EVALUATION OF CCD SYSTEMS FOR NEO SURVEYS A. W. Harris, JPL, E. L. G. Bowell, Lowell Observatory, and K. Muinonen, Helsinki Observatory

In August 1994 NASA appointed a study group to consider means of detecting as many as possible Near-Earth Objects larger than 1 km in diameter within ten years. Since the publication of the Spaceguard Survey Report of the NASA International Near-Earth-Object Detection Workshop [1], there have been several advances in CCD technology and computer detection algorithms that allow for considerably improved performance of telescope systems over that assumed in that report. Thus for the new report, we have re-evaluated several existing or planned telescope systems to assess their ability to achieve the above stated goal. To do this, we have evaluated the performance of various systems, in terms of the limiting magnitude achievable vs. the rate of motion in the sky of a point source target (a moving asteroid). If the target object is moving only very slowly, so that the image does not trail in a given exposure time, the limiting magnitude is the same as for fixed objects (stars). For images that are short trails, image reconstruction can improve the detection threshold, so the limiting intensity of a detectable object falls off only as the square root of rate of motion. Beyond some limit (we assume 100 pixels of trail length), image reconstruction fails or becomes too computer-intensive, so the limiting intensity falls of in proportion to trail length. In Figure 1, we plot the performance for the Spacewatch Camera, in its original configuration [2] as well as the current somewhat improved system and the Spacewatch II 1.8 m system under construction [Rabinowitz, personal communication], a ~0.5 meter Schmidt-system being constructed at Lowell Observatory (Lowell Observatory Near-Earth Object Survey = LONEOS), and a CCD system under development by Lincoln Laboratory for retro-fitting into a USAF system of 1 m short-focus telescopes currently in use for tracking Earth satellites (Ground-based Electro-Optical Deep Space Surveillance system = GEODSS). The performance characteristics are obtained by scaling from actual performance obtained by the original Spacewatch camera [2], to include higher quantum efficiency, faster readout, and lower signal-to-noise thresholds expected for the systems under development.

Using these performance characteristics, and the rate of sky-coverage that each system is capable of achieving, we have estimated the effectiveness of some of these systems in detecting NEOs. To do this evaluation, we created a synthetic set of 1000 NEA orbital elements which we estimate to be a fair representation of the expected distribution in semi-major axis, eccentricity, and inclination. The other elements were distributed randomly, with the exception of argument of perihelion: That argument we chose in a range such that the current orbit comes within 0.05 AU of intersection with the Earth's orbit. Thus our synthetic set of objects excludes those which currently do not approach the Earth close enough to become potential hazards within several centuries; so we are measuring our ability to detect primarily those objects which could potentially collide with the Earth on a time scale.

In Figure 2, we plot results of a first simulation of a 10-year survey with these simulated NEOs, showing how LONEOS and GEODSS perform in three modes: short exposures of each field covering essentially all of the sky each month, longer exposures covering only the near-opposition region of the sky each month, and an intermediate case. Each curve is labeled with the exposure time and maximum elongation from the opposition point achievable with that exposure. These results are very preliminary, and do not include such effects as declination limits reachable from a given site, or parts of the sky not searchable because of the interference of background stars near the galactic plane. We expect to have results including these effects to show at the conference in March. These preliminary results demonstrate already that systems perform better if they are used in a mode of maximum sky coverage, even at the sacrifice of some limiting magnitude due to the shorter exposure times. The largest sky-coverage curves require reaching within 45° of the direction to the sun, which is probably not practical from the ground. Thus these curves might be taken as an indication of the capability of such a telescope in space. the intermediate curves for each system are probably not far from the best performance that can be expected from the ground, allowing for the unmodeled limitations mentioned above. Thus it appears that the LONEOS camera could probably detect ~2/3 of all NEOs larger than 1 km in diameter after 10 years of surveying, and a single GEODSS telescope could achieve >80% completeness in a similar time. Using several of the GEODSS telescopes (there are more than 10 in existence), it should be possible to achieve the Spaceguard Survey goal of >90% completeness, in about a decade.

Figure 1. Limiting magnitude performance of various CCD survey systems

Figure 2. Survey completeness achieved, 1 km diameter objects of albedo 0.15