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ETHILE: A THRUSTER-IN-THE-LOOP FACILITY TO ENABLE AUTONOMOUS GUIDANCE AND CONTROL OF AUTONOMOUS INTERPLANETARY CUBESATS

Abstract

In the last two decades CubeSats have revolutionized the utilization of space, allowing more and more actors to gain access to low-Earth orbit. The same trend is now foreseen for interplanetary missions: In 2018 the two NASA's MarCO CubeSats were operated in Mars proximity, and more are expected to being launched in the next few years. A bottleneck for further exploration of deep-space is represented by the ground segment: interplanetary CubeSats are operated, navigated and controlled with the supervision of the Flight Dynamics experts, like regular, monolithic spacecraft. The EXTREMA (Engineering Extremely Rare Events in Astrodynamics for Deep-Space Missions in Autonomy) project aims towards a paradigm shift on how deep-space GNC operations are performed. The goal is to enable self-driving CubeSats, capable of traveling in deep-space without requiring any control from ground. The project has received a Consolidator Grant from the European Research Council (ERC), a prestigious acknowledgment that funds cutting-edge and disruptive innovation research in Europe.

This work presents the Extrema Thruster in The Loop Experiment (ETHILE), under development at the DART laboratory of the Politecnico di Milano. The aim of this facility is to test and validate novel guidance algorithms tailored for satellites traveling autonomously in deep space. Therefore, it shall model the real actuation of low-thrust propulsion systems, measure the produced thrust, and feed the measurements to a high-fidelity numerical propagator. It is worth noting that a true real-time simulation would require an extremely long time: interplanetary transfers require many months or even years. EXTREMA aims at exploiting a scaled model of the system, and to correlate the results to the original one thereafter. Through a mapping between the original system and a fast-evolving one, it will be possible to execute the guidance and control simulations in a shorter time frame, lasting a few hours or days.

This paper and presentation will be structured as follows: An overview of ETHILE will be initially given, focusing first on the functional requirements, and then detailing the facility design and realization. Subsequently, an outlook of the guidance algorithms will be provided, emphasizing the characteristics that allow their use on CubeSats on-board computers and detailing the interfaces between ETHILE and the flatsat prototype. Some preliminary simulations and their corresponding results will be presented thereafter. To conclude, a critical analysis of the current performances of ETHILE will be made and possible improvements in the design and algorithm validation will be finally outlined.