A view of a transparent **FLUIDICS** sphere aboard space station. The FLUIDICS investigation studies the dynamics of liquid sloshing to better understand turbulence in spacecraft tanks and to optimize fuel use. NASA ID: iss066e146914.

Publication Highlights

Physical Science

The presence of gravity greatly influences our understanding of physics and the development of fundamental mathematical models that reflect how matter behaves. The space station is the only laboratory where scientists can study long-term physical effects without the complications of gravity-related processes such as convection and sedimentation. This unique environment allows different physical properties to dominate systems, and scientists are harnessing these properties for a wide variety of investigations in the physical sciences. From the beginning of station to date, more than 700 articles have been published in the area of Physical Science.

The investigation **The Materials International Space Station Experiment-13-NASA (MISSE-13-NASA)** encompasses a group of experiments that examine the effect of the space environment on material quality. MISSE experiments fly similar materials on multiple missions to better understand degradation, predict durability, ensure feasibility of in-space manufacturing, and prepare for long-term use of materials in a harsh environment.

For 10 months, a promising low-cost, high-performing semiconductor material known as Metal Halide Perovskites (MHP) that absorbs sunlight and converts it into electrical energy was exposed to the space environment as encapsulated thin films. Confocal microscopy analysis conducted postflight on the ground showed localized surface defects (i.e., bubbles) that resulted from trapped moisture, and 13 percent of its surface was optically inactive. However, the surface flaws, carrier recombination lifespan, and response to solar exposure were repaired or improved after 15 hours of solar illumination of the sample (Figure 18).

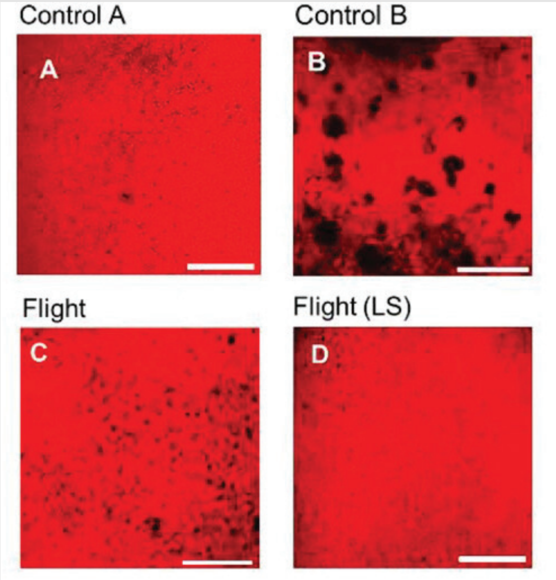

Figure 18. Confocal flourescence images of Earth control samples (A and B, with and without a layer of silicon dioxide, repectively), fligh (C) and flight sample after light exposure (D). *Images adopted from Delmas, Advanced Energy Materials.*

These results demonstrate that MHPs in microgravity have a stable response to solar light, can be restored, and have a good charge lifespan that assists in overcoming the known longevity issues of MHP devices. Improved MHPs could lead to enhancements in solar cells, light emitting diodes, and optoelectronic devices, which could in turn assist in the development of life support systems, telecommunications, and electric propulsion systems to support space exploration.

The JAXA investigation **Hourglass** examines the behavior of granular materials in various low-gravity environments aiming to enhance the design of spacecraft, landers, and other mobility systems.

The Moon, Mars, and asteroids in our solar system can be covered by a layer of loose material known as regolith. To ensure the

Delmas W, Erickson S, Arteaga J, Woodall M, Scheibner M, et al. Evaluation of hybrid perovskite prototypes after 10-month space flight on the International Space Station. Advanced Energy Materials. 2023 May 19; 13(19): 2203920. DOI: 10.1002/aenm.202203920.

proper functioning of the equipment developed for use on the celestial surface, it is essential to conduct a ground test that verifies the reaction force and the sinkage caused by loose regolith. Previous research has employed computerized simulations to predict equipment performance in the most challenging environments.

A recent study published in *npj Microgravity* provides verification of the hypothesis of granular flows by analyzing data from experiments conducted on the station under various levels of artificial gravity (0.063 to 2.0 times Earth's gravity).

The hourglass device was designed to control the flow of alumina beads, silica sand, Toyoura sand, and five variations of regolith simulants as analogous grains (Figure 19). Stable gravitational fields were generated by rotating a centrifuge and flipping an hourglass-shaped instrument in the Japanese Experiment Module (JEM).

