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Author: Mr. Pieter van Tilburg Bernardes
Universidade Federal de Santa Catarina UFSC, Brazil, pietervtbernardes@gmail.com

CUBESAT MISSIONS TO EXPLORE THE PHA APOPHIS

Abstract

The asteroid (99942) Apophis has a diameter of about 350 meters and was discovered in June 2004. Soon after the discovery, it was classified as a Potentially Hazardous Asteroid (PHA), getting the world-wide attention because of the close approach it will have with the Earth in 2029. On the 13th of April of 2029 the body will pass within six Earth radii, much closer than the geostationary satellites. The 2029 encounter is a window of opportunities to acquire crucial knowledge for planetary defense. The asteroid can be explored through space missions, with measurements providing fundamental information on the physical nature of this kind of PHA. Of particular importance is its composition and internal structure. One low-cost way for such exploration is the use of CubeSats, which are often built with commercial off-the-shelf structure and components. A planned set of CubeSats could explore Apophis with different instruments, as lidars, imaging multispectral radiometers and mass spectrometer, reaching several goals. In the current work are explored different scenarios and the possibilities of trajectories to make flybys and/or even impact/land on the asteroid's surface, according to requirements defined by the instruments of each CubeSat. A wide range of spacecraft trajectories exploration is performed by using numerical simulations. The study is made considering the orbit of Apophis with respect to the Earth, during the 2029 close encounter. It is a hyperbole with the following orbital elements: semi-major axis a=11 681.1 km, eccentricity e=1.02, inclination I=162.8 deg, longitude of the ascending node Ω=152.2 deg, argument of perigee ω=202.8 deg. The relative velocity of Apophis with respect to the Earth at closest approach is about 7.2 km/s. Such high velocity imposes the strongest constrain, once the asteroid passage within the Earth-Moon distance will take less than 35h. During that arc of trajectory close to the Earth, the Cube-Sats can transfer the collected data to the Earth without much effort in terms of antenna. Among the considered scenarios, in this work, are the transference from trajectories that are initially in LEO, GTO and even highly eccentric Lunar orbit. The paper also show the study of possibilities of using swing-by in the Earth-Moon system, in order to increment the velocity of the CubeSat during the encounter with Apophis, allowing a longer time of exploration.