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

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ABSTRACT

On April 13, 2029, the ~340-m-diameter Apophis will fly within ~32,000 km of Earth's surface (<10% the lunar distance). NASA recently approved an OSIRIS-Rex extended mission designated OSIRIS-APEX (APEX) to target asteroid Apophis. Orbital mechanics prevent OSIRIS-APEX to reach proximity of Apophis prior its 2029 encounter with the Earth with APEX approach phase scheduled to start on April 22, 2029. Thus, APEX will be able to document Apophis in detail in its post-encounter state, while the pre-encounter observations will rely on relatively low-resolution ground-based observations.

In this study we identify key requirements for a complementary rendezvous mission to provide crucial pre-encounter information in order to reliably document any changes in Apophis spin state, shape, internal structure, or surface due to its close encounter with the Earth. The APEX concept, goals and objectives are listed in https://www.lpl.arizona.edu/sites/default/files/resources/staff/OSIRIS-APEX_Mission_Plan_06062022.pdf. Four APEX objectives are dependent on pre-encounter information:

1.1 Determine the evolution of Apophis' rotation state
1.2 Globally search for morphologic and spectrophotometric signatures of mass shedding and recent resurfacing on Apophis
1.3 Regionally characterize surface features on Apophis that have been recently disturbed
1.4 Determine the collisional history of Apophis to establish the population of impactors witnessed both before and after its reaccumulation

Two key (1-2 in red) and four supplementary (3-6 in blue) observation requirements with reference to APEX science objectives were identified for pre-encounter mission:

1. 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)
2. Produce **global albedo map** (min 80% surface coverage, ideally 6 cm/px), or **spectral map** (ideally 50 cm/px albedo and slope, 30-60 m with 1 and 2-µm silicate absorptions covered. In particular the spectral observations should be in-line with MapCam filters (0.47, 0.54, 0.71, 0.84 µm) (APEX 1.2, 1.3)

3. **Thermal mapping** in range of 7-25 µm and 20 m/px (APEX 1.2)
4. 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)
5. Measure **boulder frequency size distribution** and **identify crater candidates** to enable monitoring of any encounter-induced changes (APEX 1.4)
6. 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)

The numerical observation requirements values match these of APEX and are considered as ideal case. Exact values for the pre-encounter observations will be determined based on instrument selection and spacecraft capabilities.

We envision that key requirements 2 and to some extent 1, 4 and 5 can be addressed with single-payload (e.g. VIS-NIR camera with spectral capability) CubeSat-grade mission (e.g. similar to ESA M-ARGO concept). To address all six requirements with required precision a larger spacecraft with high resolution camera, VIS-NIR spectral imager, and thermal imager are needed (e.g. similar to ESA Hera mission).

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Comments:

Oral, in-person