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AN OVERVIEW OF EXTREMA PROJECT PILLAR II: VALIDATING AUTONOMOUS GUIDANCE ALGORITHMS VIA HIL TESTING

Abstract

Over the past twenty years, CubeSats, shoebox-sized satellites, have transformed the way we explore space, opening low-Earth orbit to a growing number of participants. This trend is expected to extend to interplanetary missions, as demonstrated by NASA's deployment of two MarCO CubeSats near Mars in 2018, and by two ESA-funded missions M-ARGO, aiming at rendezvous with an asteroid, and SATIS, for close approach with Apophis asteroid. However, a significant obstacle to further exploration of deep space lies in the ground segment: according to the state of the art, operating, navigating, and controlling interplanetary CubeSats requires the expertise of flight dynamics specialists and the exploitation of limited ground assets, as traditional and larger spacecraft.

In 2020, the European Research Council funded EXTREMA (Engineering Extremely Rare Events in Astrodynamics for Deep-Space Missions in Autonomy), a project aiming towards a paradigm shift of guidance, navigation, and control (GNC) operations from ground to on board CubeSats. The goal is to enable autonomous miniaturized spacecraft, capable of traveling in deep space without requiring any interaction from ground. The project is planned to last until 2025, and it is based on three fundamental pillars: Pillar I: Autonomous Navigation, Pillar II: Autonomous Guidance and Control, and Pillar III: Autonomous Ballistic Capture. The outcome of each pillar will be integrated into a series of experiments and brought together in the EXTREMA Simulation Hub (ESH): a hardware-in-the-loop (HIL) testing facility that will allow testing integrated GNC.

This work presents the state of the art of Pillar II at the beginning of the fourth year of the project. Two autonomous guidance algorithms, one direct-based and one indirect-based, have been developed and tested, and are here presented. Their deployment on representative onboard processors is discussed, along with the challenges that this process requires. The integration of the algorithms in the ESH is discussed, focusing on the interfaces with ETHILE, the Extrema Thruster in The Loop Experiment, the facility modeling the real actuation of low-thrust propulsion systems. ETHILE measures the produced thrust and feds measurements to a high-fidelity numerical propagator. This enables performing simulations of whole mission profiles in an accelerated framework. Some preliminary simulations and their corresponding results will be presented thereafter, showcasing how autonomous guidance algorithms can be validated with the proposed HIL-approach. To conclude, an overview of the future steps and developments are discussed.