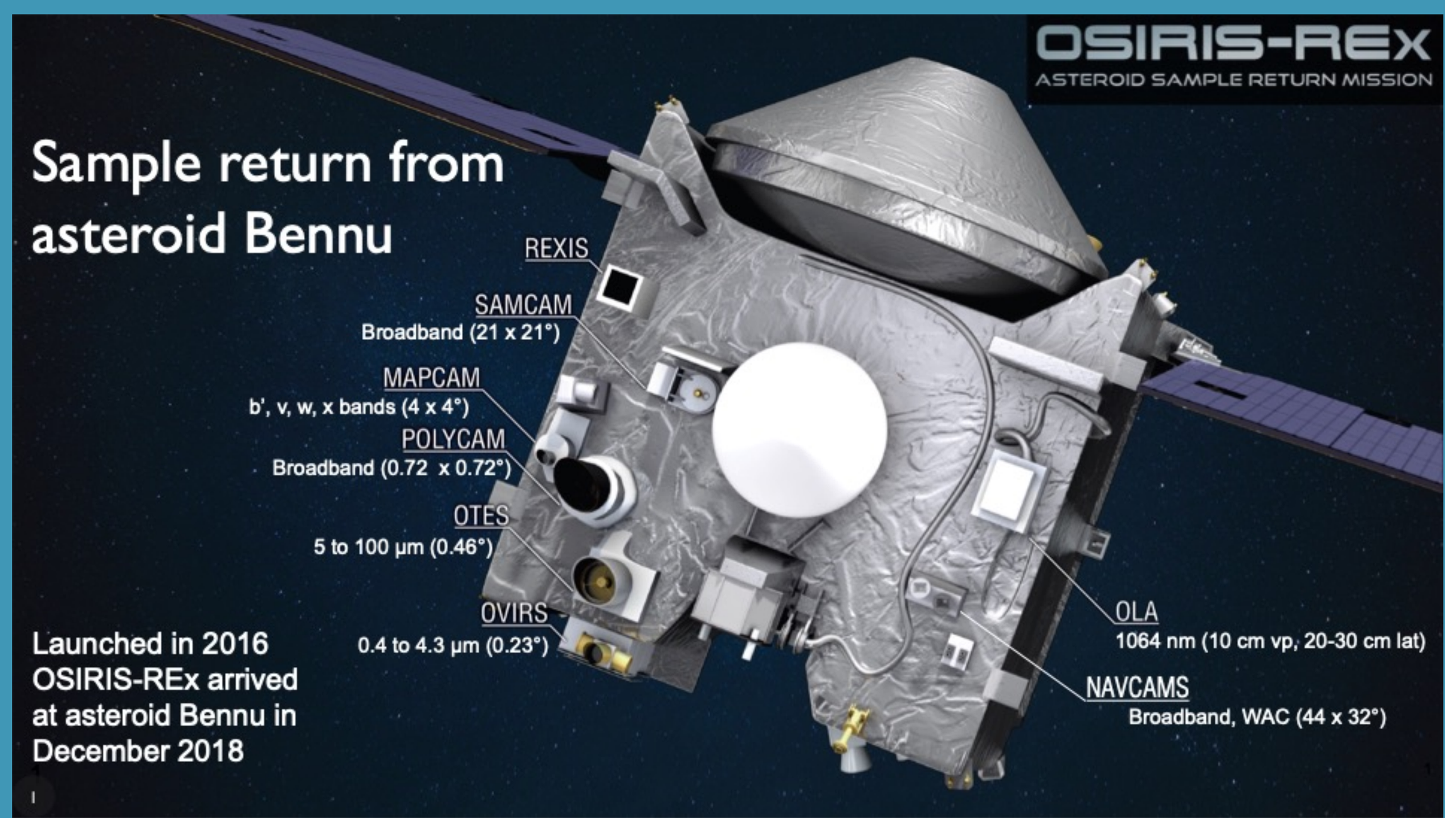
OSIRIS-APEX: Implications of Mission Objectives for Planetary Defense

R. Terik Daly[1], E. G. Rivera-Valentín[1], M. C. Nolan[2], D. N. DellaGiustina[2], O. S. Barnouin[1], R.-L. Ballouz[1], M. G. Daly[3]

