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

Author: Mr. Iosto Fodde
University of Strathclyde, The Netherlands

Dr. Jesus Gil-Fernandez
ESA, Spain
Dr. Feng Jinglang
University of Strathclyde, United Kingdom
Prof. Massimiliano Vasile
University of Strathclyde, United Kingdom

COMBINED TRAJECTORY DESIGN AND NAVIGATION ANALYSIS FOR HERA'S VERY-CLOSE FLYBY OF DIMORPHOS.

Abstract

The Asteroid Impact and Deflection Assessment (AIDA) collaboration, consisting of NASA's DART mission and ESA's Hera mission, aims to test the capability of a kinetic impactor to deflect an asteroid. At the end of September 2022, DART successfully impacted the secondary of the binary asteroid system Didymos, called Dimorphos. Hera will launch in 2024 and aims to characterize the physical properties of Didymos, and investigate the consequence of the impact in more detail. The final nominal phase of Hera is the experimental phase, where the highest resolution images of the impact crater will be taken. This requires the distance of the spacecraft with respect to Dimorphos to be in the order of hundreds of meters, increasing the risk of impact significantly compared to the previous mission phases. Therefore, the trajectory design of these fly-bys needs to consider the possible execution errors of the ΔV manoeuvres and include autonomous navigation and control systems to correct for deviations with respect to the nominal trajectory. Currently, this process is subdivided between a trajectory design step and a navigation analysis step, where first a nominal trajectory is designed and afterwards the performance when uncertainties and execution errors are included is investigated. This process can be inefficient and possibly result in sub-optimal designs. To address these problems, this work investigates the use of novel uncertainty quantification and propagation techniques that are able to combine these two steps and provide a trajectory while simultaneously checking for its performance under uncertainties. The specific approach used here consists of an uncertainty propagation method (non-intrusive polynomial interpolation), navigation algorithm, and closed-loop controller, all embedded inside a trajectory optimization problem. For each segment of the trajectory, the uncertainties are propagated, resulting in a polynomial representation of the distribution of states over time. Then, the state estimation covariance, which comes from the optical navigation strategy of Hera, is propagated as well using this polynomial function. This gives the dispersion of states and the error in the estimate of each state, which is consequently used to determine the distribution of closed-loop control maneuvers for the start of the following segment. This formulation is solved using a shooting-like transcription, and results in a trajectory fulfilling all robustness constraints while maintaining good observation and ΔV performance. This work shows the application of novel uncertainty propagation and trajectory optimization techniques to real-life scenarios like the one presented here for the Hera mission.