THE CASE FOR A DEDICATED NEAR-EARTH-OBJECT RADAR OBSERVATORY

Steven J. Ostro, JPL/Caltech

For the NASA Workshop on Near-Earth Object Detection, Characterization, and Threat Mitigation

Vail, Colorado

June 2006

The role of radar in dealing with the impact hazard and the relationship between radar reconnaissance and optical surveys was described by Ostro (1994; see also Ostro and Giorgini 2004):

"One can expect a progression from dedicated search programs to identification of objects that will make very close Earth approaches during, say, the next century, to refinement of those objects' trajectories, eventually resulting in either classification of the object as nonthreatening or decisions to take increasingly serious forms of action, beginning with groundbased observing campaigns and perhaps proceeding to spacecraft reconnaissance. The pervasive issue will be the state of our uncertainty about possibly threatening objects, what can be done to reduce that uncertainty, and associated costs. The response of NASA (and other agencies) to the NEO hazard attacks three realms of ignorance. First, although we know the gross character of the population and average collision rates, we have discovered only an insignificant fraction of the potential impactors. Optical search programs aim to dispel this kind of ignorance. The second kind of uncertainty concerns known objects' orbits and the circumstances of future close approaches, and the third concerns the outcome of the impact of a specific object on a specific collision course, and hence the object's physical properties, including mass, dimensions, composition, internal structure, and whether the object is one object or two. If spacecraft inspection or defensive action are to be undertaken, then spin state, detailed surface properties, and the presence of accompanying swarms of macroscopic particles could be of concern. Groundbased radar is uniquely suited for cost-effective trajectory refinement and physical characterization, that is, for reducing both kinds of post-discovery uncertainty about potential NEO hazards."

Search programs aiming for achievement of 90% completeness for NEAs as large as 140 m within the next 15 years will produce an enormous surge in the NEA discovery rate. In coming years, it will become increasingly clear that most of the NEO radar reconnaissance that is technically achievable with the optimally supported Arecibo and Goldstone antennas is precluded by their limited accessibility, and that a dedicated NEO radar observatory is desirable.

An ideal NEO radar system (Ostro, 1997) might consist of two antennas like the 100-m NRAO Greenbank Telescope (GBT, in West Virginia), operating at a wavelength of about 1 cm (Ka band), one antenna for receiving only and one equipped with a megawatt transmitter and far enough from the receive-only antenna to ensure its isolation from leakage of the transmitted signal. Each antenna's gain could be ~88 dB, compared to 72.4 dB for Arecibo.

A two-antenna (bistatic) configuration would eliminate the frequent transmit/receive alternation and klystron power cycling required in single-antenna observations of NEOs -- the roundtrip travel time (RTT) of the signal between the radar and the target in seconds is numerically nearly equal to the target's distance in mAU, e.g., 10 seconds for a target 0.01 AU away. Advantages of a two-antenna telescope for NEOs include:

(1) no on/off switching of the transmitter, which ages klystron amplifier tubes;

(2) no interruption of data acquisition or of coherent integration;

(3) no interruption of orientational coverage;

(4) no switching of antenna pointing between transmit and receive directions, which can differ by more than a beamwidth for a rapidly moving target;

(5) doubled data integration time; and

(6) accessibility of arbitrarily close targets, including those within a few Earth-Moon distances (RTT < 10 s), using the same configuration as for distant targets.

Since this instrument would be dedicated to NEOs, it would compile more NEO observation time in one year than Arecibo and Goldstone could in a decade. Given the current state of the art of antennas, receivers and transmitters, it could be an order of magnitude more sensitive than the upgraded Arecibo telescope. The telescope's lifetime would probably be at least several decades, during which it would do flyby-level science (delay-Doppler image sequences placing thousands of pixels on the target, over enough orientations to allow detailed reconstruction of the 3D shape) of over a thousand of the optically discoverable NEAs, as well as orbit-refining follow-up astrometry on many thousands of newly discovered NEOs.

The capital cost of this system, as calibrated by the experience with the GBT, would be comparable to the cost of a Discovery mission. (It may be cost-effective to substitute an antenna array for at least the receive-only dish.) Three such bistatic systems suitably spaced in longitude and latitude would ensure constant visibility of any part of the sky.

Acknowledgment. This research was conducted at the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration (NASA).

References

Ostro, S. J. (1994). The role of groundbased radar in near-Earth object hazard identification and mitigation. In *Hazards Due to Comets and Asteroids*, T. Gehrels, ed., Univ. of Arizona, Tucson, pp. 259-282.

Ostro, S. J. (1997). Radar reconnaissance of near-Earth objects at the dawn of the next millennium. In *Near-Earth Objects: The United Nations International Conference* (J. Remo, ed.), Annals of the NewYork Academy of Sciences 822, pp. 118-139.

Ostro, S. J., and J. D. Giorgini (2004). The role of radar in predicting and preventing asteroid and comet collisions with Earth. In *Mitigation of Hazardous Comets and Asteroids* (M. J. S. Belton, D. K. Yeomans and T. H. Morgan, eds.), Cambridge Univ., pp. 38-65.