PDC2019
Washington, DC, USA

☐ **Key International and Political Developments**
☐ **Advancements and Progress in NEO Discovery**
X☐ **NEO Characterization Results**
☐ **Deflection and Disruption Models & Testing**
☐ **Mission & Campaign Designs**
☐ **Impact Consequences**
☐ **Disaster Response**
☐ **Decision to Act**
☐ **Public Education & Communication**

Goldstone and Arecibo radar observations of (99942) Apophis in 2021 and 2029

Marina Brozović [1], Lance A. M. Benner[1], Michael C. Nolan[2], Jon D. Giorgini[1], Shantanu P. Naidu[1], Patrick A. Taylor[3], Michael W. Busch[4], and Davide Farnocchia [1]

[1]*Jet Propulsion Laboratory/California Institute of Technology, Pasadena, CA, marina.brozovic@jpl.nasa.gov*
[2]*University of Arizona, Tucson, AZ*
[3]*Lunar and Planetary Institute, Houston, TX*
[4]*SETI Institute, Mountain View, CA*

Keywords: *radar, characterization, Apophis*

ABSTRACT

Goldstone (8560 MHz) and Arecibo (2380 MHz) radar observations of Apophis in 2012–2013 at ~0.097 au revealed an elongated, asymmetric object that could be bi-lobate. The next opportunity for radar observations of Apophis will occur in March 2021 at a distance of ~0.113 au. Arecibo will be able to observe Apophis sooner after the closest approach than it was in 2013, resulting in a three-fold increase in the signal-to-noise ratios (SNRs). We expect to obtain Arecibo delay-Doppler images with a resolution as fine as 15 m/pixel and bistatic Goldstone/Green Bank images with a resolution up to 37.5 m/pixel. The 2021 radar data will help refine estimates of the shape, size, moment of inertia ratios, and spin state, and radar ranging will likely reveal the magnitude of the Yarkovsky acceleration that is currently the dominant source of orbital uncertainties for Apophis. Radar astrometry will reduce the statistical uncertainties in position for future planetary encounter predictions, providing more accurate hazard assessment. A Yarkovsky effect detection and an improved estimate of the size will also facilitate estimation of the mass and bulk density, particularly if better estimates of thermal inertia are obtained in 2021.

Apophis will be an astounding radar target before, during, and after the <6 Earth radii from the geocenter encounter on April 13, 2029. Apophis will approach from the south at a declination of about –30 deg. Observations at Goldstone could start as

early as mid-March and last until mid-May. Goldstone imaging at a resolution of 3.75 m/pixel, the finest resolution available at the 70 m DSS-14 antenna, will likely occur between April 6–21. We also plan to use the 34 m DSS-13 antenna at Goldstone that can achieve up to 1.875 m resolution, which should place thousands of pixels on the asteroid for at least two days centered on the closest approach. DSS-13 resolution is twice as fine as the highest resolution at DSS-14 and four times as fine as the best resolution at Arecibo. Apophis will be observable at Goldstone twice on April 13: first from 0.9–0.7 lunar distances ~14 hours prior to the flyby and again for several hours starting just a few minutes before the closest distance. Apophis becomes observable at Arecibo one day after the closest approach and 7.5 m resolution imaging should be possible until early May. Apophis will be detectable at SNRs strong enough for ranging measurements until at least early June. Detailed delay-Doppler radar images obtained before and after the flyby should reveal changes to the asteroid's spin state and might reveal subtle changes on the surface. Radar images obtained in 2021 and 2029 should provide high-precision estimates of the moment of inertia ratios, which can be used to test for heterogeneity in the asteroid's mass distribution, and modeling using detailed images obtained after the 2029 flyby will offer a test for changes caused by the close encounter. The combined Goldstone and Arecibo radar astrometry after April 13, 2029 should enable accurate orbit predictions for at least decades farther into the future.

****