Leaving No CAPSTONE Unturned: How a CubeSat Pathfinder Will Enable the Lunar Gateway Ecosystem

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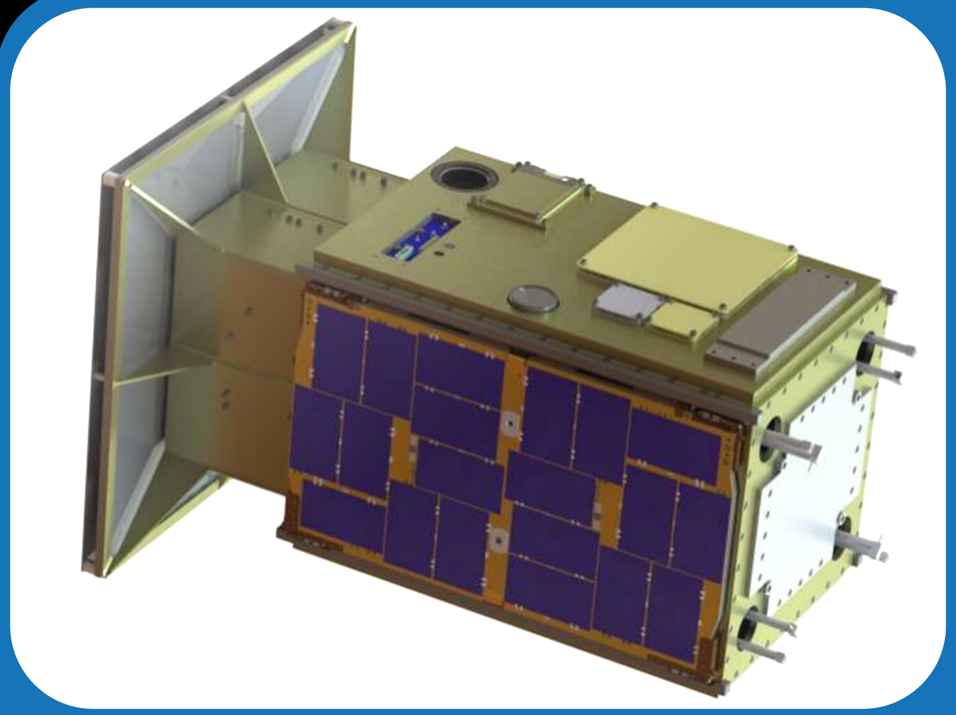
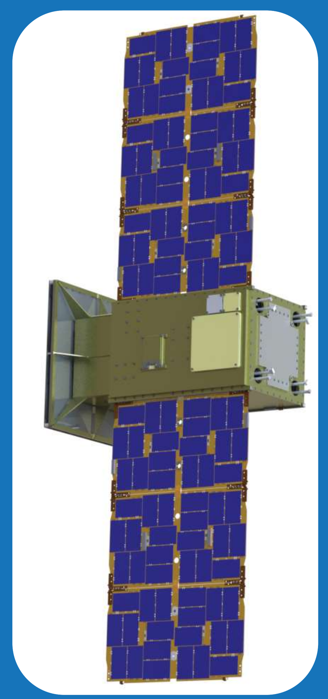
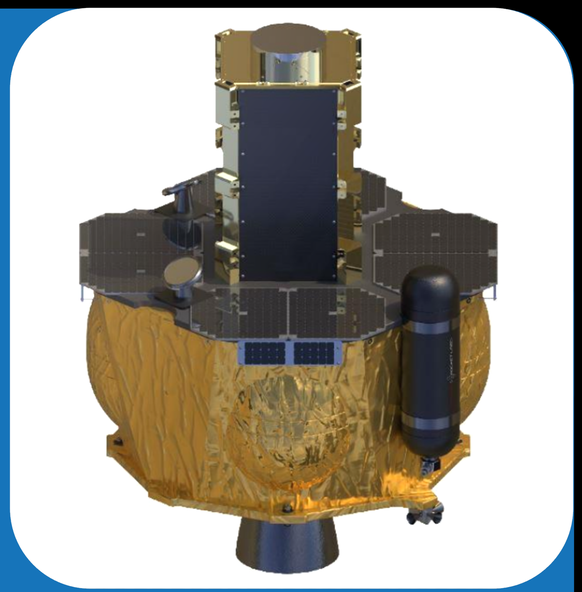
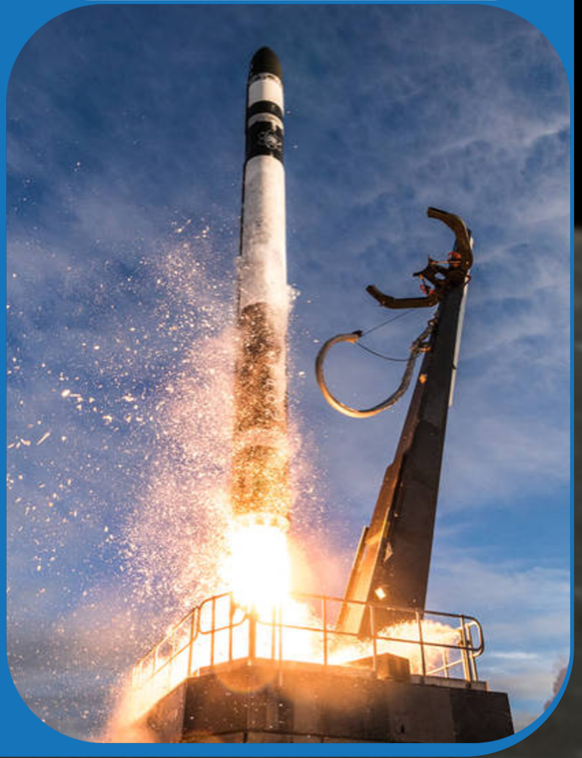




