The MESS Payload: Hands-on Experience for Undergraduates in Planetary Science Spaceflight Hardware

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Background

Small asteroids in the near-Earth space are known to be so-called rubble-piles composed of granular material accreted through self-gravity (Walsh, 2018). Their study is of utmost importance both to our understanding of the formation and evolution of our Solar System and for assessing planetary defense threats and mitigation options. Of particular interest is the mechanical structure and dynamical behavior of these granular bodies, as gravitational forces and material cohesion and strength compete with rotational centrifugal forces and impact-induced dismantling. The asteroid material structure and strength, and in particular its response to impact-induced seismic waves, dictates the body's shape, its surface features, and potential activity (Quillen et al., 2019; Tancredi et al., 2016).

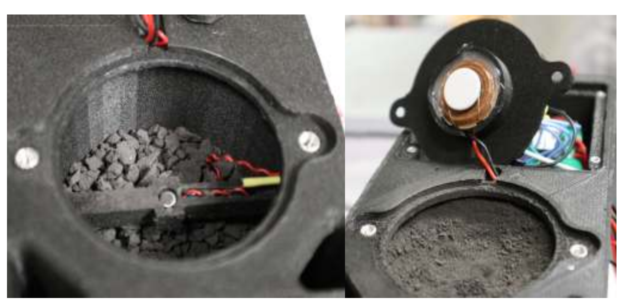
Granular materials have been shown to have a different behavior under low gravity conditions, for example in their flow (Hofmeister et al., 2009) and strength behavior (Murdoch et al., 2013), as well as their response to stimuli such as impacts (Brisset et al., 2020; Brisset et al., 2018) and seismic shaking (Zeng et al., 2007). In addition, the way sound waves travel through granular material has been shown to strongly depend on the stress applied to the material (confining pressure) and the force chains that develop in response to that stress (Hostler, 2005). Therefore, speed of sound measurements relevant to materials in small asteroids can only be accurately performed under microgravity conditions.

Experimental Setup

The experiment is called Microgravity Experiment for Speed of Sound (MESS) and aims at measuring the speed of sound in asteroid regolith simulant under microgravity condition. It was funded by the Florida Space Grant Consortium (FSGC) and the Florida Space Institute (FSI) and flew with Blue Origin's P12 New Shepard suborbital rocket as a Mini-Payload.

For the experiment, we produce three types of regolith simulant samples: fine grains (~0.1 mm), mm-, and cm-sized grains. These granular samples are prepared from a high-fidelity asteroid regolith simulant (Britt et al., 2019) into irregular grains most representative of material found at the surface of asteroids. We generate sound waves within these regolith simulant samples and record their arrival at two different distances from their source. To this purpose, three sample tubes are outfitted with a speaker on one end, a microphone in the middle of the tube, and a second microphone at the other end. The tubes have fixed lengths: 50 mm for fine and mm-sized grains and 100 mm for cm-sized grains.

The three tubes containing grains of different sizes are accommodated within a 4U volume (20x20x10 cm). The 4U format also allows for the accommo-



dation of the experiment electronics. These are very simple and adapted to a short suborbital test flight, and recording data onto a memory card, which is retrieved after the flight.

Educational Mission

At any given time, the student team was composed of one Mechanical/Aerospace Engineering student, one Electrical Engineering student, and one Computer Science student. Due to the pandemic, the project stretched of five semesters instead of two and, as more senior students graduated, new students were integrated into the team to take over. For this reason, students were not only trained in hands-on skills in their respective areas of expertise and integrated team work, but also in mentoring and project management as well. They learned to handle deadlines and project documentation, and overall, had an exceptional experience preparing them for their post-graduation professional life.

Students who were involved in the project and graduated all went on to pursue space-related careers, including Aerospace Engineering/Planetary Sciences graduate programs as well as jobs in the thriving space industry.

Coming Next

We are looking forward to reflying the experiment with Blue Origin, after the P12 attempt. As the project continues, we hope to involve even more students. So far, we impacted 12 students with this one educational payload and it will be >15 by the end of the project.