

PLANETARY DEFENSE IMPLICATIONS OF THE OSIRIS-APEX MISSION

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INTRODUCTION

After surveying asteroid Benu, the OSIRIS-REx mission successfully sampled the surface in October 2020 and returned the sample to Earth in September of 2023. With a new designation as OSIRIS-APEX (Origins, Spectral Interpretation, Resource Identification, and Security–Apophis Explorer), the spacecraft diverted into a heliocentric orbit to enable subsequent Earth flybys. OSIRIS-APEX will approach and rendezvous with asteroid (99942) Apophis in the spring of 2029, just after its close approach to Earth [1]. **APEX has three primary mission goals.**

1. To study the processes that drive the evolution of small asteroids.
2. To determine the characteristics of a “stony” (S-complex) object to study physical and dynamical evolution.
3. to examine the properties of a potentially hazardous S-complex asteroid to help inform planetary defense knowledge and strategies

PROCESSES

The first mission goal is to study the processes that drive the evolution of small asteroids, including tidal effects from close encounters with terrestrial planets.

- Apophis will come within 0.1 lunar distances of Earth (Figure 3) [2]. This encounter is expected to result in potentially dramatic tidal deformation [4].
- APEX proximity operations will help to reveal changes in the rotation state. By comparing the spin states of Apophis before and after Earth close-approach, APEX will be able to constrain the internal density distribution, an important property needed to inform **impact threat assessments** [5].
- Apophis-Earth encounter provides a natural experiment to study a change in the Yarkovsky effect due to the change in orbit and rotation state (Figure 4).

