Radar characterization of orbital debris with Arecibo Observatory and the Planetary Radar Investigation, Demonstration, and Exploration (PRIDE) Laboratory

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ABSTRACT

Arecibo Observatory and the Planetary Radar Investigation, Demonstration, and Exploration (PRIDE) Laboratory, located at the Lunar and Planetary Institute, are potentially untapped assets for orbital debris studies. Arecibo Observatory has a limited history of use for detecting geocentric and lunar-centric debris. Meanwhile, the PRIDE Lab can provide ground truth for the radar scattering properties of orbital debris. Our goal is to interface with the broad space situational awareness and orbital debris communities to gauge the utility of these resources.

The 305-m William E. Gordon Telescope at Arecibo Observatory houses two radar systems: an S-band (2.38 GHz; 12.6 cm), continuous-wave radar used predominantly for studies of near-Earth asteroids and a P-band (430 MHz; 70 cm), pulsed radar used predominantly for studies of Earth's ionosphere. The S-band system, up to 1 MW output power with a ~2 arcmin beam size, was used to study orbital debris by pointing to a patch at 575 km altitude and receiving echoes from passing mm- and cm-sized debris at an auxiliary 30-m telescope several km away (Thompson et al., 1992) and for scanning regions around the Moon to locate defunct spacecraft, e.g., Chandrayaan-1, by receiving echoes at the 100-m Green Bank Telescope in West Virginia (Brozović et al., 2017). The nature of the S-band system requires a separate antenna to receive echoes from geocentric and lunar-centric targets. The pulsed, P-band system, 2.5 MW peak power and ~5% duty cycle with a ~12 arcmin beam size, does not require a separate receiving antenna and often serendipitously detects satellites passing through the radar beam while observing the ionosphere. The slew rates of the telescope limit tracking to targets at least 6000 km above the surface of the Earth, i.e., upper medium-Earth, half-geosynchronous, geosynchronous orbits and higher. An additional caveat is the fixed reflecting surface at Arecibo restricts the field of view to a declination range from -1 to +38 degrees, limiting visibility of, say, the geosynchronous belt.

The PRIDE Lab, currently under construction, is a laboratory intended to study radar scattering of analog materials to increase the scientific return of radar observations of asteroids and planetary surfaces, but could be extended to studies of orbital debris. The first phases of Pride Lab will use continuous-wave, K-band (~24 GHz; ~1.3 cm) radar equipment capable of emitting and receiving both senses of circularly polarized light. Thus, the lab will enable measurements of the radar albedos of materials and the (de-)polarization of their echoes in a controlled environment. Such measurements will facilitate the interpretation of radar observations after scaling from K band to the radar frequency of interest. Later phases of PRIDE Lab will include more sophisticated instrumentation for radar imaging and for bistatic modes where the transmitter and receiver are not co-located. First light is expected later this year.

Brozović, M., et al. (2017) Radar Observations of Spacecraft in Lunar Orbit, International Symposium on Space Technology and Science, http://issfd.org/ISSFD_2017/paper/ISTS-2017-d-107__ISSFD-2017-107.pdf

Thompson, T.W., et al. (1992) Radar Detection of Centimeter-Sized Orbital Debris: Preliminary Arecibo Observations at 12.5-cm Wavelength, Geophysical Research Letters, 19, 3, 257-259.