural P.[12] [1]Department of Geology and Geophysics, University of Calgary, 2500 University Drive NW, Calgary, AB, Canada T2N 1N4 (ahildebr@ucalgary.ca); [2]University of New Hampshire, Space Science Center, 39 College Road, Durham, New Hampshire, USA 03824; [3]3 Gondola Crescent, Brampton, Ontario L6S 1W5; [4]Department of Physics and Astronomy, University of British Columbia, 6224 Agricultural Road, Vancouver, BC, Canada V6T 1Z1; [5]Department of Physics and Astronomy, The University of Western Ontario, London, ON, Canada N6A 3K7; [6]Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ, USA 85721; [7]NASA Ames Research Center, Moffett Field, CA, USA 94035; [8]Defence Research & Development Canada, 3701 Carling Ave., Ottawa, ON, Canada K1A 0Z4; [9]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA 91109; [10]Observatory, Kopernikuksentie 1, P.O. Box 14, FIN-00014, University of Helsinki, Finland; [11]Applied Physics Laboratory, 11100 Johns Hopkins Rd., Laurel, MD, USA 20723; [12]Science Applications International Corporation, 4501 Daly Drive, Suite 500, Chantilly, VA, USA 20151.

Introduction: Most near-Earth object (NEO) search efforts/discussions have employed/considered ground-based searches, but space-based sensors have been assessed for several years [e.g., 1; 2]; Stokes, Yeomans, et al. [2] have performed the most extensive analysis of the search capabilities of space-based and ground-based systems and combinations thereof. Traditional opposition-based searches are particularly effective at discovering the Apollo and Amor orbital classes of NEO's, less effective at discovering Atens, and nearly incapable of finding IEO's. Members of the IEO class may only be found by ground-based searches at low solar elongations with the ecliptic region most favourable [e.g., 3]. The low delta-v fraction of the NEO population is also most efficiently sought along the ecliptic plane near the Sun with the most favourable solar elongations dependent upon the limiting magnitude of the survey instrument. Deployment of a survey telescope in space allows much more efficient searching of the near-Sun regions of sky as the limitations of the day – night cycle are removed. A low-Earth orbit deployment also results in the greatest warning efficiency for any space – based sensor considered by [2].

NEOSSat Spacecraft Design: The NEOSSat spacecraft will be used by the Near-Earth Space Surveillance (NESS) project to discover and track NEO's [4]. NEOSSat will be a dual use mission, also observing artificial satellites in Earth orbit. Much of the microsatellite derives its technology from the MOST (Microvariability and Oscillations of Stars) asteroseismology microsatellite mission [5] which is now in its fourth year of operation. NEOSSat will be ~50 kg deploying a telescope similar to the 15-cm aperture f5.88 Maksutov on MOST. The spacecraft will be 3-axis stabilized with a pointing precision of ~2 arcseconds in a ~100 second exposure. The NEOSSat mission has completed Phase A with launch currently anticipated in 2009, and will be the first in a series of microsatellites based upon a multi-mission bus concept developed by the Canadian Space Agency in cooperation with Defence Research and Development Canada [6]. The spacecraft will be deployed into a Sun – synchronous orbit similar to that occupied by the MOST spacecraft.

IEO Search Considerations: The capabilities and advantages of a space-based asteroid search program with this class spacecraft have been studied by [4], with the near-Sun region offering the greatest research return and results complementary to the much larger ground-based search programs (Figure 1). This sky region can only be routinely accessed from Earth orbit and the search greatly benefits from having parallax determinations to discriminate asteroids of interest from Main Belt detections. The near-Sun ecliptic region does suffer from zodiacal light sky brightness that can result in as much as one magnitude loss in detection limit in the planned search region.

By definition, IEO's occur only inside Earth's orbit so cannot be found by opposition searches. However, the recent extension of search regions to the near-Sun regions has resulted in the discovery of seven IEO's (as of this writing) primarily in 2003-2006. Figure 2 from [4] illustrates the sky distribution of IEO's based upon a model population. The planned NESS search regions extend from 45° to 55° helioecliptic longitude and ± 40° ecliptic latitude; although obviously desirable to search still closer to the Sun, baffle engineering becomes more difficult as does zodiacal light interference (though the area could be profitably searched to at least within 40°). Aside from the necessity of looking near the Sun and the zodiacal light sky brightness problem, a near-Sun survey has some advantages over traditional opposition surveys: firstly, as the search angle is tangential through the orbital distribution a much larger volume of prospective space is covered per search field for all NEO's, and, secondly, the near-Sun region has a relatively great path length where asteroids are above a given brightness due to the asteroid – Sun distance remaining relatively constant while the increasing asteroid – Earth distance is compensated by the increasingly illuminated phase of the asteroid with decreasing phase angle (Figure 3).

Population detection completeness is presented in Figure 4 for a model IEO population and with a slightly different search region [4]. For IEO's, assuming limiting V magnitudes of 19 and 20, the completeness limits are 29% and 39%, respectively, for >1 km diameter in a 3-year survey. Simulation showed that almost all IEO's detected were found at 45° to 55° elongation, so this is the region that will be searched pending additional simulation and observation results.

