Cislunar Explorers Mission Description

The Cislunar Explorers are competing in NASA's CubeQuest challenge, a NASA Centennial Challenges program, which offers a total of $5.5 million to teams that meet the challenge objectives of designing, building and delivering flight-qualified, small satellites capable of advanced operations near and beyond the moon. The teams will compete for a secondary payload spot on NASA's Exploration Mission 1 (SLS/Orion).

The Cislunar Explorers team is led by Professor Mason Peck of Cornell University, and has designed their spacecraft to demonstrate a game-changing technology: electrolysis propulsion. Each spacecraft carries a tank of inert, liquid water, which is then electrolyzed using energy collected by solar cells, splitting H_2O into hydrogen and oxygen gas. This is a readily combustible mixture, widely used in launch vehicles and spacecraft.

Hydrogen and oxygen are cryogenic liquids and must be stored at very low temperatures and very high pressures. For CubeSats, neither are acceptable. CubeSat specifications prohibit extreme pressures and cryogenic storage tanks are too bulky to be usable at this scale. So are the turbopumps used to feed LOX/LH2 rocket engines. Electrolysis propulsion achieves very dense propellant storage of 1000 kg/m^3, several times denser than LOX/LH2 and it does so without complex, expensive, and heavy additional apparatus. This is a way to bring green propellant into the CubeSat framework, producing substantial ΔV in a compact, simple package.

The Cislunar Explorers have been carefully designed around their use of water propellant, ensuring passive subsystem symbiosis to reduce the cost and complexity of the spacecraft. For example, the presence of water acts as a partial radiation shield and heat sink for the RF Power Amplifier.

The most significant synergy is with the attitude control subsystem. To separate the electrolyzed gas from the liquid water, the spacecraft each spin about their major axis, centrifugally forcing the water away from the spin axis. That spin is facilitated by a spring-loaded mechanism that separates the two Cislunar Explorers from each other after deployment. The angular momentum of the spinning spacecraft keeps it pointed in the same direction, like a gyroscope. When a torque is applied, whether deliberately for reorientation or as a side effect of an electrolysis thruster firing, the spin axis will begin to nutate. However, this nutation will damp out due to the sloshing of water in the propellant tank dissipating energy, and the spacecraft will soon return to a spinning steady-state. Therefore, the Cislunar Explorers do not require a bulky, power-hungry attitude stabilization system, such as reaction wheels. Instead, each needs only a single cold gas thruster, used to exert torque to change the spin axis as desired.

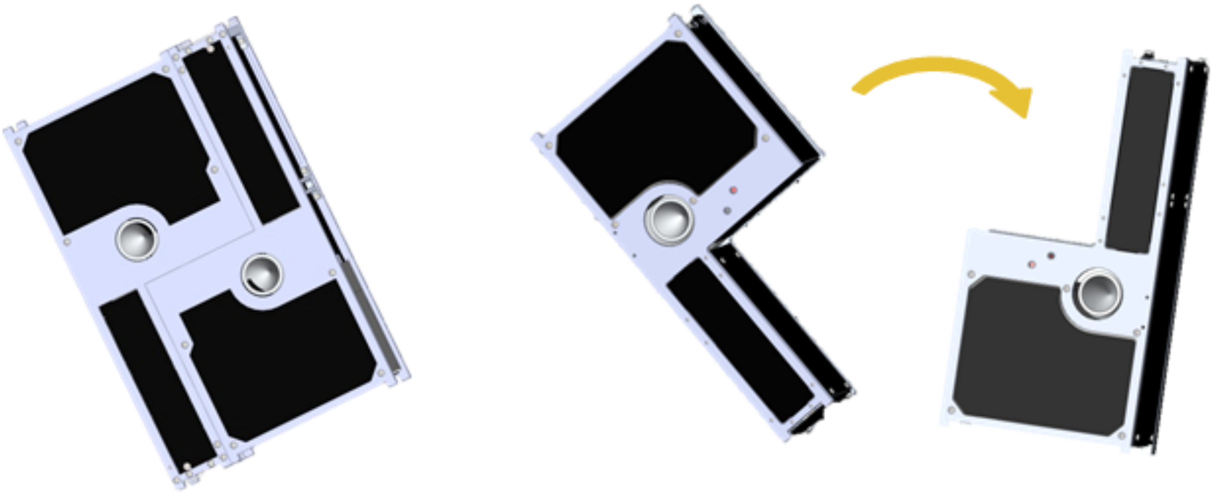
Figure 1: Spacecraft Separation

the Cislunar Explorers carry several inexpensive onboard cameras. These are repeatedly used to capture images of the Sun, the Earth, and the Moon. The cameras can distinguish between the three bodies, and use image processing techniques to compute their apparent size and angular separation in each spacecraft's field of regard. All three celestial bodies act as landmarks in space. By comparing the apparent locations of the celestial bodies with their ephemerides, each spacecraft can compute its own and attitude. The Cislunar Explorers' method is uniquely able to simultaneously determine position and attitude onboard a spinning spacecraft. This technique can function with any three celestial bodies at least one of which is resolvable as a discrete disc; these need not be the Sun, Earth, and Moon. Brief radio transmissions are used to downlink data packets of computed coordinates to keep the ground station appraised of the spacecraft's position and attitude. In this way, the Cislunar Explorers are able to navigate robustly and autonomously, in a way that is well suited to lunar orbit.

Apart from the novel technologies to be demonstrated, the Cislunar Explorers make use of inexpensive and readily available components wherever possible. The flight computer for each unit is a Raspberry Pi, an inexpensive minicomputer that is popular with hobbyists and educators. Both the attitude and propulsion thrusters use off-the-shelf parts. The spacecraft communicate using the 70 cm UHF radio band, popular with amateur radio operators across the world. The entire design is open-source, with the goal of enabling further innovations. A successful demonstration of their optical navigation and electrolysis propulsion technologies could make them attractive for future missions, and the team wants the space development community to be able to benefit immediately.