CAPSTONE By the Numbers

- Mass: 27 kg (Wet)
- Dimensions: 50 cm x 33 cm x 144 cm
- Mission Length: 22 months
- Maximum Distance from Earth: 1.5M KM





- CAPSTONE launch in early 2021 on a Rocket Lab Electron from NASA Wallops Flight Facility at their Launch Complex 2 (LC-2).
- Rocket Lab is developing a Lunar Photon upper stage solution to inject CAPSTONE into a deep-space, Ballistic Lunar Transfer (BLT) orbit that enables a low ΔV entry into the the NRHO.
- Ballistic (or Low-Energy) Lunar Transfers utilize solar gravity to raise perigee and insert into lunar orbit for minimal ΔV.

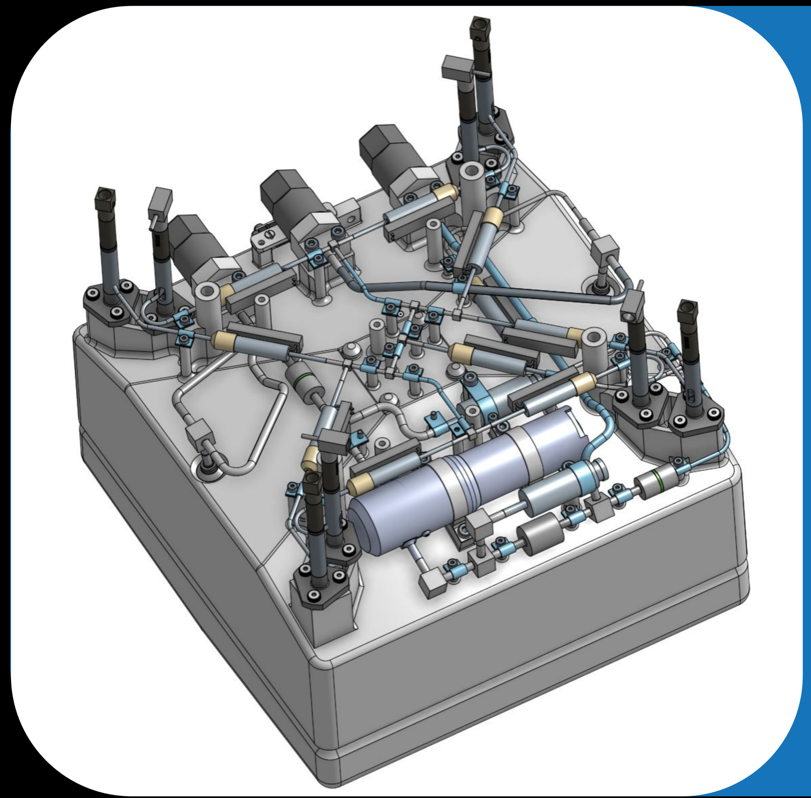
Mission Objectives

1) Validate and demonstrate NRHO/three-body Earth-Moon operations.
2) Inform future lunar exploration requirements and operations such as for the Artemis Lunar Gateway.
3) Demonstrate and accelerate the infusion of the Cislunar Autonomous Positioning System (CAPS)