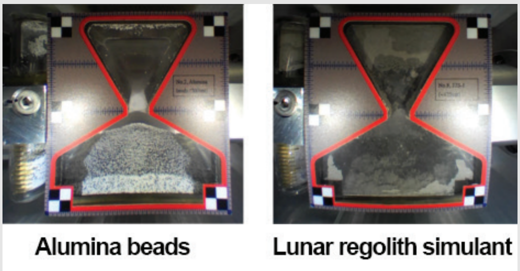
Alumina beads
Lunar regolith simulant

Figure 19. The state of Deposition after the hourglass is inverted and the granular particles have moved through the neck. *Image provided by Hourglass research team.*

The researchers found that the low-gravity behavior of grains generally follows previously postulated physical laws of flow rate, but with some differences. And the researchers presumed that the bulk density of the flow is unstable but decreases with gravity. In addition, the researchers observed that the specific type of granular material and slant angle in the hourglass influenced the flow rate, with powder-like material adhering, depositing, and aggregating in the device.

These findings can improve simulations and inform the development of advanced technologies for successful roving on extraterrestrial bodies.

The ESA investigation **FSL Soft Matter Dynamics - Hydrodynamics of Wet Foams (FOAM)** examines changes to liquid foams, (e.g., soap and champagne) in microgravity. On Earth, bubbles in liquids rapidly rise to the top and the liquid moves to the bottom of a container due to gravity. In microgravity, however, changes to the liquid foam are slower and can be studied in detail. Through this station research, investigators enhance the understanding of liquid foams to design better liquid systems in agriculture, brewery, detergent, and oil industries.

In a new study published in *Soft Matter*, researchers observed changes to the size and distribution of bubbles created in microgravity by mixing water with a pure and chemically stable foaming agent. Researchers tested several mixed samples using 11 different liquid amounts (e.g., 15 percent water, 20 percent water, up to 50 percent water) to identify which liquid percentage most effectively led to the growth and dispersion of the bubbles (transitioning from a soft gel-like network of packed bubbles to a more liquefied solution). A camera recorded the changes in the samples, and manual analyses of the images occurred on Earth.

Researchers revealed that small bubbles shrank and large bubbles grew even larger over time because of pressure dynamics in the bubbles (Figure 20). Additionally,

Ozaki S, Ishigami G, Otsuki M, Miyamoto H, Wada K, et al. Granular flow experiment using artificial gravity generator at International Space Station. npj Microgravity. 2023 August 8; 9(1): 1-13. DOI: 10.1038/s41526-023-00308-w.

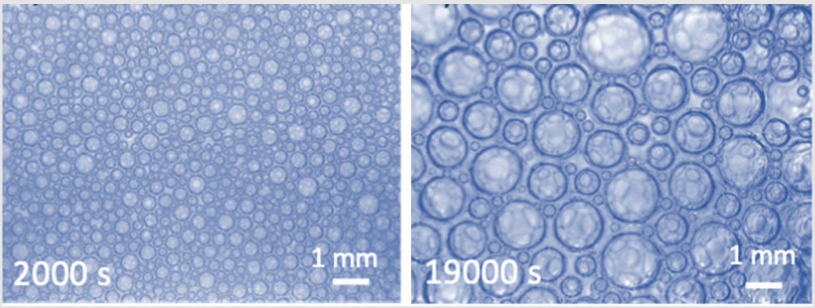

Figure 20. Changes in bubble size in a mixture of foaming agent and 25 percent liquid after approximately five and a half hours. *Image adopted from Pasquet, Soft Matter.*

researchers identified that bubbles transitioned from a crowded to a scattered arrangement when the mixture contained 39 percent liquid. This finding differed from their theoretical prediction of 31 percent liquid to observe such transition in microgravity. As packed bubbles separated and diffused, distorted polyhedral-shaped bubbles became more spherical and uniform. Weak interactions and reduced contact forces among bubbles may explain their separation and dispersion. Despite the uniqueness of these results, researchers also acknowledge similarities to phase separation in alloys and capillary pressure changes observed in biology.

By studying the mechanical properties of liquid foams, researchers can learn how to stabilize and enhance their shelf life. This research not only improves liquid systems but also contributes to the improvement of foam solidification in applications such as packaging, insulation, and car-collision prevention through metallic foams.

Pasquet M, Galvani N, Requier A, Cohen-Addad S, Hohler R, et al. Coarsening transitions of wet liquid foams under microgravity conditions. Soft Matter. 2023 August 8; 19(33): 6267-6279. DOI: 10.1039/d3sm00535f.