STRATA-1: AN INTERNATIONAL SPACE STATION EXPERIMENT INTO FUNDAMENTAL REGOLITH PROCESSES IN MICROGRAVITY. Fries M.[1], Abell P.[1], Brisset J.[2], Britt D.[2], Colwell J.[2], Durda D.[3], Dove A.[2], Graham L.[1], Hartzell C.[4], John K.[1], Leonard, M.[5], Love, S.[6], Sánchez, D.P.[7], Scheeres D.J.[7], [1]Astromaterials Research and Exploration Science (ARES), NASA Johnson Space Center, [2]University of Central Florida, [3]Southwest Research Institute, [4]University of Maryland, [5]T STAR, Bryan, TX, [6]NASA Johnson Space Center, [7]University of Colorado Boulder. Contact: marc.d.fries@nasa.gov

Introduction: The Strata-1 experiment will study the evolution of asteroidal regolith through long-duration exposure of simulant materials to the microgravity environment on the International Space Station (ISS). Many asteroids feature low bulk densities, which implies high values of porosity and a mechanical structure composed of loosely bound particles, (i.e. the "rubble pile" model), a prime example of a granular medium. Even the higher-density, mechanically coherent asteroids feature a significant surface layer of loose regolith. These bodies are subjected to a variety of forces and will evolve in response to very small perturbations such as micrometeoroid impacts, planetary flybys, and the YORP effect. Our understanding of this dynamical evolution and the inter-particle forces involved would benefit from long-term observations of granular materials exposed to small vibrations in microgravity. A detailed understanding of asteroid mechanical evolution is needed in order to predict the surface characteristics of as-of-yet unvisited bodies, to understand the larger context of samples collected by missions such as OSIRIS-REx and Hayabusa 1 and 2, and to mitigate risks for both manned and unmanned missions to asteroidal bodies. Understanding regolith dynamics will inform designs of how to land and set anchors, safely sample/move material on asteroidal surfaces, process large volumes of material for in situ resource utilization (ISRU) purposes, and, in general, predict behavior of large and small particles on disturbed asteroid surfaces.

The Strata-1 Experiment: Strata-1 is a Class-1E payload that will launch to ISS in the spring of 2016. The new 1E class is being developed with a different approach from traditional ISS payloads and is a pathfinder to streamline the payload development, review, approval and integration processes. Developed under the baseline philosophies that payloads must "prove they cannot harm ISS" and "prove they cannot harm the crew", Strata-1 went from concept to flight-ready in just 10 months. Strata-1 includes four clear, polycarbonate tubes containing different regolith simulant materials that are monitored with HackHD cameras to image the movement of the simulants during its year on-orbit. Data is recorded on SD cards, and then downlinked every three months. The Strata-1 payload development team was led at NASA Johnson Space Center, with hardware primarily built at UCF and JSC, electronics provided by T STAR, and science team members from institutions around the country.

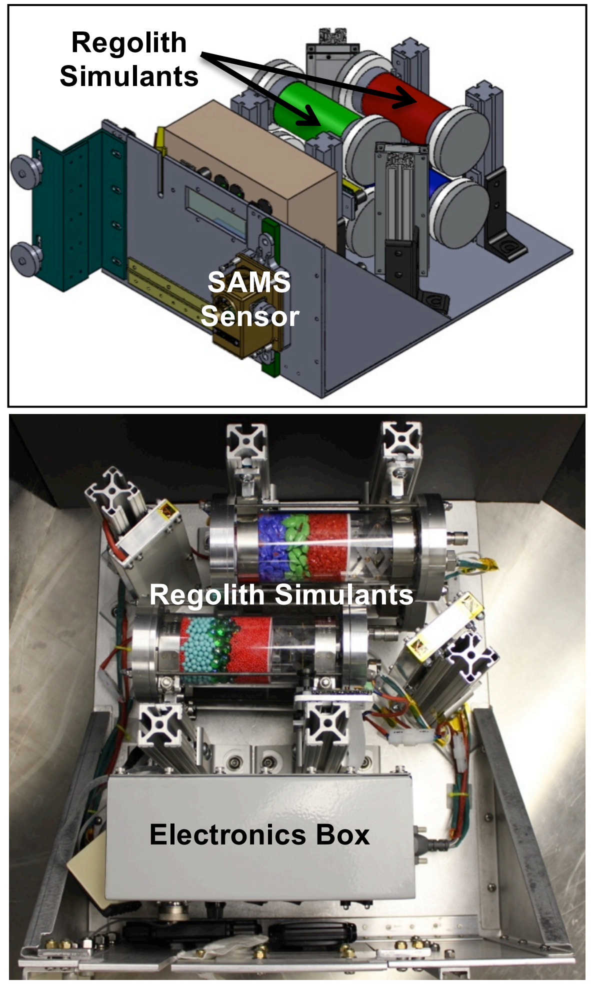

Figure 1:Top: CAD model of Strata-1 with the SAMS acceleration package attached to the front plate. Note the four tubes carrying asteroid regolith simulants. There is a camera for each tube (not shown). Bottom: Top-down image of the assembled Strata-1 experiment.