[1]Johns Hopkins University Applied Physics Laboratory
[2]Lunar and Planetary Laboratory, University of Arizona
[3]Centre for Research in Earth and Space Science, York University

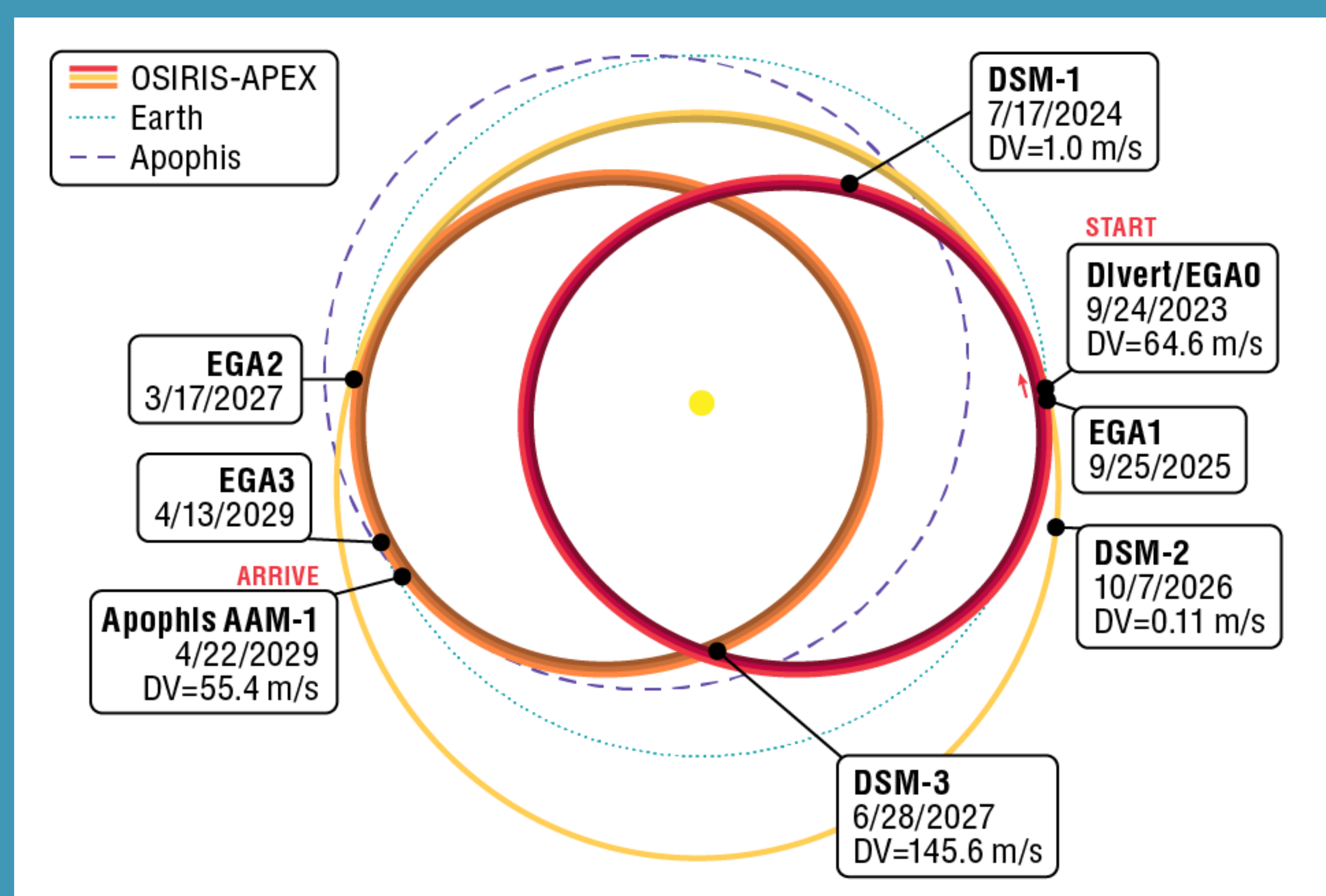
OSIRIS-APEX
APOPHIS EXPLORATION MISSION

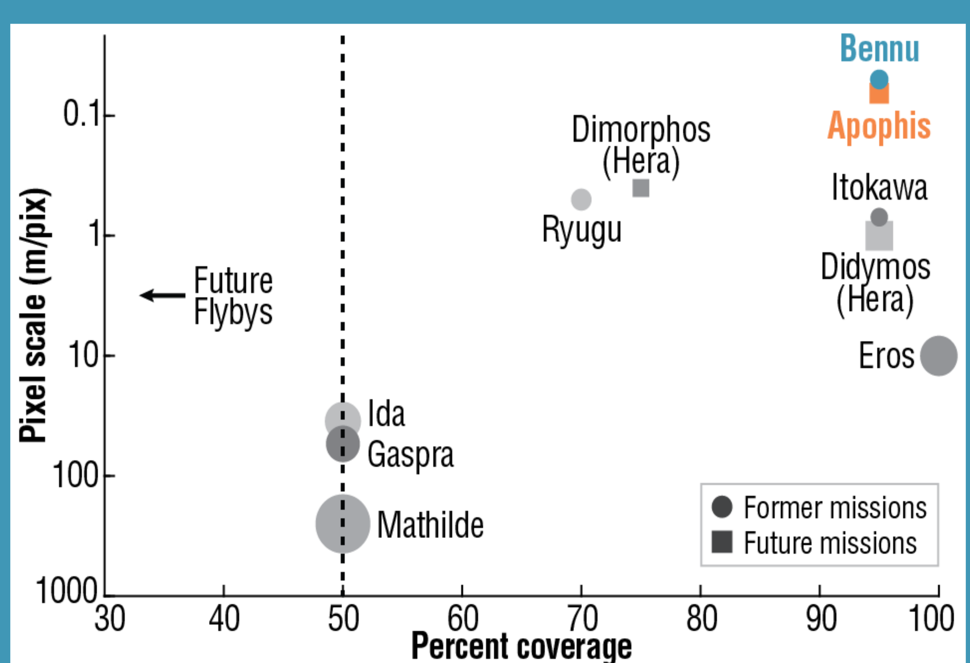
Mission Overview



The OSIRIS-REx spacecraft successfully rendezvoused with Bennu on December 3, 2018. It conducted a detailed survey of the surface of Bennu over two years by providing centimeter-scale global morphology, meter-scale maps across a broad range of wavelengths (0.4-100 microns), and sampled the asteroid. Analysis of the surface sample will further our knowledge of C-complex asteroids. The sample return capsule will be released in September of 2023. Afterwards, the spacecraft will divert into a heliocentric orbit.

