EPSC Abstracts
Vol. 18, EPSC-DPS2025-1299, 2025, updated on 20 May 2026
https://doi.org/10.5194/epsc-dps2025-1299
EPSC-DPS Joint Meeting 2025

Updates on the Apophis Interceptor Mission

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Introduction:

The close flyby of asteroid (99942) Apophis in April 2029, at a distance of about 32,000 kilometers from Earth's surface, represents a rare and scientifically highly valuable event. This close encounter provides a unique opportunity to investigate tidal effects on a small Solar System body and to characterize its physical and dynamical properties, advancing both planetary defense efforts and planetary science.

Since its discovery in 2004, numerous mission concepts have been proposed to investigate (99942) Apophis. To date, however, the only confirmed mission is NASA's OSIRIS-APEX, an extended phase of the OSIRIS-REx mission. Though, the spacecraft will not arrive until shortly after the asteroid's closest approach to Earth (ECA). In October 2024, the European Space Agency (ESA) approved funding for preparatory activities for its RAMSES mission, a proposed rendezvous mission intended to conduct a comprehensive characterization of Apophis both before and after the ECA. A final decision on full mission funding is expected by November 2025. According to presentations at the Apophis T–4 Workshop held in Tokyo in April 2025, the DESTINY+ mission is also expected to conduct a flyby of Apophis in February 2029. Additionally, eight further mission concepts are currently being explored by various international actors, though none of them have yet secured funding.

This contribution presents a low-cost small satellite mission concept currently being studied at the University of Wuerzburg. The concept involves deploying two identical CubeSats into a highly elliptical Earth orbit to observe Apophis during its close approach on 13 April 2029. In addition to providing imagery and supporting scientific data on Apophis, the mission is designed to demonstrate key small-satellite technologies relevant for future deep-space flybys with small satellites and to study Earth's magnetosphere and radiation belts.

Mission Scenario:

The Interceptor mission comprises two identical 16U CubeSats that will perform a flyby maneuver with (99942) Apophis approximately 90 minutes before the ECA at an altitude of approximately 47,000 km above Earth's surface within the equatorial plane. The primary scientific objective is to collect visual data of the asteroid. Furthermore, by accommodating magnetometers as secondary payloads, the mission will monitor magnetic field variations and the radiation environment within the upper and lower Van Allen radiation belts. Overall, the purpose of this mission is the demonstration of a German, deep-space-capable small satellite architecture with complex payload operations suitable for future asteroid reconnaissance and other interplanetary missions. To allow for initial orbit adjustments and in-orbit system testing, the target launch date is December 2028, utilizing a geostationary transfer orbit (GTO) rideshare to minimize launch costs.

Apophis Flyby Experiment

The actual flyby will be conducted as shown in Figure 1: The Interceptor satellites (Int1, Int2) will pass Apophis at a minimum flyby distance of 25 km. Due to the short observation window, expected to last on the order of one minute, and the high relative velocity (~8 km/s), multi-angle high-resolution optical imaging with a target surface resolution of about one meter is foreseen. These observations will allow constraining the asteroid's spin state, shape, topography, albedo variations, and surface texture. Additionally, magnetometer measurements will be conducted during the flyby to provide reference data on the local magnetic field environment in the vicinity of Apophis. Efforts are being made to downlink an image sequence to ground stations shortly after the flyby.

Van-Allen Belt Experiments

Following the Apophis flyby, the mission is expected to continue for approximately one year in a highly elliptical Earth orbit. While magnetic field measurements are planned to be performed continuously, the second half of the mission is specifically dedicated to focused Van-Allen Belt experiments. The planned orbit ($500 \times 47{,}000$ km) allows for repeated sampling of key regions of Earth's magnetosphere, including the inner and outer Van Allen belts, the plasmasphere, and the plasmapause transition zone, since it will traverse L-shells ranging from approximately 1.1 to 7.4 RE, covering regions with strong spatial gradients in particle density and magnetic field strength. Figure 1 provides a representative distribution of orbital dwell times across these regions, highlighting the mission's sampling potential. These measurements will help to close an observational gap after the end of the Van Allen Probes and Cluster missions and will enable the identification of features such as the plasmapause location, magnetic discontinuities, and potential wave activity.

Conclusion

By combining a timely flyby of (99942) Apophis with extended magnetospheric monitoring and the demonstration of key technologies, the Interceptor mission aims to provide valuable scientific return at minimal cost and supporting both planetary science objectives and the development of future deep-space small satellite missions.

Development Activities: With the completion of the pre-Phase A analysis, funding for Phase A has been approved. The mission analysis is currently ongoing to ensure a successful Preliminary Requirements Review (PRR). The work will be conducted at the Interdisciplinary Research Center for Extraterrestrial Studies (IFEX) at the Julius-Maximilians-University Wuerzburg.

Acknowledgement: The work on this mission is funded by the German Aerospace Center (DLR) based on a decision of the German Bundestag (Grant No. 50OO2413).