APOPHIS EXPRESS A UNIQUE OPPORTUNITY FOR VISITING APOPHIS IN 2029

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Introduction: The purpose of the paper is to present a novel design for a space mission headed towards Apophis and taking advantage from its close Earth flyby in April 2029.

Rationale: During its 2029 pass, Apophis will be easily visible from the Earth and it can be expected that its geometry and most of its physical properties will be well determined from ground based observations. However, the characterization of its interior will not be achievable from purely terrestrial remote observations. Such a characterization is however essential for planning any mitigation operation of this Potentially Hazardous Asteroid, should it be necessary in the future.

This can be done only through a dedicated space mission delivering a set of instruments to probe the interior of Apophis after being softly laid down on its surface.

Mission scenario: The mission scheme that is proposed in this paper consists in a very fast mission, less than one month, from the launch to the delivery of a scientific payload on Apophis' surface, with a possible sample return option. From a few days before its close approach to the Earth to its departure from the Earth vicinity, Apophis would be followed by a spacecraft carrying a set of scientific modules.

In March 2029, just a few weeks before Apophis is coming close to the Earth, a mission is launched into a highly eccentric orbit, the direction of the line of apsis being towards the incoming asteroid with an apogee altitude about 1 million kilometers. It will take about 3 weeks to reach the region that will be crossed by Apophis just a few days before its close encounter. From there, a ΔV of about 6 km/s is requested to cancel the relative velocity with respect to Apophis and thus allow delivering a scientific payload at its surface during its short rendez-vous.

Sample return option:
Some drilling tasks can even been achieved on Apophis to probe its interior. They will have to be executed quite fast, within a few hours in order to leave Apophis a couple of days before its close approach. The requested total amount ΔV is kept acceptably low: a few 100m/s ΔV, depending on the departure time, is sufficient to place the sample return capsule on a reentry trajectory.

Preliminary assessment based on Space Launch System:
The launch capacity of a SLS Block#1 to the interception orbit is about 25 metric tons. The fuel consumption (assuming Isp=448s) for the module acceleration to follow Apophis and the close navigation can be estimated to 6,100 m/s. The mass of the service module and its payload can thus be estimated to be around 6,000 kg.

The required ΔV for the entry capsule is due to the trajectory change and the braking maneuver required to enter the 125 km altitude layer with a velocity less than 12 km/s. The sum can be estimated to 1400m/s. Assuming an Isp of only 350s for the reentry module and a mass of 1,000 kg departing from the surface of Apophis, this leads to a final mass of 600 kg landing on Earth.

Other launch options:
The large SLS option is of course the most comfortable way to release instruments at the surface of Apophis and perform an Apophis sample return mission. Other launch alternatives with ARIANE (5 or 6), Soyouz for instance could be envisioned, depending on the specification of the scientific goals of this Apophis Express mission.

Possible science packages
As a preliminary design, Apophis Express would be composed of a set of different modules:

- a service module, which will ensure the navigation and the delivery of the landing module at the surface of Apophis and the command of the landing package and the reentry capsule, as well as the relay of telemetry from and to the Earth

- a landing modul
- a radar transponder
- a cubesat
- a reentry capsule

Depending on the relative priorities of the scientific objectives and on the payload capacity available from the selected launcher, some trade-offs between the scientific packages will have to be decided. This is beyond the scope of this paper but, as preliminary inputs for a detailed mission specification, we can think to classical:

- onboard the service module (or cubesat):
  - imagery
  - spectro-imager
  - HF and LF radar (monostatic or bistatic)
  - radio-science
  - …
- onboard the landing module
  - drilling equipment
  - surface material analyzer
  - laser ranging retroflector
  - reentry capsule (if selected)

Main advantages of this scenario

The main advantage of the proposed scenario is to execute a short duration mission (~ one month) while covering all the most important scientific aspects of a scientific mission dedicated to an asteroid: observation of the possible changes induced by the Earth close flyby, internal structure, sample return, orbitography, education and public outreach.

References:

SLS Mission Planner's Guide ESD 30000 Released 12/19/18 Fig 4.13

ARIANE 5 User's Manual Issue 5 rev 2