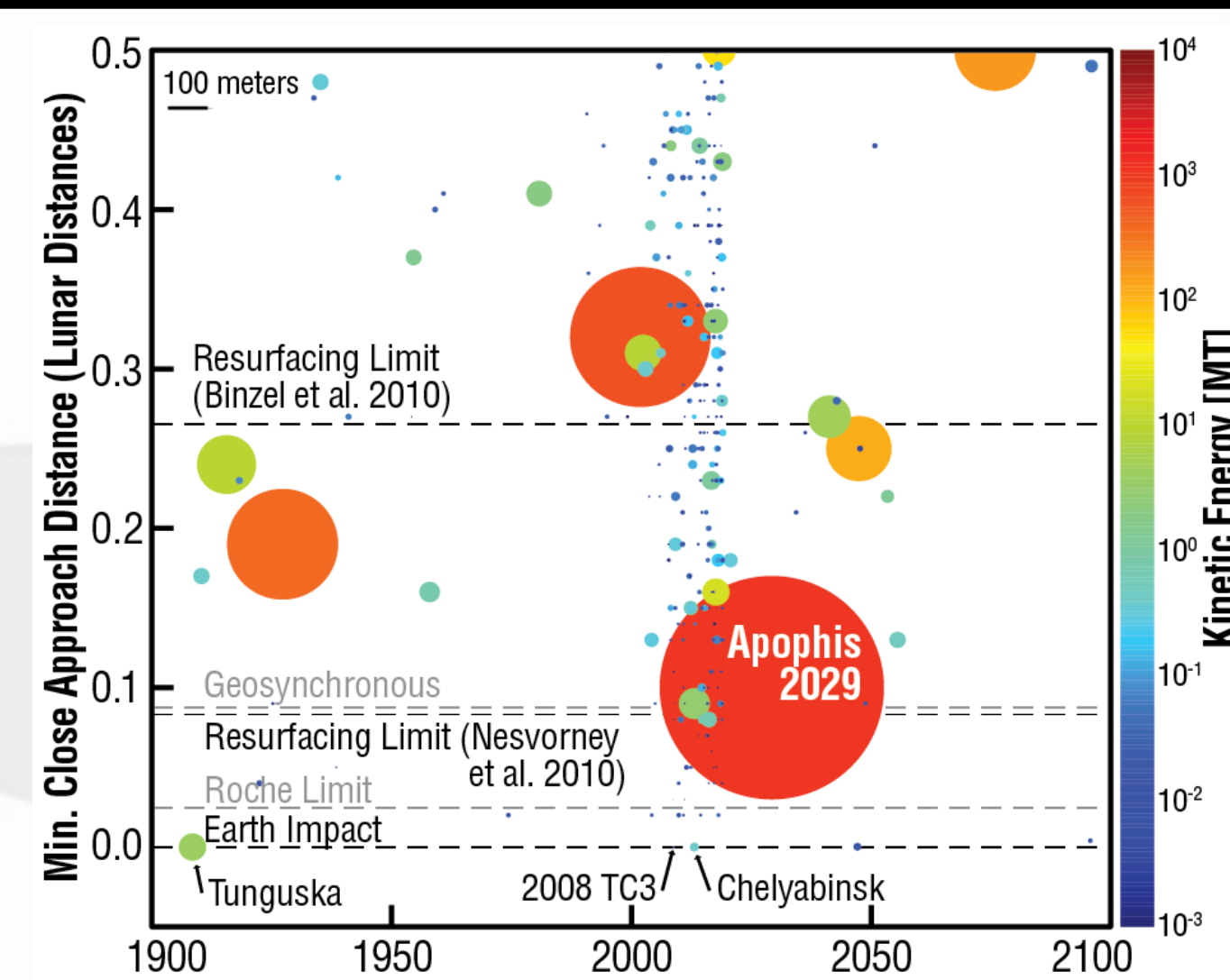


Figure 3: The size and proximity of Apophis during 2029 stands out as a rare, 1 in 7500 year event. Adapted from [3].

