Paper ID: 95797
student

IAF ASTRODYNAMICS SYMPOSIUM (C1)
Mission Design, Operations & Optimization (1) (6)

Author: Dr. Tomohiro Ishizuka
ISAE - Institut Supérieur de l'Aéronautique et de l'Espace, France

Dr. Joan Pau Sanchez Cuartielles
ISAE-Supaero University of Toulouse, France
Prof. Stéphanie Lizy Destrez
Institut Supérieur de l'Aéronautique et de l'Espace (ISAE), France

FEASIBILITY ANALYSIS OF A CUBESAT LANDING ON APOPHIS PRIOR TO THE EARTH CLOSE APPROACH

Abstract

Near-Earth asteroid 99942 Apophis will make a close approach to Earth on April 13, 2029, coming within 32,000 kilometers of our planet. NASA's OSIRIS-APEX spacecraft will fly by Apophis on April 23, 2029, and then rendezvous with it in June for observation campaigns. The European Space Agency (ESA) is also working on a planetary defense mission called Rapid Apophis Mission for Space Safety (RAMSES). This mission will involve sending a spacecraft to rendezvous with Apophis before the close approach and remain during the close approach to observe the changes in the asteroid's sphere.

The RAMSES spacecraft will carry a cubesat named LLEVANT, which will be released by the mothership. The cubesat is anticipated to reach the surface of Apophis at least 40 hours prior to the Earth close approach. Landing on Apophis presents significant challenges, primarily due to the dynamical uncertainties associated with operations near a slow-tumbling, highly irregular object undergoing a hyperbolic passage to the Earth. Strong Earth tidal forces are predicted during the close approach.

The primary objective of this study is to conduct a feasibility analysis for the landing of LLEVANT on Apophis prior to the Earth close approach. The landing trajectory will be divided into four distinct phases: departure from the mothership, approach descent, final descent, and touchdown. The dynamical environment will be modeled as a high-fidelity framework that incorporates the high-order gravitational force of Apophis and the ephemerides of the Sun, Earth, and Moon. It is anticipated that the solar radiation pressure will have a negligible impact on the landing trajectory due to the expected short duration of the landing. Furthermore, multiple uncertainties will be considered during this analysis. The physical properties of Apophis, including its size, mass, shape, and spin, are subject to uncertainties due to limited observation capability, and these uncertainties, influence the dynamics of the landing trajectory. Additionally, uncertainty in the cubesat release will introduce uncertainty in the initial position and velocity of the landing trajectory. Furthermore, control execution errors and navigation errors from the spacecraft guidance, navigation, and control (GNC) system will affect the descent guidance and control performance. In light of these considerations, this study aims to explore feasible landing trajectory designs on Apophis that are robust against the uncertainties for LLEVANT operation.