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THE VALUE OF CONFIGURABLE AND INTELLIGENT ONBOARD SOFTWARE FOR THE CAPSTONE MISSION

Abstract

The Cislunar Autonomous Positioning System Technology Operations and Navigation Experiment (CAPSTONE) spacecraft is a 12U nanosatellite launched into a ballistic lunar transfer orbit in July 2022. CAPSTONE successfully inserted into a Near Rectilinear Halo Orbit (NRHO) about the Earth-Moon L2 point in November 2022. Since its insertion, CAPSTONE has fulfilled the mission's primary objective to demonstrate operations in NRHO to validate the cislunar CONOPS anticipated for NASA's Lunar Gateway. As a subcontractor to Advanced Space for the NASA mission, Terran Orbital designed and manufactured the CAPSTONE spacecraft, and currently provides on orbit operations services.

This paper will examine the value of a highly configurable and intelligent Guidance, Navigation and Control (GNC) software that enabled success of the CAPSTONE mission, particularly during critical anomaly resolution responses. Following the completion of Trajectory Correction Maneuver 3 (TCM-3) on September 8, 2022, while unloading system momentum, one of CAPSTONE's eight thrusters became stuck open. The stuck thruster induced a high-rate tumble exceeding 70 deg/s. Given the ballistic nature of the insertion trajectory, the timeliness of anomaly resolution was paramount. After evaluating the state of the spacecraft with limited available telemetry, a team of engineers successfully reconfigured the thruster control algorithm in CAPSTONE's GNC software to counteract the stuck thruster and enable a successful detumble. The highly configurable and intelligent onboard software, designed and implemented by Terran Orbital, was invaluable in supporting the recovery of the CAPSTONE mission in a timely manner.

Since reaching NRHO, CAPSTONE's propulsion system and thruster controller was further tuned to decrease thrust enabling execution of accurate low magnitude trajectory maneuvers. Additional adjustments to burn preparation sequences and momentum management CONOPS were implemented to compensate for the continually stuck thruster. For over a year, CAPSTONE has maneuvered with sufficient precision to maintain NRHO. In addition to maneuver performance assessment and reconfiguration of the thruster controller, this paper will discuss CAPSTONE's ability to accomplish a diverse range of tasks while in NRHO, including ranging with NASA's Lunar Reconnaissance Orbiter (LRO) and imaging the Moon's surface.