Pre-encounter mission requirements to complement OSIRIS-APEX post-encounter-studies of Apophis

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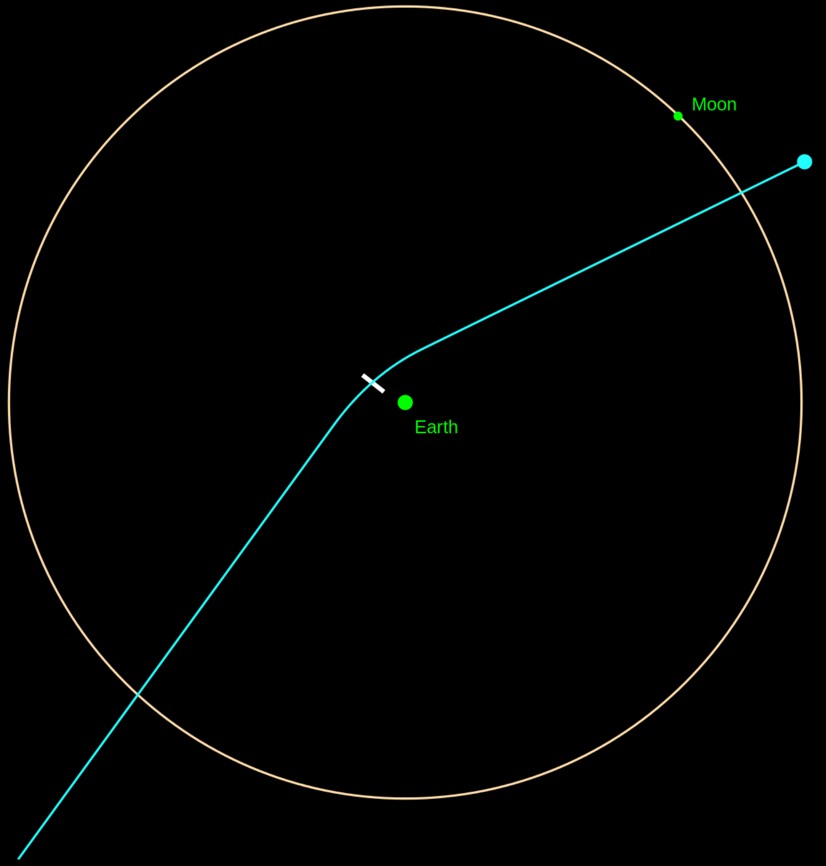
Apophis 2029 fly-by