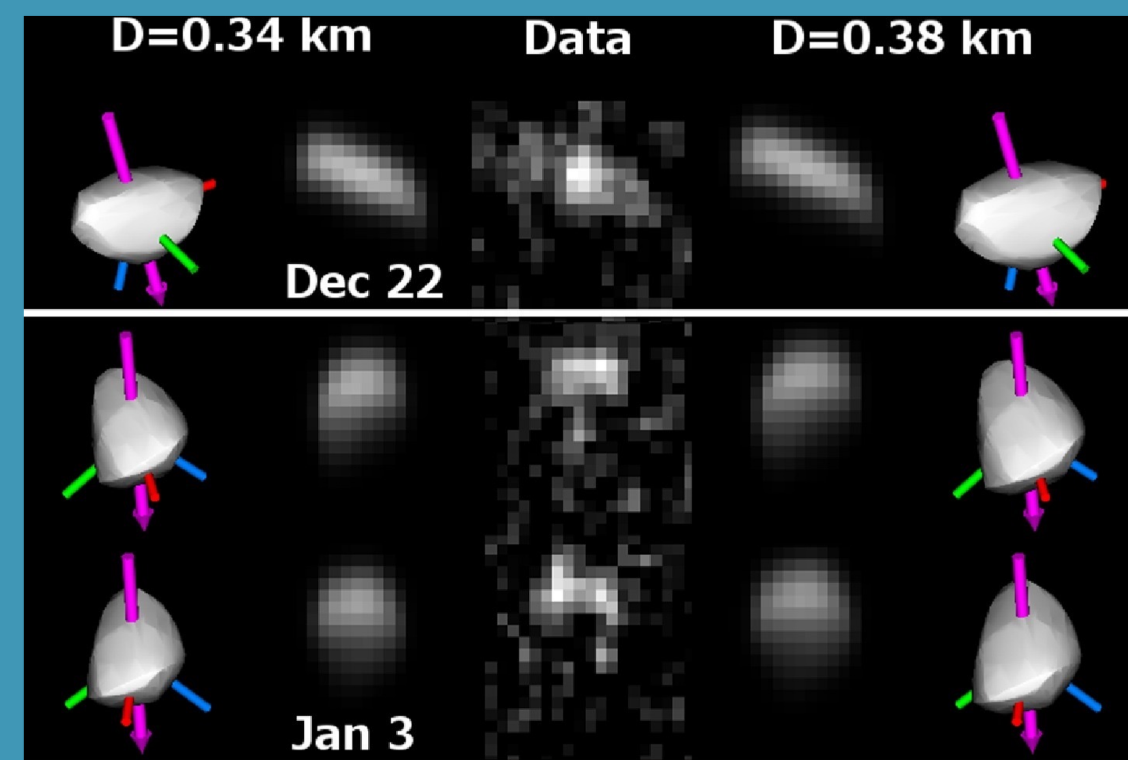
The spacecraft's cruise to Apophis will begin after sample release. During the cruise phase, three Earth Gravity Assists (EGA), three deterministic Deep Space Maneuvers (DSM), and several perihelion passages and solar conjunction events occur. Beginning in early 2029, APEX will approach Apophis systematically to characterize it to a level sufficient for accurate navigation. This will position APEX to gather in situ observations and satisfy the mission science objectives. During approach, the spacecraft will acquire observations to develop a shape model and determine the post-Earth encounter rotation state of Apophis.