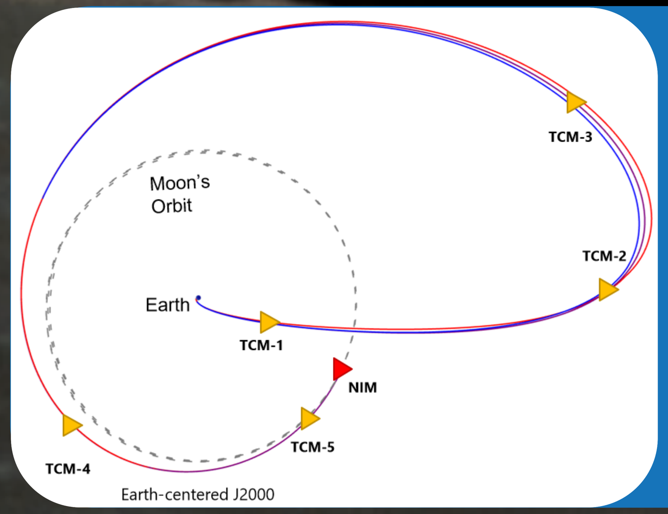
Objective 1 is focused on mitigating technical uncertainties associated with operating in the uniquely beneficial and challenging orbital regime defined as Near Rectilinear Halo Orbits. This objective will include demonstrating navigation capabilities and validating station keeping simulations.

Objective 2 is focused on building experience operating in complex lunar orbital regimes to inform future lunar exploration requirements and operations, including human exploration flights with lower risk thresholds and higher certainty of success requirements. This will include the establishment of commercially available capacity to support NASA, commercial, and international lunar missions in the future.

Objective 3 is focused on demonstrating core technical components of the Cislunar Autonomous Positioning System (CAPS) in an orbital demonstration. This objective will include collaboration with the operations team at NASA Goddard Space Flight Center to demonstrate inter-spacecraft ranging between the CAPSTONE spacecraft and the Lunar Reconnaissance Orbiter in operation at the Moon. In addition to demonstrating key inter-spacecraft tracking, CAPSTONE will also enhance the technology readiness level of the CAPS software.



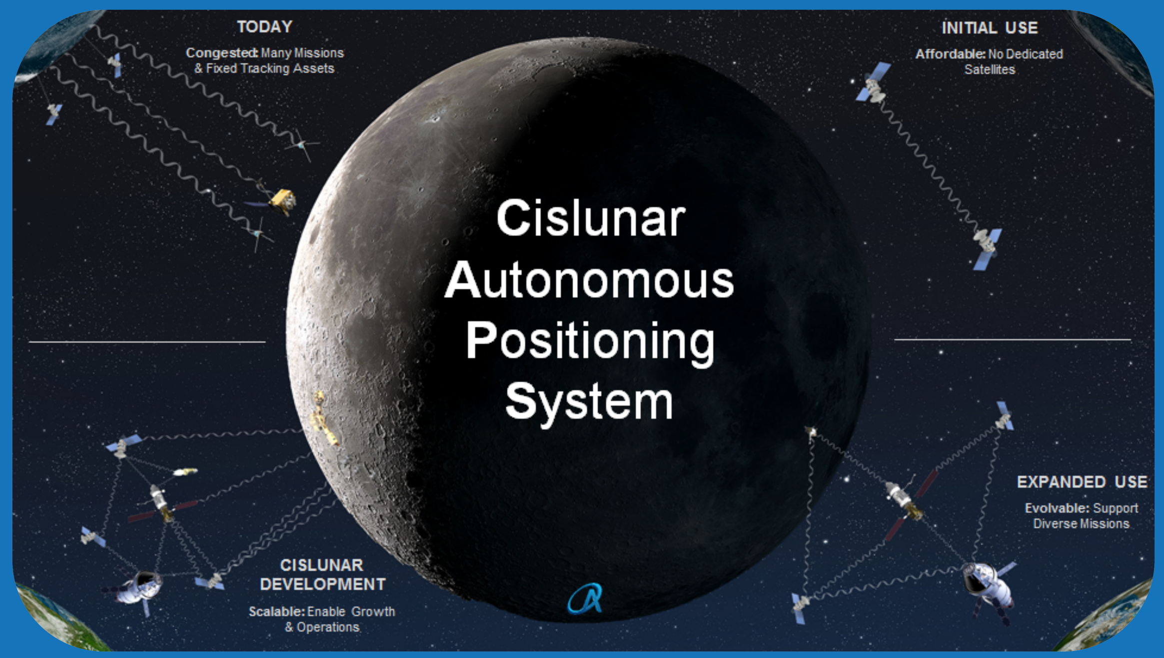
- CAPSTONE's propulsion system is provided by Stellar Exploration, Inc.
- A custom-built tank with 4 translational thrusters and 4 rotational thrusters.
- The system will use Hydrazine (HPH) as the monopropellant.
- The pump-fed system will provide a Steady-State I_{sp} of ~200 sec.



