In-Space Propulsion and Power from Planetary Volatile Resources: From Exploration Robots to NEO Mitigation

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ABSTRACT

To date, the use of solar radiation to provide onboard electrical power remains the sole application of a space resource that has been exploited to sustain exploration missions. Even if one includes vacuum and the thermal sink offered by interplanetary space as exploited resources, our fleet of spacecraft is designed to operate in space environments without tapping their vast potentials. We propose to break through the paradigm and demonstrate the feasibility of a novel architecture concept based on the extensive use of volatile space resources to generate propulsive and mechanical power for a variety of space missions. The concept also departs from other In Situ Resource Utilization schemes by its inherent simplicity in applying heat to cause a change of state rather than to induce a chemical reaction. Furthermore, we envision the possible application of the concept to propel large near-Earth objects (NEOs) off their course and potentially address a critical issue confronting NASA in the coming decades; how to protect Earth from threats of asteroids and comets as described in NASA's Space Technology Grand Challenge titled "Near-Earth Object Detection and Mitigation."

Volatile solids occur naturally on most planetary bodies including the Moon, Mars, asteroids and comets. Solid ices composed of carbon dioxide or water have been detected remotely at the poles or in permanently shadowed craters on Mars and on the Moon. Comets consist mostly of ice (>85%), and icy asteroids also contain solid ices in various amounts. In the outer solar system, several moons of the giant planets host the same resources; Ganymede, Europa and Callisto are composed of silicate rock and water ice to varying degrees, and observations of Titan by the Cassini-Huygens probe have revealed methane snow and water ice crusts.

We investigate the concept of performing the sublimation of these ices and minerals to form gases when they are heated sufficiently under low-pressure atmospheres or in vacuum, which prevail on many planetary surfaces in the Solar System. Experimental results obtained so far yield potential in-space propulsion applications.