Simulation Tool for Autonomous Multi-Spacecraft Mission Design around Small Bodies

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ABSTRACT

Over the past few years, the acceleration in technology development and maturation enables new capabilities and ambitions in terms of space mission design. In particular, the miniaturization of equipment for small-sat and CubeSat enhances the possibilities for multi-spacecraft mission architecture (e.g. Double Asteroid Redition Test (DART) and Light Italian CubeSat for Imaging of Asteroids (LICIACube) to Dimorphos; Hera, Juventas, and Milani to Didymos). These new configurations however introduce new challenges during the preliminary mission design phase since the current tools are mostly adapted for single-spacecraft architecture and the number of feasible configurations grows exponentially for multi-spacecraft architecture. Thus, a need for a new generic and modular simulation tool appears. This tool shall allow the implementation of any mission configuration with multiple spacecraft, each of them configured with different equipment, capabilities, and different mission objectives while being able to interact with each other in a common simulation environment.

Multi-Spacecraft Concept and Autonomy Tool (MuSCAT) aims to answer this need. It has been built for the Distributed Radar Observation of Interior Distributions (DROID) mission concept, which is a three-spacecraft architecture around the small-body Apophis. This case study illustrates the need for a such tool, having multiple spacecraft that are built differently (e.g. attitude and navigation actuators, science instrument, guidance navigation and control instrument, power system, battery, solar panels, telecommunication, ...), with different trajectories, different role to play during the mission and interacting between each other (i.e. exchanging data, joint small-body science using multiple spacecraft flyby). MuSCAT's objective is to iterate quickly from one design to another, allowing us to assess the design's success and performance in terms of science (small body coverage, data generated and sent to Earth, ...) according to the technical design choices (e.g. actuators sizing and precision for orbit control and attitude pointing, data management and link budget between the spacecraft and for Direct-to-Earth communication, power management with equipment's consumption and solar generation, ...). Additionally, the simulation is also intended to demonstrate the autonomy capabilities of those technical choices and autonomy needs according to the mission goals. This paper aims to demonstrate the implementation and capabilities of the MuSCAT tool for the DROID mission.

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