BLT Reference Transfer – TCM Design

Maneuver	Purpose	Timing
TCM-1	Clean up launch errors	24 hours after deployment
TCM-2	Expand launch period	30 days after deployment
TCM-3	Clean up sensitive TCM-2	50 days before NIM
TCM-4	Target NRHO insertion	10 days before NIM
TCM-5	Target NRHO Insertion	1 day before NIM

TCM = Trajectory Correction Maneuver
NIM = NRHO Insertion Maneuver

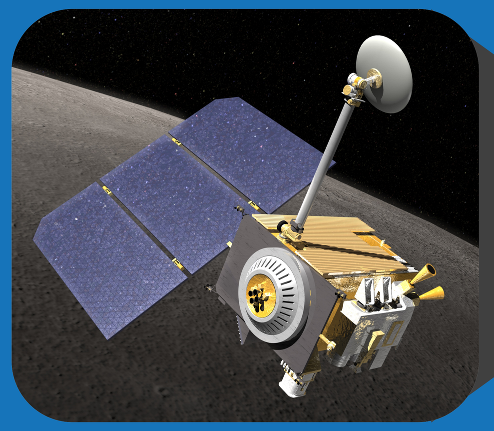


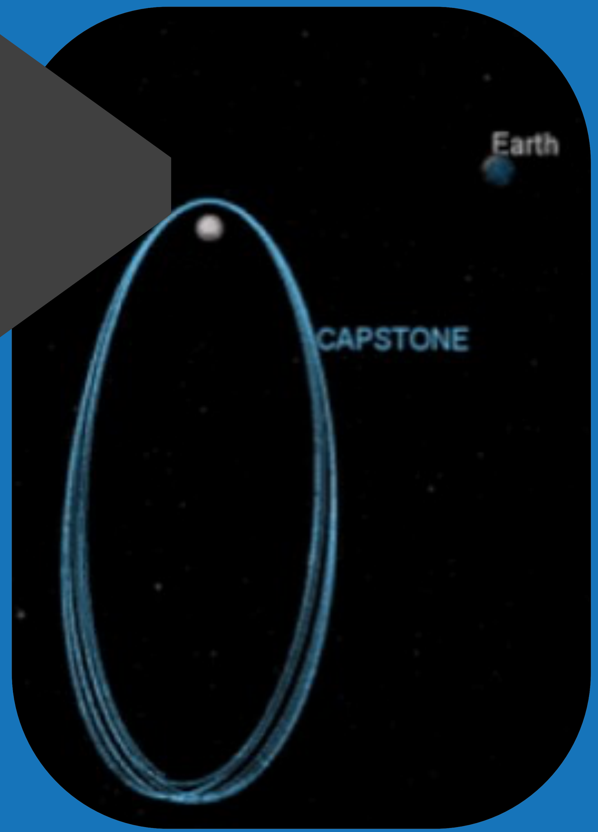
The Vision of a CAPS Enabled Ecosystem

The Cislunar region is poised for significant activity but the timing and scope of that activity is uncertain as missions large and small are constrained by current availability of ground tracking under the ongoing congestion of terrestrial networks. Many mission orbits in cislunar require frequent tracking and station keeping, and cislunar navigation is a critical piece of infrastructure to enable NASA, commercial, and international missions in the near and far term.

CAPS is aiming to alleviate constant ground communications with spacecraft by enabling the spacecraft themselves to determine their position with the crosslink input from other crafts. This will ultimately enable ground contact to be used for the more data-heavy and more relevant communications that is to come with the Lunar Gateway and other future science missions to the Moon.

In The NRHO





- The CAPSTONE NRHO is in 9:2 resonance with lunar synodic period which gives repeating geometry in the Sun-Earth rotating frame and avoids Earth eclipses. The CAPSTONE reference NRHO is also offset from Gateway's planned orbit to avoid interference when the first pieces begin to arrive.
- As part of the mission objectives, once CAPSTONE is in the NRHO it will communicate with the Lunar Reconnaissance Orbiter (LRO) to test key CAPS functions.
- Using a cost effective CubeSat to mitigate the technical risk of NRHO operations and validate the current simulations of station keeping will support the future of the Lunar Gateway.