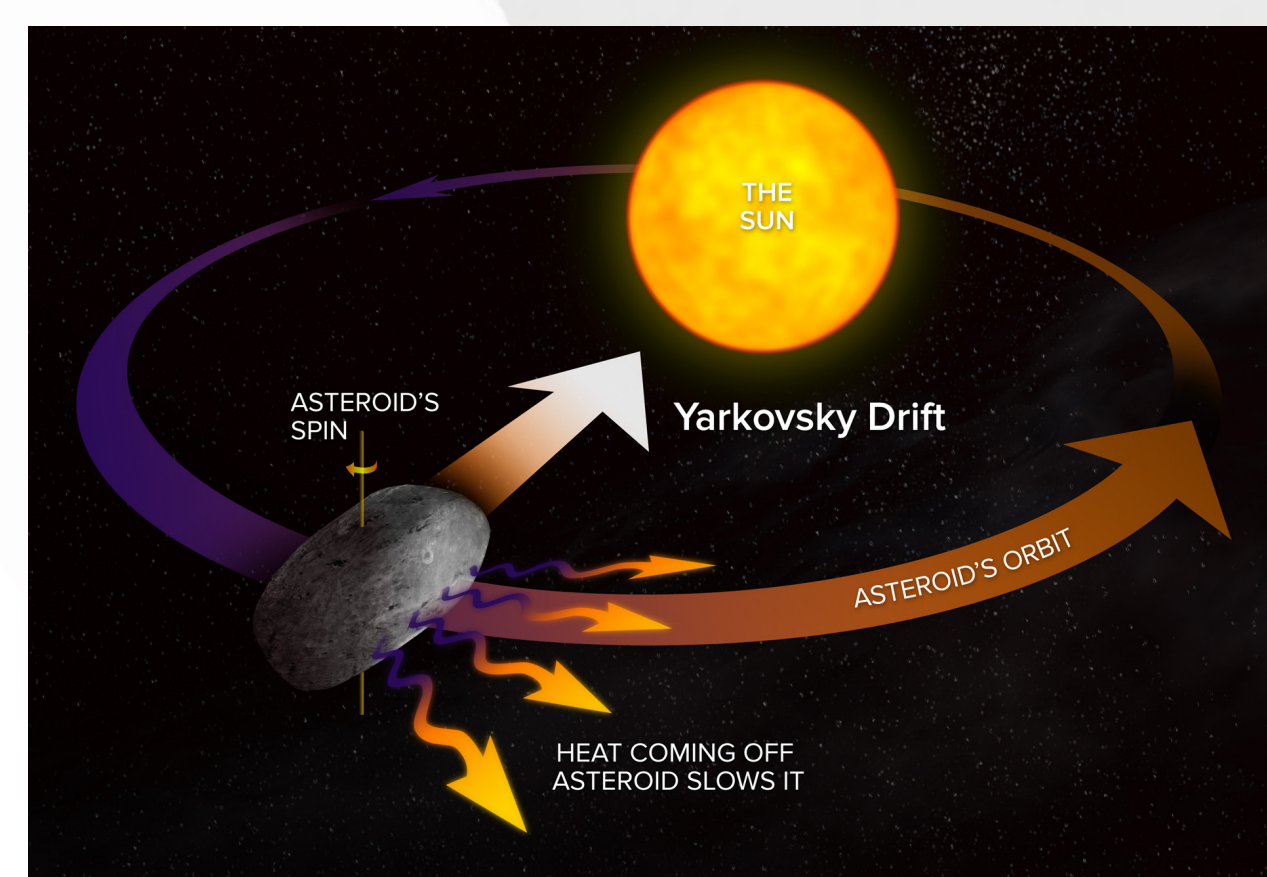


Figure 4: Ranging to the APEX spacecraft during orbital operations around Apophis will provide accurate post-encounter Yarkovsky drift measurements. Image Credit: A. Angelich, NRAO/AUI/NSF.

CHARACTERISTICS

The second mission goal is to determine the characteristics of a “stony” (S-complex) object to study physical and dynamical evolution, including any previous Earth encounters.

- Images across a broad range of wavelengths (0.4–100 μm)
- Lidar ranging data to produce meter-scale maps and centimeter-scale global morphology.
- Radio science will be used to determine the mass of Apophis and the degree-2 gravity field, providing information about mass, interior structure, and surface properties (Figure 5).
- Taken together, these measurements will constrain the mechanical structure of Apophis including surface heterogeneities – key properties that help **inform planetary defense strategies** [4].

