ABSTRACT

CubeSats are a newly emerging, low-cost, rapid development platform for space exploration research. They are small spacecraft with a mass and volume of up to 12 kg and 12,000 cm^3, respectively. To date, CubeSats have only been flown in Low Earth Orbit (LEO), though a large number are currently being designed to be dropped off by a mother ship on Earth escape trajectories intended for Lunar and Martian flyby missions. Advancements in propulsion technologies now enable these spacecraft to achieve capture orbits around the moon and Mars, providing a wealth of scientific data at low-cost. However, the mass, volume and launch constraints of CubeSats severely limit viable propulsion options.

We present an innovative propulsion solution using energy generated by onboard photovoltaic panels to electrolyze water, thus producing combustible hydrogen and oxygen for low-thrust applications. Water has a high storage density allowing for sufficient fuel within volume constraints. Its high enthalpy of formation provides more fuel that translates into increased ΔV and vastly reduced risk for the launch vehicle. This innovative technology poses significant challenges including the design and operation of electrolyzers at ultra-cold temperatures, the efficient separation of the resultant hydrogen and oxygen gases from liquid water in a microgravity environment, as well as the effective utilization of thrust to produce desired trajectories.

Analysis of the gas combustion and flow through the nozzle using both theoretical equations and finite-volume CFD modeling suggests an expected specific impulse of 360 s. Preliminary results from AGI’s Satellite Toolkit (STK) indicate that the ΔV produced by the system for an 8kg CubeSat with 6kg of propellant in a LEO orbit (370 km altitude) is sufficient for an earth escape trajectory, lunar capture orbit or even a Mars capture orbit. These results suggest a promising pathway for an in-depth study supported by laboratory experiments to characterize the strengths and weaknesses of the proposed concept.