

CAPSTONE: A Summary of a Highly Successful Mission Currently Operating in the Cislunar Environment

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Introduction: NASA, Advanced Space, Terran Orbital, Rocket Lab, Stellar Exploration, JPL, the Space Dynamics Lab, and Tethers Unlimited have partnered to successfully develop, launch, and operate the Cislunar Autonomous Positioning System Technology Operations and Navigation Experiment (CAPSTONE) mission, which is serving as a pathfinder for Near Rectilinear Halo Orbit (NRHO) operations around the Moon. This low-cost, high-value mission has demonstrated an efficient, low-energy orbital transfer to the Moon and a successful insertion into the NRHO. The NRHO is the intended orbit for NASA's Gateway lunar orbital platform. The mission is now demonstrating the operations within the NRHO that ultimately will serve to reduce risk and validate key exploration operations and technologies required for the future success of NASA's lunar exploration plans, including the planned human return to the lunar surface.

Launched on June 28, 2022, by a three stage Rocket Lab Electron rocket, and utilizing a highly capable 12U CubeSat, CAPSTONE has been successfully operating in the NRHO since November 13, 2022. The CAPSTONE spacecraft has recently performed its 10th Orbit Maintenance Maneuver (OMM) to maintain the baseline NRHO. Additionally, the spacecraft has successfully performed 3 CAPS technology ranging communications passes in collaboration with the Lunar Reconnaissance Orbiter (LRO) team at NASA's Goddard Space Flight Center to demonstrate the CAPS autonomous navigation system. The CAPS software enables cislunar missions to manage their navigation functions themselves and reduces the reliance on Earth based systems. Success criteria achieved thus far for CAPSTONE include 1) semi-autonomous operations and orbital maintenance of a spacecraft in an NRHO, 2) collection of inter-spacecraft ranging data in support of the autonomous navigation process, and 3) execution of the CAPS navigation software in an autonomous mode on-board the CAPSTONE spacecraft. Additionally, CAPSTONE has demonstrated an innovative one-way ranging navigation approach utilizing a Chip Scale Atomic Clock (CSAC) in combination with autonomous navigation algorithms developed by JPL.

This high value mission has already demonstrated an efficient low energy orbital transfer to the NRHO and has demonstrated full-scale operations in this unique orbit for the past 7 months. Over the next 12+ months,

CAPSTONE will continue to validate these key operations and navigation technologies required for the success of NASA's lunar exploration plans. The ultimate goal that extends this experiment will be the development of an autonomous navigation system/approach that support routine operations in cislunar space and in support of activities related ISRU resource extraction and utilization. This presentation will include an overview of the current mission status, lessons learned from the launch, transfer, and insertion into the NRHO, a summary of the challenges encountered thus far, and an overview of the successful mission operations and navigation technology demonstration to date.



CAPSTONE Launch: 28 June, 2022