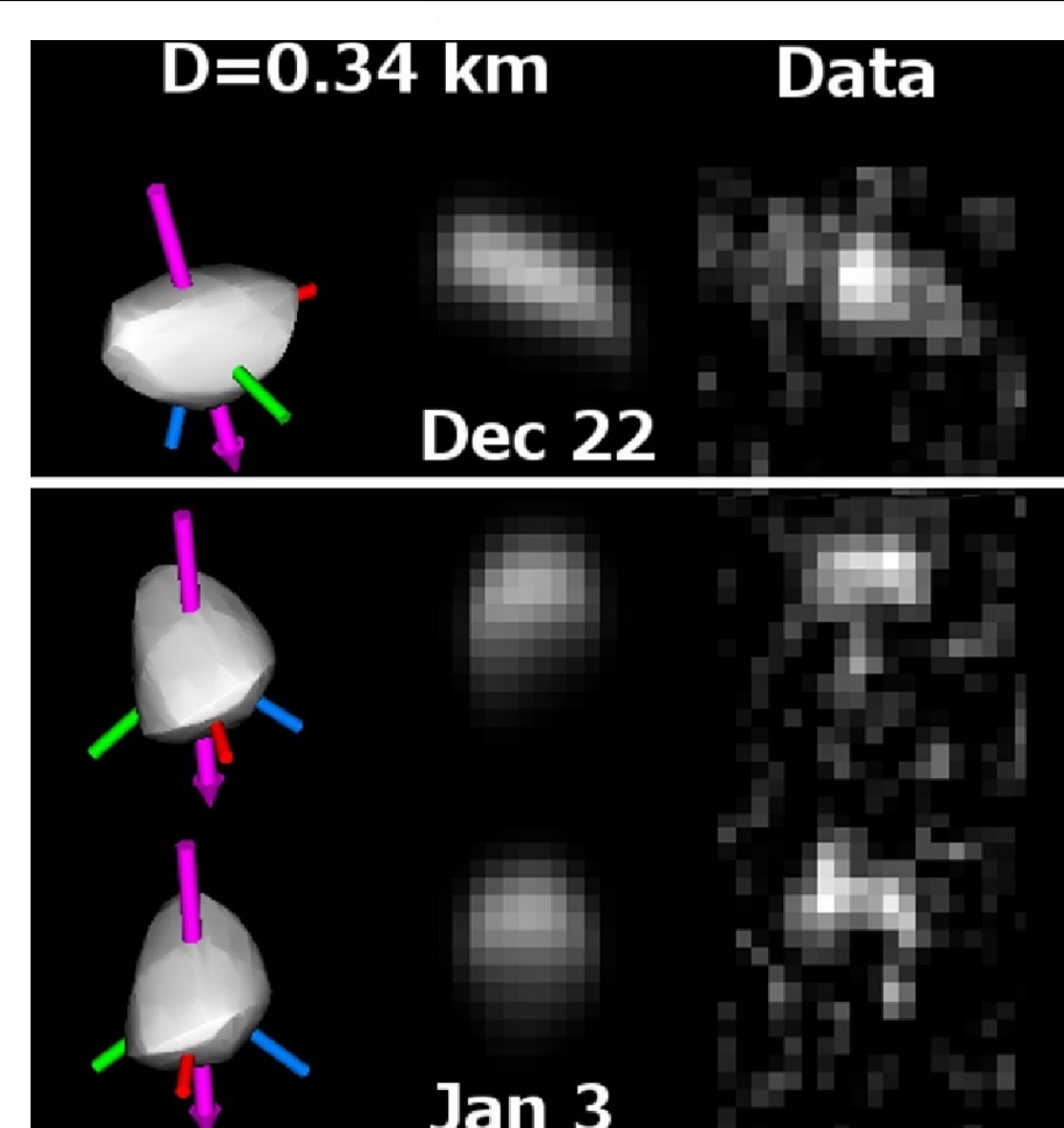


Figure 5: Plane-of-sky renderings of a 3D model scaled to $D = 0.34$ km (panel a), corresponding fits or “synthetic” images (middle), delay-Doppler radar images (Right). The magenta arrow shows the instantaneous orientation of the spin vector, and the red, green, and blue poles show the long, intermediate, and short principal axes, respectively. Adapted from [6], Figure 5.