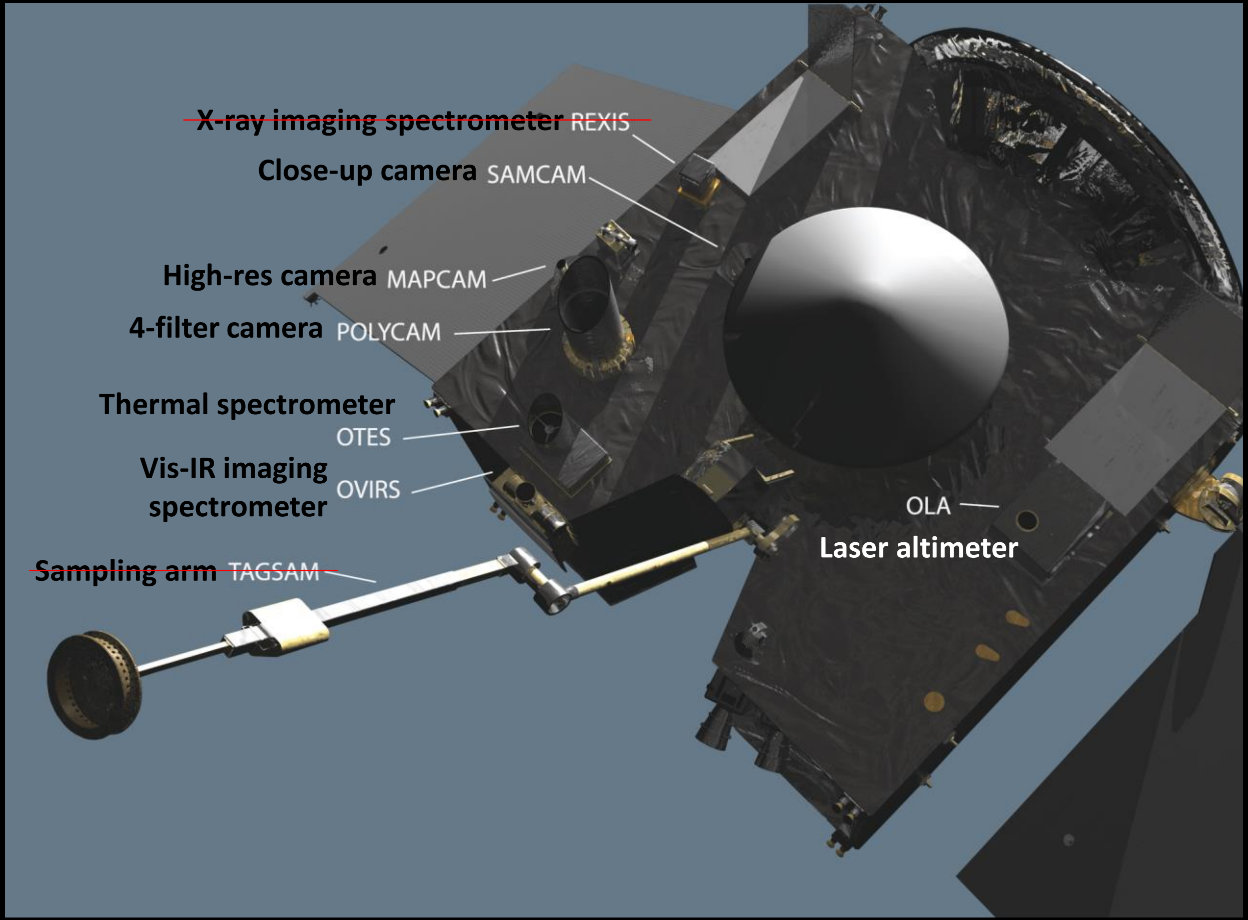


Josef Ďurech, Vojtěch Sidorin

(99942) Apophis

- Aten-asteroid
- S-type
- ~500 x 200 m
- Close-Earth fly-by on April 13, 2029
- 31600 km (within geosynchronous orbit)

OSIRIS-REx → APEX



- OSIRIS-REx is a mission to asteroid Bennu
- Sample return delivery to Earth in 2023 will conclude primary mission
- The spacecraft will divert into an orbit around the Sun, allowing for subsequent close Earth flybys
- Spacecraft will approach Earth in 2029 alongside asteroid Apophis, enabling an extended mission OSIRIS–Apophis Explorer (APEX)
- The Apophis approach phase will begin on April 22, 2029 – 9 days after Apophis Earth fly-by (April 13)
- The aim of this study is to identify key pre-encounter observations to maximize APEX science return

OSIRIS-APEX Mission Plan document

OSIRIS-APEX science goals and objectives

Science goal	Objective
Establish the processes that drive the evolution of rubble-pile asteroids, including tidal effects from close-encounters with terrestrial planets	**1.1** Determine the evolution of Apophis' rotation state
	1.2 Globally search for morphologic and spectrophotometric signatures of mass shedding and recent resurfacing
	1.3 Regionally characterize surface features on Apophis that have been recently disturbed
	1.4 Determine the collisional history of Apophis
Determine the characteristics of an S-complex NEO to establish the link with its parent-asteroid family and its dynamical evolution from main belt through multiple Earth encounters	**2.1** Obtain the global composition, photometric, and thermal properties of Apophis
	2.2 Characterize Apophis' bulk structural properties (shape, density, macroporosity, and mass)
Examine the properties of an S-complex, potentially hazardous asteroid (PHA) as an analog for other PHAs and to defend the Planet	**3.1** Apply knowledge of Apophis' bulk structure and geotechnical properties to inform mitigation strategies
	3.2 Assess the orbital evolution and long-term hazardous potential of Apophis.
	3.3 Provide "space truth" for ground-based observations of Apophis at the 2029 Earth encounter.
Characterize Earth's reflected light spectrum as a function of largescale biological state and distribution.	**4.1** Determine variations in Earth's surface and atmosphere using an analogous technique for observations of extrasolar Earth-like planets.

