Impact Warning Times for Near-Earth Asteroids. P.W. Chodas[1] and J.D. Giorgini[1], [1]JPL/Caltech, 301-150, Pasadena, CA 91109.

Introduction: If a Near-Earth Asteroid is headed for impact with the Earth sometime within the next century, how long after discovery will it be before we know that the object will impact? The answer depends on factors such as the object's orbit and size, the discovery time before impact, observatory magnitude limits, use of radar observations, and intervening close passages to the Earth or other planets. We have carried out a study to address this question statistically, using a realistic set of simulated Earth impactors, and a simulation of both optical and radar observations for each object at a range of assumed sizes. This is the first statistical analysis of the effect of radar observations on impact warning times.

Study Description: Our study began with a set of nearly a thousand “typical” impactor orbits based on a Near-Earth Asteroid population model [1]. The motion of each impactor over the 80-year period leading up to impact was modelled via numerical integration. Each impactor was analyzed at three different sizes: 700 m (H=18.5), 140 m (H=22), and 70 m (H=23.5). Geocentric optical observations were simulated whenever the object passed within a set of geometrical and magnitude constraints. Observations were excluded at low solar elongations, when the object was near the Moon, or within 3 days of full moon. Discovery opportunities were identified whenever the object magnitude brightened past a discovery magnitude threshold. The magnitude constraints were set to mimic the current observational survey, with the discovery at 20th magnitude and follow-up observations continuing down to 22nd magnitude. The observation rate varied geometrically according to magnitude.

Radar observations were simulated for each object by monitoring the signal-to-noise ratios (SNR) for both the Goldstone and Arecibo radars. Site parameters such as latitude, elevation limits, transmit power, dish radius, and aperture efficiency were factored into this computation, along with asteroid range, size, and radar reflectivity. Radar observations were considered possible only when the SNR exceeded 10, and, except during the last year before impact, were restricted to 8-day windows surrounding the day of peak SNR.

From the full set of possible discovery times, one was selected at random for the warning time analysis, effectively simulating objects impacting randomly within 80 years of discovery. The orbit prediction process was simulated by repeatedly determining the object's orbit based on the ever-increasing set of observations, while monitoring the impact probability. We defined "warning point" as the time when the impact probability passed 50%, and "warning time" as the interval between this point and the impact time.

Results: We would expect that in most cases the warning point would be reached during the second observation period (“apparition”), and results of the study confirmed this expectation. The warning times were very dependent on object size. For the 700-m size, the warning point was reached within five years of discovery for the majority of cases (73%). These objects are large enough to have frequent apparitions, and most have a second apparition within 5 years. Some required longer to reach the warning point, because of orbits with long synodic periods or with intervening close approaches which make impact predictions difficult. For the smaller-sized objects, the warning point is reached much later, only 27% reaching this point within 5 years for the 140-m size, and only 17% for the 70-m size. There were simply a lot fewer observational opportunities for the smaller objects

With radar observations included, the warning point was naturally reached earlier on average, but the improvement again depended heavily on object size. For the 700-m objects, the warning point was reached about a year earlier on average, and within four years of discovery for 72% of cases. But the improvement with radar was most dramatic for the smaller objects: the warning point could be reached within a year after discovery for 32% of the 140-m objects vs. only 6% without radar observations; for 70-m objects, the improvement due to radar was even larger, 38% reached the warning point after a year, rather than only 5% without radar.

References: [1] Chesley, S.R, and Spahr, T.B., Earth impactors: Orbital characteristics and warning times, in *Mitigation of Hazardous Comets and Asteroids*, M.J.S. Belton *et al.*, *eds*, 2004.