ACKNOWLEDGEMENTS

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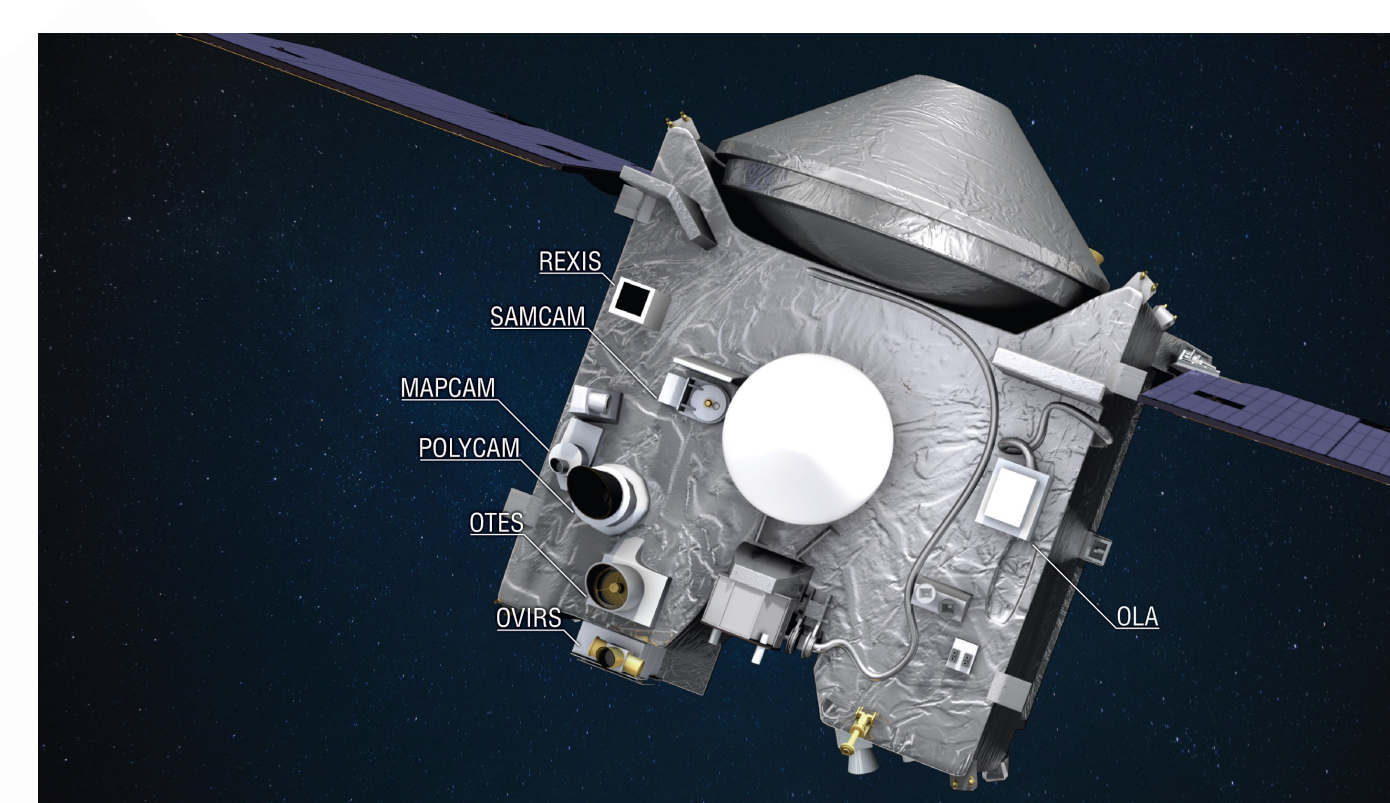


Figure 1: The OSIRIS-REx spacecraft, having delivered its Benu samples to Earth, has been repurposed to rendezvous with Apophis. While the sample collection was a one-time opportunity, the rest of the payload remains functional to study Apophis.

