AN EFFICIENT SEARCH STRATEGY FOR NEAR EARTH ASTEROIDS.

P. Tricarico, *Planetary Science Institute, 1700 E. Ft. Lowell, Suite 106, Tucson AZ 85719, USA (tricaric@psi.edu)*.

Introduction. The surveys searching for Near Earth Asteroids (NEAs) are working in synergy to achieve the NASA Spaceguard Goal to find 90% of NEAs larger than 1 km diameter by 2008 [1,2]. The search strategy adopted by each survey is dictated by the survey's operative parameters (limiting magnitude, field of view, duty cycle), and can consist of one or more of the following: search near opposition; search near the ecliptic plane; search at the sweet spots; all-sky search. We argue that the selection of any of those *static* search strategies is not optimal in general, and the *dynamic* strategy described here should be adopted.

We present here a NEA search strategy which by design maximizes the volume searched in the space of the orbital elements of the unbiased NEAs distribution. After a description of the strategy, we present the preliminary results obtained using numerical simulations. Then the discussion follows.

Method. This search strategy, here labelled *sieve*, is implemented with the following steps:

1. selection of a set of reference surveys, for which the Minor Planet Center (MPC) provides detections of asteroids (either NEA or MBA) that can be used to reconstruct the telescope pointing of the survey at a given epoch, the field of view, the limiting magnitude, and the range of apparent-velocities detected;

2. use the data obtained at point 1 to obtain a debiased NEA population [3,4];

3. generate a very large number of *potential* NEAs with orbital elements and absolute magnitude distribution resembling the debiased population, and then propagate them through the observing period covered by the reference surveys, while constantly checking whether a survey could have detected any of them;[1] if a potential NEA could have been detected in the past, it is removed from this list;[2]

4. finally, propagate all the potential NEAs still included in the list at point 3 to the present epoch, project them to the RA-Dec plane, and choose to observe sky regions with a high concentration of potential NEAs that are detectable by your survey.

It should now be clear why this search strategy is dynamic: the list of potential NEAs needs to be routinely tested against the latest observations by all the surveys considered, at least with a monthly cadence, possibly weekly.

[1] A detection probability is associated to each potential detection, and the NEA is considered detected when the cumulative probability is greater than a given threshold.

[2] An alternative approach could be to lower the absolute magnitude to the NEA so that it would not be detected, and keep it in the list.

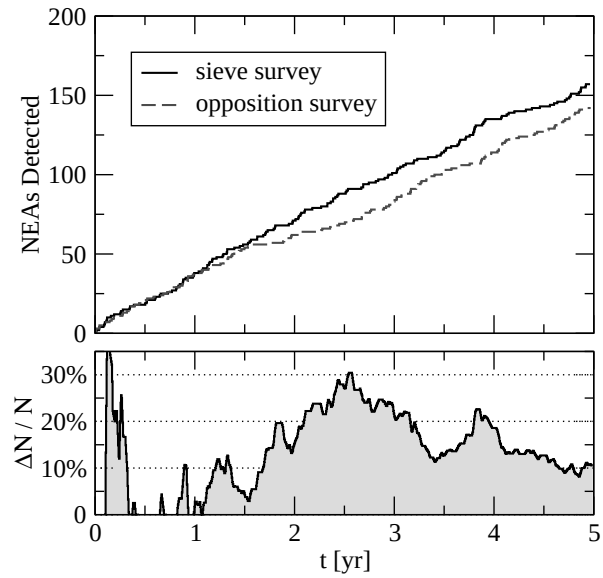

Figure 1: Cumulative number of discoveries for each simulated survey (top), and relative improvement of the sieve survey over the opposition survey (bottom).

Results. We have developed numerical code to simulate realistically a NEA survey, with the intent to test the sieve survey. Here we present the results relative to the comparison of the simulated sieve survey and a simulated opposition survey.

The two surveys have identical operative parameters: a field of view of 1° by 1°, a limiting magnitude $V_{50\%} = 20$, a recycle time[3] of 10 days, a duty cycle for a single acquisition of 3 minutes, 4 expositions per field. The simulated surveys are located at a latitude of 32° North.

The synthetic NEA population[4] is composed of 2K members, with a flat orbital elements distribution: 1 AU < a < 2 AU, 0.05 < e < 0.40, 0.1° < i < 45°, and the other angles uniformly distributed between 0° and 360°. The absolute magnitude distribution is displayed in Fig. 2. Both simulations use exactly the same synthetic NEA population.

Each simulation runs for 5 years, with realistic limits on the maximum Sun elevation, minimum Moon phase and minimum Moon angular distance. Simulated weather is not included. While the opposition survey scans the sky with a scheduling that does not depend on the synthetic NEA population, the sieve survey updates the list of potential NEAs daily, and observes always and only the sky regions with a high con-

[3] The minimum time between two observations of the same part of the sky.

[4] The NEAs that we want to discover.

