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INVESTIGATING ASTEROID SURFACE GEOPHYSICS WITH AN ULTRA-LOW-GRAVITY CENTRIFUGE IN LOW-EARTH ORBIT

Abstract

There are thousands of asteroids in near-Earth space and millions expected in the Main Belt. They are diverse in their physical properties and compositions. They are also time capsules of the early Solar System making them valuable for planetary science, and are strategic for resource mining, planetary defense/security, and as interplanetary depots. But we lack direct knowledge of the geophysical behavior of an asteroid surface under milligravity conditions. Near-Earth small-body mission targets 162173 Ryugu, 101955 Bennu, and 25143 Itokawa produce gravity fields around 4 orders of magnitude below that of Earth and their irregular shapes, combined with rotational effects produce varying surface potentials. Still, we observe familiar geologic textures and landforms that are the result of the granular physical processes that take place on their surfaces. The nature of these landforms, however, their origins, and how these surfaces react to interrogation by probes, landers, rovers, and penetrators, remain largely unknown, and therefore landing on an asteroid and manipulating its surface material remains a daunting challenge.

Towards this goal, we are putting forth plans for AOSAT+, a 12U CubeSat that will be in Low-Earth Orbit (LEO) and that will operate as a spinning centrifuge on-orbit. Parts of this 12U CubeSat will contain a laboratory that will recreate asteroid surface conditions by using crushed meteorite. Here we will present an overview of the systems engineering, spacecraft instrumentation design, and granular dynamics simulations representative of the laboratory chamber. The laboratory will spin at 0.1 to 2 RPM during the primary mission to simulate surface conditions of asteroids 2 km and smaller, followed by an extended mission where the spacecraft will spin at even higher RPM. The result is a bed of realistic regolith, the environment that landers and diggers and maybe astronauts will interact with. The CubeSat is configured with cameras, lasers, actuators, and small mechanical instruments to both observe and manipulate the regolith at low simulated gravity conditions. A series of experiments at varying effective gravity will measure the general behavior, internal friction, adhesion, dilatancy, coefficients of restitution, and other parameters that will be modeled and constrained by extensive numerical simulations. This detailed microgravity laboratory study of dynamical meteoritic properties will feed into asteroid surface dynamics simulations. We will exploit the benefits that come with having a long-term, sustained experiment,

including the ability to observe the dynamics inside the chamber continuously for long periods—important given the low velocities and weak forces.