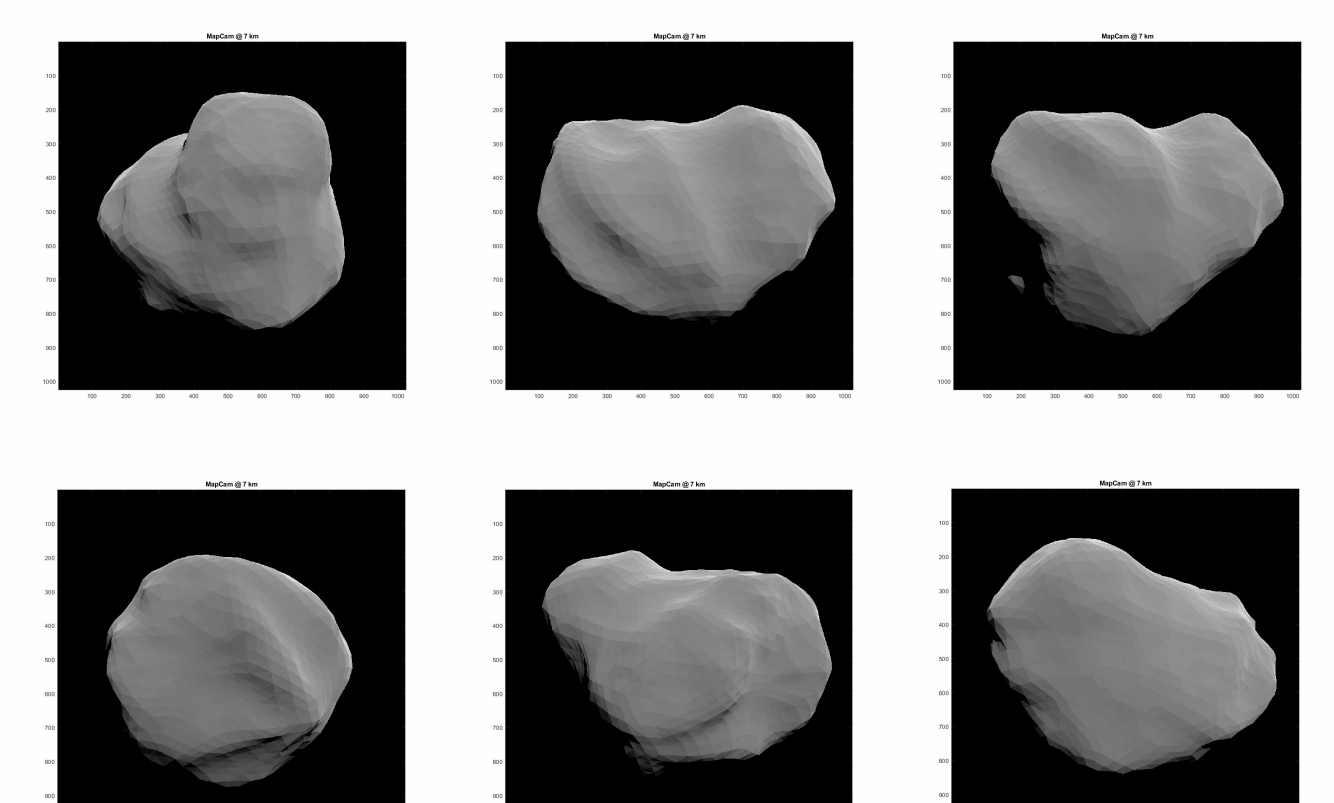


Figure 2: Simulation of Apophis as it would appear in the OCAMS MapCam Imager from a range of ~7 km, using the shape of Apophis [6] interpolated to 15 m facets shown at 6 points over a rotational period.

STRATEGIES

The third mission goal is to examine the properties of a potentially hazardous S-complex asteroid to help inform planetary defense knowledge and strategies.

- APEX will measure the near-surface strength of Apophis through the Spacecraft Thruster Investigation of Regolith (STIR) maneuver. The spacecraft will approach Apophis’s surface, then back away using its thrusters, which will excavate material.
- The response of the surface will provide constraints on material strength, porosity, and bulk density — key properties controlling momentum transfer efficiency for a **kinetic deflection mission** [7].

