ASTEROID RADAR ASTRONOMY AT THE DAWN OF THE NEW MILLENNIUM. S. J. Ostro[1], L. A. M. Benner[1], J. D. Giorgini[1], C. Magri[2], J.-L. Margot[3], and M. C. Nolan[4], [1]Jet Propulsion Laboratory, California Institute of Technology, [2]University of Maine at Farmington,[3]California Institute of Technology, [4]Arecibo Observatory

Radar is a uniquely powerful source of information about asteroid physical properties and orbits; this technique has been applied to 65 main-belt asteroids (MBAs) and 96 near-Earth asteroids (NEAs) to date. Measurements of the distribution of echo power in time delay (range) and Doppler frequency (radial velocity) constitute two-dimensional images that can provide spatial resolution as fine as ~10 m if the echoes are strong enough. With adequate orientational coverage, such images can be used to construct geologically detailed three-dimensional models, to define the rotation state precisely, and to constrain the object's internal density distribution. The size of radar wavelengths (3.5 cm to 13 cm) and the observer's control of transmitted and received polarizations make radar experiments sensitive to near-surface bulk density and structural scales larger than a few centimeters. Since delay-Doppler measurements are orthogonal to optical plane-of-sky measurements and have a fractional precision as fine as 10^-9, they are invaluable for refining orbits and prediction ephemerides: a single radar detection secures the orbit well enough to prevent "loss" of newly discovered asteroids, shrinking the instantaneous positional uncertainty at the object's next close approach by orders of magnitude with respect to an optical-only orbit.

The sizes of radar-detected asteroids span four orders of magnitude. C and S main-belt asteroids have radar albedos (and hence near-surface bulk densities) that are similar to each other but higher than those of B, G, F, and P asteroids. The large radar albedos of 1986DA, Kleopatra, and Psyche suggest metallic compositions. The accuracy of constraints on the shape of Eros derived from relatively weak echo spectra gives us confidence in physical modeling based on much stronger data sets. High-resolution images of Toutatis reveal a geologically complex object in a slow, complex rotation state. 1999 JM8 and 4486 Mithra also are slow, complex rotators. The combination of Arecibo radar echoes and available vis/IR data indicates that Glauke is an S-class object slightly smaller and less elongated than 243 Ida, with radar surface properties near the average for S asteroids in the main belt, in an extraordinarily slow (~50-d) rotation state. 1999 RQ36, 7822 (1991 CS) and 2100 Ra-Shalom are spheroidal; Castalia and Bacchus are bifurcated and may be contact binaries; and 1982TA has a triangular pole-on shape. Golevka is the most angular object imaged so far, with significant exposure of regolith-free rock. 1998 ML14 is a 1-km-diameter spheroid with prominent topography on one "hemisphere" and subdued topography on the other. The ~30-meter, rapidly rotating, spheroidal, and apparently carbonaceous asteroid 1998 KY26 is more accessible to spacecraft than any other asteroid with a well known orbit. Kleopatra is a dogbone-shaped metallic object the size of New Jersey; its surface and perhaps most of its interior are unconsolidated rubble. The near-unity polarization ratios of 2101 Adonis, 3103 Eger, 1992QN, 1998 WT24 and 2000 EE104 indicate extreme near-surface roughness at cm-to-m scales. Radar has revealed that NEAs 2000 DP107, 2000 UG11, 1999 KW4, and 1998 ST27 are binary systems.

A major upgrade of the Arecibo telescope has made that instrument an order of magnitude more sensitive and much more versatile than it was a decade ago. Arecibo can see almost twice as far as Goldstone and can achieve finer range resolution than Goldstone, while Goldstone's greater steerability gives it access to twice as much sky and lets it track objects at least three times longer than Arecibo. Although main-belt asteroids are generally beyond the range of Goldstone, the best NEA radar experiments use both instruments.

This talk will use images, movies, and radar-derived three-dimensional models to present recent highlights of asteroid radar research, concentrating on objects that are low-delta-V candidates for missions. There will be a special emphasis on the extraordinary scientific opportunities offered by the upgraded Arecibo radar, which is observing asteroids at a rate approaching one per week.