The Entrapulator: Contained in each regolith tube is an "entrapulator" that is used to compress the simulants in place during launch and landing and preserve the arrangement of the simulant particles.

The Experiment Materials: The contents of the four experiment tubes are shown in Table 1. These materials were chosen to span a range of complexity from a relatively simple system composed of glass spheres to a relatively complex system of crushed/sieved meteorite material, as well as a carbonaceous chondrite simulant. The material in each tube is sorted into three size species pre-launch, and this configuration is maintained during launch by the entrapulator. Analysis of data from the four tubes will allow refinement of models using observed materials behavior.

	Features	Diameter: Mass	Material
Exp 1	Spherical, Single Material	2mm: 292.95g 5mm: 130.35g 10mm: 125.90g	Glass
Exp 2	Angular, Single Material	2mm: 267.15g 5mm: 134.90g 10mm: 132.25g	Glass
Exp 3	Angular, Multiple Materials	Fines: 337.20g 1mm: 154.10g 4mm: 160.20g	Ordinary Chondrite
Exp 4	Angular, Carbon-Rich	Fines: 161.50 g 1mm: 72.25g 4mm: 69.15g	Carbonaceous Simulant

Experiment 1: The first tube of the Strata experiment is composed of spherical particles with three discrete grain sizes and colors. This will allow comparison of the size segregation observed on-orbit with Earth-based experiments, which have previously demonstrated that size segregation will occur with spherical glass beads, and computational simulations of the system, as spherical grains are most easily modeled by Discrete-Element-Method (DEM) codes. The grain sizes and quantity of each species were chosen due to numerical constraints and constraints involving interaction with the sample tube walls, porosity of the sample, and the Knudsen number (a measure of the mean free path of the grains). The Knudsen number was chosen to be 0.003 so that particle-particle collisions dominate [1]. The largest grain size was limited to 10 mm in order to keep the grains relatively small compared to the inner diameter of the tube (63 mm).

Experiment 2: The properties of the second tube are identical to those of Experiment 1, except with angular particles. Angular particles were created by manually fracturing hemispherical particles and then sieving to achieve the desired size distributions. A major limitation of current modeling efforts is the difficulty of including aspherical grains. Thus, by comparing the segregation observed in Experiments 1 and 2, we will be able to identify the influence and significance of grain shape on the segregation process.

Experiment 3: The third tube contains a crushed and sieved ordinary chondrite in order to simulate the behavior of an ordinary chondrite-based regolith. The material was sorted to three size distributions similar to Tubes 1 and 2, but contains particles of a wider range of density to include metal- and sulfide-bearing meteorite fragments.

Experiment 4: The fourth tube contains a carbonaceous chondrite simulant, sieved to three size fractions. The simulant was designed to mimic the mineralogy, particle size, and strength properties of CI carbonaceous chondrites. The behavior of materials in this tube will directly inform missions to carbonaceous bodies such as OSIRIS-REx, Hayabusa2, and the ARM mission concept.

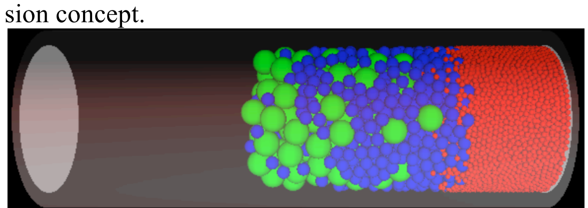

Figure 2: Prototype simulation (SSDEM) of one of the experimental tubes. The cylinder contains 2 mm, 5 mm and 10 mm glass-like spherical beads. Gravity is pushing to the right.

Simulation Methods: There are two simulation methods that have been proposed for this research, the first, Soft-sphere Discrete Element Method (SSDEM) [2,3] and the second, Contact Dynamics Method (CD) [4,5]. In SSDEM, the particles interact through soft potentials (spring dashpot-type) that model the forces and deformation that occurs during collisions or enduring contacts. In CD, particles are not allowed to interpenetrate and forces are calculated unilaterally so that this premise is upheld. Fig. 2 shows a preliminary simulation result obtained by using the SSDEM code mentioned above for Experiment 1. All particles are frictional and are contained in a cylindrical container with the same material characteristics. This container can also be made to vibrate so that the experimental conditions in the ISS are matched.

Post-Flight Analysis: All samples will be returned to Earth after a year to quantify the spatial distribution of particles in terms of size and density (where appropriate). Imagery will be processed into video showing the movement of all tube materials over the course of a year, and compared to simulation results.

References: [1] Harth, K. *et al.* (2015) *Adv. Space Res., 55,* 1901-1912. [2] P. Sanchez, et al. (2011) *Astrophys. J.* **727**(2):120. [3] P. Cundall (1971) in *Proc. Int'l. Sym. on Rock Mechanics V.1* 129–136 -, Nancy. [4] C. M. Hartzell, et al. (2014) in *LPSC 45* 2849. [5] J. J. Moreau (1994) *Eur J Mech A* 13:93.