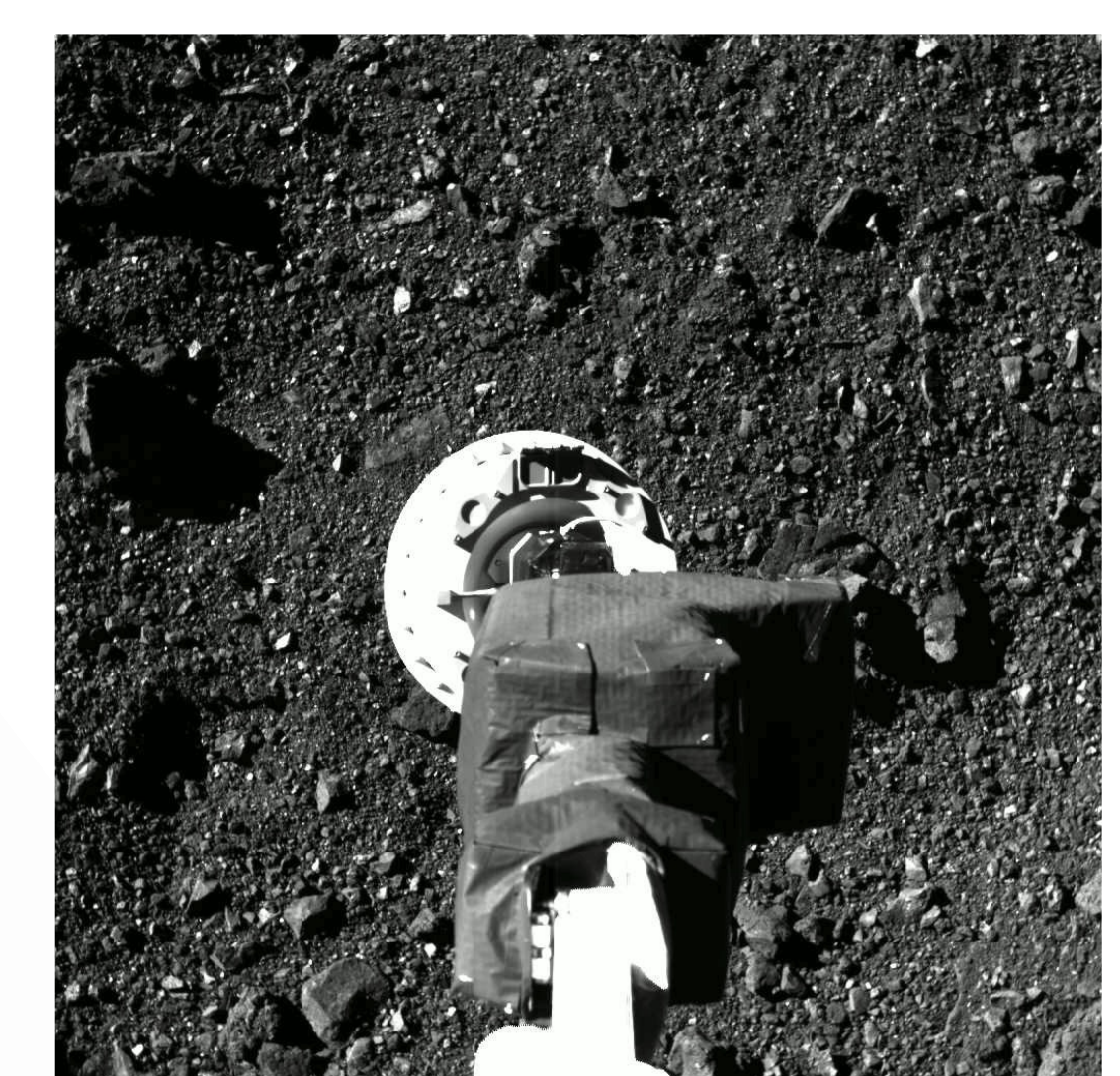


Figure 6: During TAG maneuvers at Benu, the spacecraft approached the surface and released gas from a pressurized canister to excavate material and loft it into the sample canister. At Apophis a similar excavation will be performed with the thrusters.

DISCUSSION

The rare close encounter of Apophis with Earth will provide excellent viewing conditions for many ground-based observatories. Comparing in situ rendezvous data from APEX with ground-based observations will enable synergistic analysis and calibration of datasets and improved higher-order science products. In particular, data returned by APEX will help to assess the accuracy of ground-based measurements of **properties relevant to planetary defense**.

Thus, the Apophis close encounter and APEX mission present the opportunity for a **globally coordinated planetary defense exercise** using both ground- and space-based assets [8].

