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Trajectory and CubeSat Mission Design for Plasma Physics Observations during the 2029 Apophis Flyby

Lucas Barbero Sanchez[a,1,*], Emil Vinterhav[b,2], Stas Barabash[c,3]

[a] *KTH Royal Institute of Technology, Brinellvägen 8, 114 28 Stockholm, Sweden*
[b] *Vinterstellar, Drottninggatan 33, 111 51 Stockholm, Sweden*
[c] *IRF, Box 812, SE-981 28 Kiruna, Sweden*

Abstract

On the 13th of April 2029, Apophis, a 400 meter asteroid, will pass within 31 600 km of Earth's surface in a retrograde orbit, moving through the magnetosphere and encountering the outer radiation belt, ring current, and outer edges of the plasmasphere. Therefore, this event offers a fantastic opportunity to investigate how small scale airless bodies interact with Earth's magnetosphere.

The asteroid surface will interact with various particle populations, from cold and dense plasma of the plasmasphere to high energy penetrating particles of the radiation belts. These interactions release ions and neutrals from the outermost layer of Apophis's surface, revealing its composition and defining the conditions and dynamics of levitating dust, released as a result of surface deformations due to tidal forces. Additionally, these deformations may release volatiles accumulated in the asteroid's materials, contributing to changes in the asteroid environment.

This paper proposes a CubeSat mission, equipped with high TRL instruments to conduct plasma and neutral gas measurements during the Apophis flyby. The payload will include a mass spectrometer and an ion/electron analyzer, with a total mass under 4 kg, power consumption below 8 W, and telemetry rates under 50 kbps. These parameters align with a 4U CubeSat, which will operate for approximately 3 hours around the asteroid's closest approach (CA), at less than 1 km from Apophis's surface.

The main focus of this research is the design and optimization of the spacecraft trajectory using a combination of a Weak Stability Boundary (WSB) transfer and a lunar Gravity Assist (GA) maneuver. This approach aims to minimize propulsion requirements while addressing the challenge of catching up to a cis-lunar object in a retrograde orbit from a prograde orbit. Consequently, this could open up opportunities for future rideshare launches to lunar transfer orbits, offering a significant advantage in both cost and flexibility over dedicated launches.

Keywords: Apophis, asteroid, CubeSat, trajectory, orbit

*Corresponding author

Email addresses: lucasbs@kth.se (Lucas Barbero Sanchez), emil.vinterhav@vinterstellar.se (Emil Vinterhav), stas@irf.se (Stas Barabash)

[1]MSc Student in Aerospace Engineering, KTH Royal Institute of Technology, Stockholm, Sweden

[2]CEO, Vinterstellar, Stockholm, Sweden

[3]Researcher, Swedish Institute of Space Physics (IRF), Kiruna, Sweden