Magnetic Grapples for Asteroid Regolith Sample Collection, Anchoring, and Mobility. A. H. Parker[1], K. J. Walsh[1], D. D. Durda[1], K. Nowicki, and the Project ESPRESSO Team. [1]Southwest Research Institute, 1050 Walnut St. Suite 300, Boulder, CO, 80302, USA. (aparker@boulder.swri.edu).

Introduction: The arrivals of OSIRIS-REx and Hayabusa2 at the Near-Earth Asteroids Bennu and Ryugu have highlighted the challenges of near-surface operations on small bodies, particularly where landing and sample collection are concerned. The strong heterogeneity of the surfaces of both asteroids also illustrates that future sample return missions will be well-served if they can conduct sampling at multiple sites to better capture material from the distinct surface units.

We present a novel sampling, anchoring, and mobility architecture for missions to the surfaces of small asteroids. The regoliths of these objects typically have a measurable ferromagnetic component, and can be manipulated with magnetic fields. Shielded or "switchable" permanent magnets can provide a safe, low-power means of controlled interaction with an asteroid surface. Such systems provide the advantage of being able to prevent any unwanted magnetic interference during flight, while also being smaller and lighter than comparable electromagnets and only requiring power to switch between "on" and "off" states. Magnetic systems for mechanical coupling to asteroid regoliths have not been broadly explored to date, and we present an initial proof-of-concept test conducted in an asteroid-like pressure and gravity environment.

Reduced Gravity Experiments: In October 2018, we conducted a series of four flights on board the NRC-CNRC's Falcon 20 Reduced Gravity Research Aircraft. We developed a mid-scale vacuum chamber to house a regolith simulant sample and a magnetic sampling experiment. For these flights, we used the high-fidelity CI chondrite regolith simulant produced by the UCF Exolith Lab.

The magnetic sampler demonstrator was composed of a 1 cm diameter N42-grade permanent magnet suspended by a low-*k* Kapton ring spring from a linear actuation stage. The magnet was coupled to a high-frequency vibration micro-motor to enable shaking before, during, or after interaction with the regolith sample. When the aircraft entered the reduced gravity portion of a parabola, the magnet was lowered into the regolith bed, shaken, and then withdrawn. Once the aircraft entered the hyper-g phase of a parabola, the magnet and any collected sample were shaken again under the 2g load to clear the majority of any collected sample and re-set the experiment for the next parabola.

In typical parabolas, a ~15 gram, ~3cm diameter sphere of material was bound and extracted by the magnet during a sampling experiment (see Figure 1). While we were unable to detect the required extraction force, the size of the hemispherical contact patch of the extracted sample was 18 times that of the bare magnet's surface, providing a substantial increase in effective surface area over which shear and tensile forces can act to anchor a landed mechanism.

Mission Concept: We envision a mission concept that uses magnetic sample collection to enable safe, efficient multi-site sampling across the surface of one or more NEAs. A parent spacecraft carries a fleet of small sampling microsatellites which are deployed onto the surface of the target body. These microsatellites have two mechanical states; by adopting a tetrahedral / triangular bipyramidal shape, folding panels can allow them to "evert" – that is, their entire outer surface can become their inner surface (see Figure 2). During deployment, their outer surface exposes magnetized plates. After touchdown, the surface is everted to encapsulate any collected sample and shield the magnets from any further surface interaction or interactions with the parent spacecraft. Small thrusters lift each microsat off the surface to be collected by the parent spacecraft and returned to Earth, each bearing a small sample from a unique location on the surface of the body.

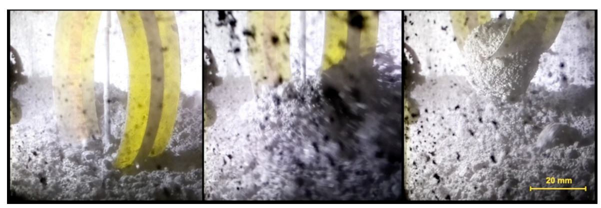

Figure 1: Example magnetic sampling sequence from October 2018 flight campaign. Regolith under vacuum and in a microgravity environment.

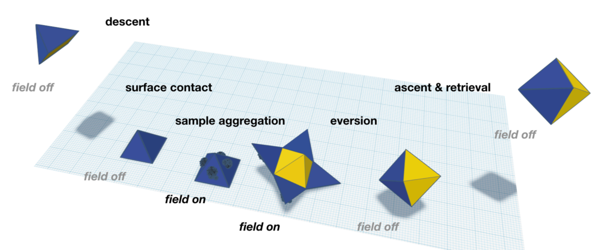

Figure 2: Concept sampling sequence on the surface of an asteroid, illustrating a single microsatellite sampler and its everting geometry.