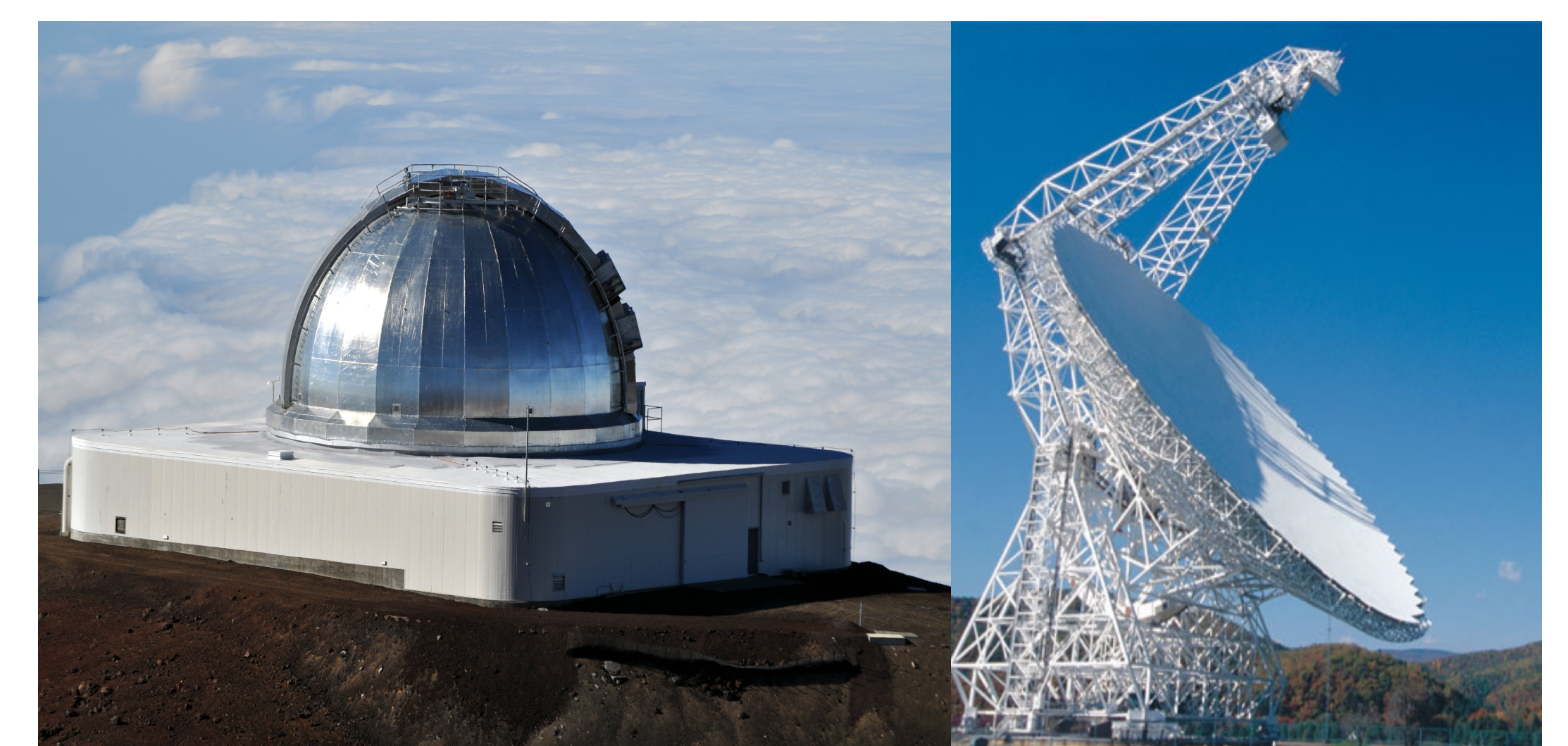


Figure 7: Ground-based optical and radio telescopes will observe Apophis concurrently with APEX.

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