OSIRIS-APEX science goals and objectives

Science goal	Objective requiring or benefitting from pre-encounter knowledge
Establish the processes that drive the evolution of rubble-pile asteroids, including tidal effects from close-encounters with terrestrial planets	**1.1** Determine the evolution of Apophis' rotation state
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Characterize Earth's reflected light spectrum as a function of largescale biological state and distribution.	**4.1** Determine variations in Earth's surface and atmosphere using an analogous technique for observations of extrasolar Earth-like planets.

Key pre-encounter observations

Primary

1. Produce global albedo map (min 80% surface coverage, ideally 6 cm/px), or spectral map (ideally 50 cm/px) albedo and slope with 1 and 2-µm silicate absorptions covered. Spectral observations should be in-line with MapCam filters (0.47, 0.54, 0.71, 0.84 µm) APEX 1.2, 1.3
2. Identify preliminary areas (1. high local slopes where resurfacing is expected, 2. mature stable area where changes are not expected) for APEX REST (Regolith Excavation by S/C Thrusters) observations) APEX 1.3
3. Thermal mapping in range of 7-25 µm and 20 m/px APEX 1.2
4. Search for any ejected particles (ideally 5-cm and larger) in vicinity of Apophis in order to provide pre-encounter background information to APEX post-encounter observations APEX 1.2

Secondary

5. Constrain rotation state, especially determine precise pre-encounter shape (ideally 1-m vertical and horizontal resolution), volume (ideally 3%), mass (ideally 0.5%), and location of rotation axis APEX 1.1
6. Measure boulder frequency size distribution and identify crater candidates to enable monitoring of any encounter-induced changes APEX 1.4

Quantitative observation requirements match these of APEX and are considered as ideal case

APEX 1.1 Determine the evolution of Apophis' rotation state
1.2 Globally search for mass shedding and recent resurfacing
1.3 Regionally characterize recently disturbed features
1.4 Determine the collisional history of Apophis

Candidate pre-encounter payloads

Primary

1. Produce global albedo map (min 80% surface coverage, ideally 6 cm/px), or spectral map (ideally 50 cm/px) albedo and slope with 1 and 2-µm silicate absorptions covered. Spectral observations should be in-line with MapCam filters (0.47, 0.54, 0.71, 0.84 µm) **Hyperspectral imager or multispectral camera (filters)**
2. Identify preliminary areas (1. high local slopes where resurfacing is expected, 2. mature stable area where changes are not expected) for APEX REST (Regolith Excavation by S/C Thrusters) observations) **Visible camera**
3. Thermal mapping in range of 7-25 µm and 20 m/px **Thermal imager**
4. Search for any ejected particles (ideally 5-cm and larger) in vicinity of Apophis in order to provide pre-encounter background information to APEX post-encounter observations **High-res vis. camera, close limb – low phase obs.**

Secondary

5. Constrain rotation state, especially determine precise pre-encounter shape (ideally 1-m vertical and horizontal resolution), volume (ideally 3%), mass (ideally 0.5%), and location of rotation axis **Visible camera**
6. Measure boulder frequency size distribution and identify crater candidates to enable monitoring of any encounter-induced changes **Visible camera**

Candidate pre-encounter payloads

Increasing complexity

Single payload	Visible camera	Identify preliminary areas for APEX REST (Regolith Excavation by S/C Thrusters) observations Constrain rotation state, especially determine precise pre-encounter shape, volume, mass, and location of rotation axis Measure boulder frequency size distribution and identify crater candidates to enable monitoring of any encounter-induced changes
	High-res. visible camera, close limb – low phase obs.	+ Search for any ejected particles in vicinity of Apophis in order to provide pre-encounter background information to APEX post-encounter observations
	Hyperspectral imager or multispectral camera (with filters)	+ Produce global albedo or spectral map with 1 and 2-µm silicate absorptions covered. Spectral observations should be in-line with MapCam filters (0.47, 0.54, 0.71, 0.84 µm)
Dual payload	+ Thermal imager	+ Thermal mapping in range of 7-25 µm and 20 m/px

Primary Secondary