References:

[1] Tedesco, E.F. et al. (2000). *Planet. and Space Sci. 48*, 801-816. [2] Stokes, G.H., Yeomans, D.K., et al./Near-Earth Object Science Definition Team, 2003, NASA, Office of Space Science, Solar System Exploration Division, 154 pp. [3] Masi, G., 2003, *Icarus* 163, 389-397. [4] Hildebrand, A.R. et al. (2004). *Proc. 55th Int. Astronautical Cong.*, Vancouver, B.C., Paper IAC-04-!AA.4.11.2.08 [5] Walker, G. et al. (2003). *PASP, 115,* 1023-1035. [6] Harvey, W. et al. (2006). *Proc. Astro 2006, 53rd AGM CAS*I. [7] Harris, A. et al. (2006). *Bull. Amer. Astron. Soc. 37*, #26.09.

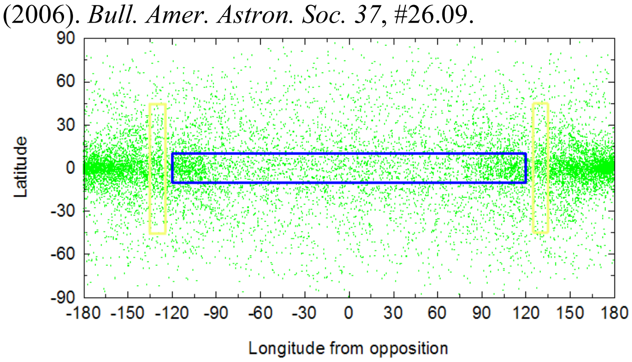

Fig. 1. Comparison of suggested search regions for ground-based versus space-based sensors. The blue box is the zone Harris et al. [7] suggest be targeted by ground based (LSST) work and the yellow boxes the straw-man NESS search regions. The green dots indicate locations of all potentially hazardous asteroids (PHA's) on the sky sampled once per lunation and only when brighter than H+2. (Adapted from Harris *et al*., 2006.) This illustrates the utility and complementarity of near Sun – ecliptic plane searches to ground-based.

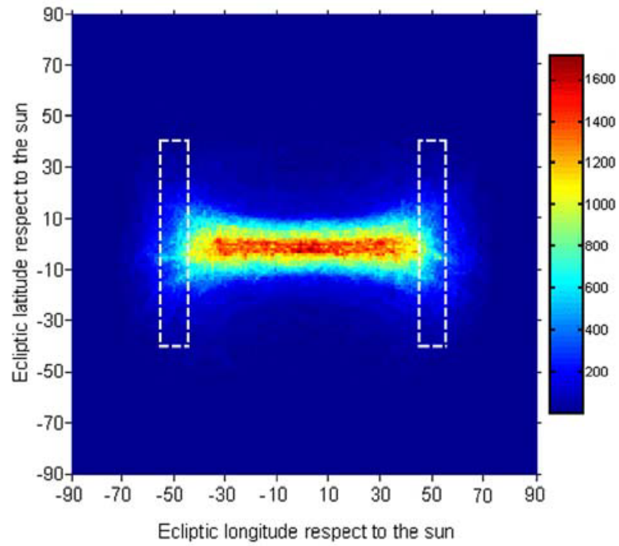

Fig. 2. A modeled sky distribution of IEO asteroid orbital class with the NESS project search areas superposed as dashed white lines. The colors defined in the legend represent the number of model asteroids present per square degree. (Adapted from Masi, 2003.)

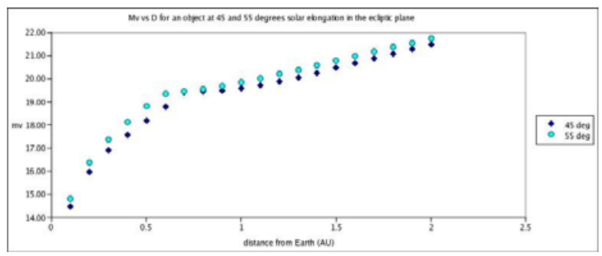

Fig. 3. Apparent V magnitudes versus distance of an H =18 asteroid at solar elongations of 45° and 55° on the ecliptic plane. The IEO prospective space limits are respectively at ~1.4 and 1.2 AU for 45° and 55°.

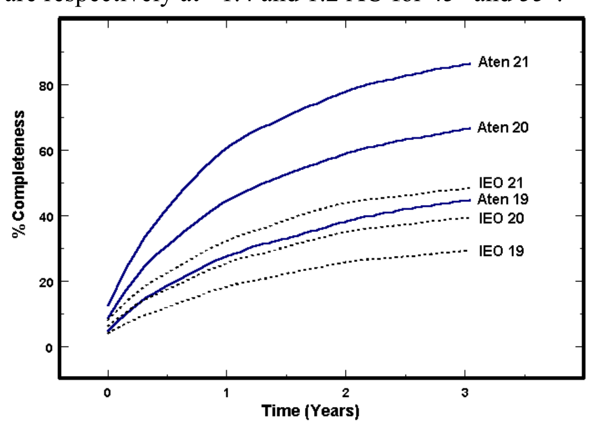

Fig. 4. Percent completeness as a function of limiting V magnitude and time for a survey of Aten and IEO asteroids with diameters >1km covering solar elongations 45° to 70° on either side of the Sun and ±20° in ecliptic latitude once per lunar month.