The capabilities of the APEX spacecraft and cameras will offer an unprecedented combination of global coverage and sub-cm resolution. The detailed characterization of an individual potentially hazardous asteroid is responsive to the identified priority investigations by the Small Bodies Assessment Group (SBAG). Additionally, the measurements enabled by APEX are directly responsive to the SBAG Specific Action Team report on Apophis science as well as to findings and recommendations by the recent Planetary Science and Astrobiology Decadal Survey.

Planetary Defense Implications

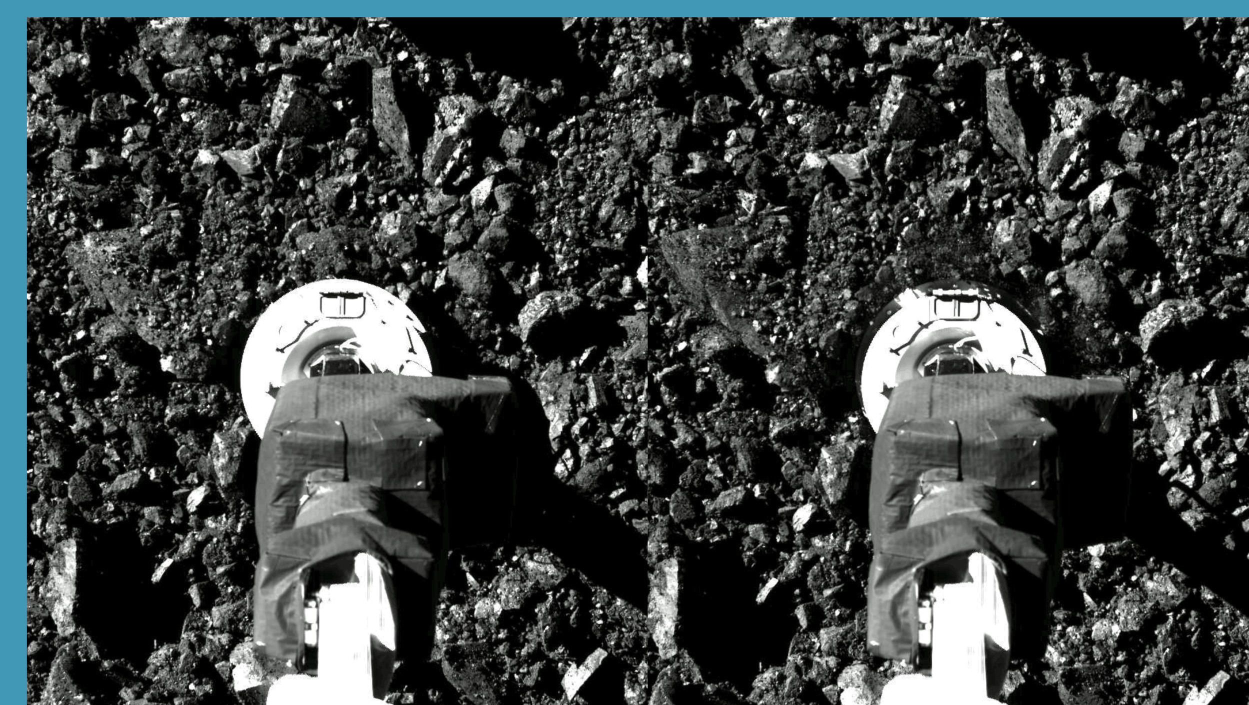


Determine the Density and Interior Structure of Apophis

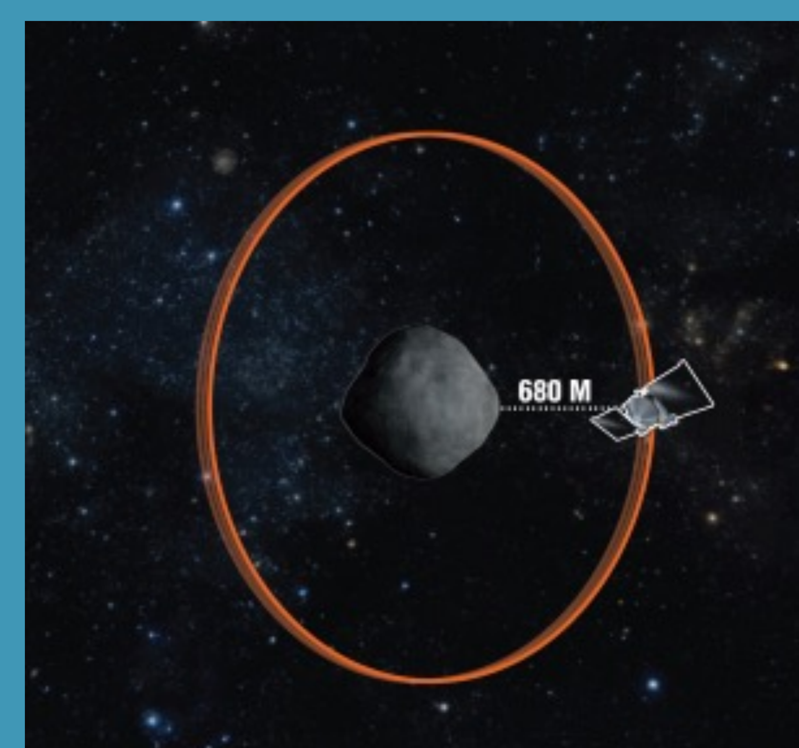
Using images taken by the spacecraft and lidar ranging, APEX will provide a detailed 3D shape model of Apophis with an average facet size of 20-cm. Additionally, radio science experiments with the high- and low-gain antennas will determine the mass of Apophis and estimate its distribution to the second degree. Such constraints will determine if Apophis is mechanically a monolith, composed of large fragments, or a rubble pile.

Image Credit: Brozović et al. (2018) Icarus 300, 115-128, Figure 5.

Constrain the Geotechnical Properties of Apophis



APEX will measure the near-surface strength of Apophis. To do this, the spacecraft will approach the asteroid's surface and then back away to excavate material with its thrusters, similar to the technique used at Bennu for sample collection. The response of the surface to thruster excavation will provide constraints on material strength, porosity, and bulk density.



Measure the post-Earth Encounter Yarkovsky Effect

The Apophis-Earth encounter provides a natural experiment to study a change in the Yarkovsky effect due to the change in orbit and rotation state. Ranging to the APEX spacecraft during orbital operations around Apophis will provide accurate post-encounter Yarkovsky drift measurements. Additionally, the spacecraft will provide detailed mapping of the surface thermal properties of Apophis. Because the primary source of uncertainty for ground-based measurements of Yarkovsky acceleration has been thermal inertia, APEX measurements of the surface thermal properties paired with post-encounter drift measurements will elucidate the Yarkovsky effect in unprecedented detail.

"Space-truth" Ground-based Observations

The rare close encounter of Apophis with Earth will provide excellent viewing conditions for many ground-based observatories. Data returned by APEX will help to assess the accuracy of ground-based measurements and help to understand the extent to which they can reliably reduce uncertainties in properties relevant to planetary defense.