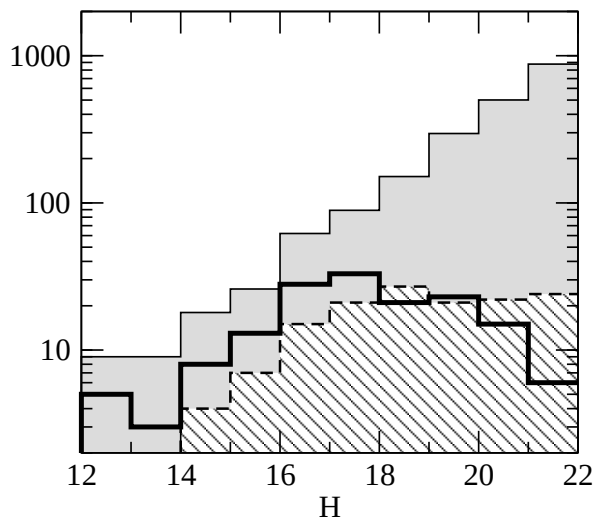

Figure 2: Distribution of all the simulated NEAs (shaded histogram), NEAs detected by the opposition survey (oblique filling histogram) and by the sieve survey (dark solid line) as a function of the NEAs absolute magnitude H, after 5 years of simulation.

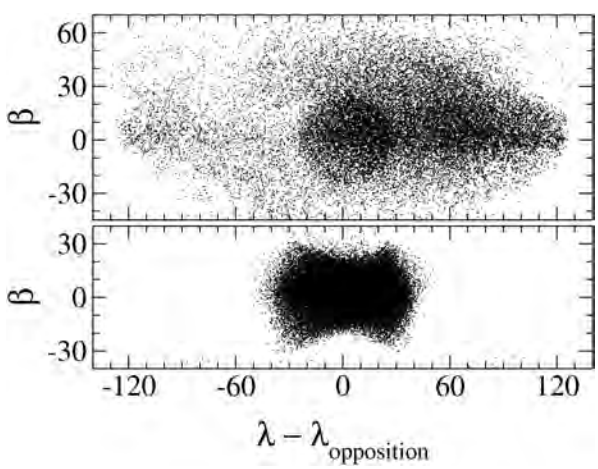

Figure 3: Scatter plot of all the telescope pointings collected in five years, by the sieve survey (top) and the opposition survey (bottom). Elliptic coordinates centered at opposition.

centration of potential NEAs that are detectable. In Fig. 1 we have plotted the cumulative number of NEAs discovered by each survey during the simulated period. In Fig. 2 we show the different H distribution relative the the NEAs detected by each survey, and finally Fig. 3 provides a sketch of the behavior of each survey.

Discussion. According to our simulations, the sieve survey tends to detect more NEAs than the opposition survey, in a given amount of time. As Fig. 1 shows, after an initial period of comparable performance, the sieve survey discovers up to 30% more NEAs than the opposition survey. This difference tends then to get smaller with time, but still up to the 10% level after 5 years. Also, the sieve survey tends to discover more NEAs larger than 1 km diameter, as visible in Fig. 2. The two surveys perform comparably in the range $18 < H < 20$, but for $H < 18$ the sieve survey seems to consistently detect more NEAs. On the other hand, the opposition survey discovers far more faint NEAs. Interestingly, the sieve survey seems to naturally decouple into an opposition survey plus an all-sky survey that focuses mostly at positive $\lambda - \lambda_{\mathrm{opposition}}$, where undiscovered potential NEAs, driving the sieve survey, seem to concentrate (see Fig. 3).

Ongoing Work. We intend to improve this initial investigation into dynamic NEA search strategies in many ways: by using a more realistic NEA orbital elements distribution, closely resembling the debiased distribution of real NEAs; by comparing the sieve survey with a generic all-sky survey; and by performing longer simulation to better assess the properties of the sieve survey as the number of the discovered NEAs approaches the total number of NEAs simulated.

Conclusions. This preliminary study shows that a dynamic NEA search strategy has the potential to perform better than traditional static strategies both in terms of overall detection rate and of number of large NEAs discovered, thus shortening the time necessary to achieve the Spaceguard Goal.

Would this search strategy be as affective in the real world? If our improved simulations will show it to be still promising, then the only way to actually answer to this question is to implement it. But this will require impressive computational resources, available only by using advanced computing technologies such as distributed computing [5]. It is important to note that this real world implementation would produce the most accurate estimate of the debiased population of real NEAs, because it would be based on the real sky coverage of a set of NEA surveys over an extended observing period.

References. [1] Morrison, D. *et al*. (1992). JPL QB651, N37. [2] Jedicke, R. *et al*. (2003). Icarus 161, 17–33. [3] Bottke, W. F. *et al.* (2002). Icarus 156, 399–433. [4] Jedicke, R. *et al.* (2002). Asteroids III, 71–87. [5] Tricarico, P. (2004). BAAS 36, 1141.

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