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FastTrack to the Moon: Technology Development of the Low-Cost Swirl Lunar CubeSat Mission Concept

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The Moon harbors many geological mysteries including localized magnetic anomalies and associated albedo features known as "swirls". To determine the nature of these magnetic anomalies and the role they may play in swirl formation requires high resolution measurements on the lunar surface or from very low altitude orbit. Such a science mission using large spacecraft is prohibitively expensive (costing hundreds of millions of dollars). A compelling low-cost alternative is to deploy from the SLS or a comparable launch vehicle bound on an Earth escape trajectory a 6U (12 cm x 24 cm x 36 cm), shoe-box sized CubeSat with a mass of 14 kg, mounted with solar panels that generate 50 W of power. Our proposed concept, called Swirl, will carry a JHU/APL supplied miniature low-noise fluxgate magnetometer with 0.1 nT resolution based on high flight heritage designs. The fluxgate sensor is hosted on an unpopulated solar array structure to mitigate magnetic signals from the bus. In addition, the spacecraft will deploy a visible camera from Ecliptic Enterprises. The spacecraft will provide measurements of the Reiner Gamma Swirl (RGS) magnetic anomaly that will answer critical questions of how these anomalies formed. Swirl is possible thanks to an innovative low-delta V trajectory combined with an ammonia based cold gas/resistojet propulsion system that will provide up 1.2 N of thrust. This mission design will enable the spacecraft with low thrusting capabilities to enter lunar orbit within 6 months of launch. The spacecraft will finally reach a periapse of 5 km above RGS to carry out high-accuracy magnetic measurements.

The spacecraft excluding the propulsion system has a mass of 4.5 kg. Most spacecraft subsystems will have one level of redundancy. The spacecraft builds on JPL's innovative design of INSPIRE and MarCO interplanetary CubeSats that utilize the X-band IRIS radio for communication and tracking. Onboard deployable gimbaled solar panels from MMA Design and body mounted panels will provide 50 W of power and charge a 140 Wh lithium ion battery. Gimbaled deployable solar panels will provide 36 W, while the body mounted panels will provide redundancy for the power system. A tried and tested "metabolic" thermal design will insulate the electronics and battery from cold temperatures by reusing waste heat. Excess heat will be diverted to the propulsion system or radiated away from the spacecraft using back and side panels. The spacecraft will contain two CD&H computer, the Tyvak Intrepid and Space Micro's CSP system. This architecture enables the spacecraft computers to have nearly 6 layers of watch-dog circuitry in addition to being able to perform processor intensive computation for low-power. The Blue Canyon Technologies XACT (sun sensor, star tracker and 3-axis reaction wheels) provides attitude determination and control providing sub 1 degree pointing accuracy. The onboard cold-gas/resisto-jet propulsion system can supplement the reaction wheels for attitude control. Spacecraft operation will be performed at JPL and Arizona State University (ASU). This Swirl spacecraft concept represents a promising pathway towards building next-generation university-led interplanetary CubeSats that perform focused high-value low-orbit science for low-cost.