NASA crew member Megan McArthur observes the Astrobee robotic free-flyer inside the Kibo laboratory module. As part of the SoundSee Mission investigation, the robotic assistant “listened” to station equipment to detect anomalies in systems that may need maintenance or repair. NASA ID: iss065e162209.

Publication Highlights

Technology Development and Demonstration

Future exploration — the return to the Moon and human exploration of Mars — presents many technological challenges. Studies on the ISS can test a variety of technologies, systems, and materials that are needed for future exploration missions. Some technology development investigations have been so successful that the test hardware has been transitioned to operational status. Other results feed new technology development.

Mochii, a scanning electron microscope for high-resolution imaging and elemental analyses of organic and inorganic materials, is a NASA investigation that was flown to the ISS in 2020 and 2021 to acquire textural, morphological, and chemical information from multiple samples. Mochii is capable of measuring sample responses to radiation, recording changes over time such as sample growth, and recording the readings of ISS instruments for spacecraft and crew safety.

In a new study published in *Microscopy and Microanalysis*, Mochii's technology was tested by analyzing a fragment of a Martian meteorite found in Antarctica in 1984 thought to possibly contain traces of minerals suggestive of microbial life. The fragment was first analyzed on Earth with a full-size scanning electron microscope and a ground version of Mochii, then compared to the analysis of Mochii's flight version.

Once astronauts aboard the ISS loaded the meteorite sample into Mochii, researchers could analyze the samples remotely from Earth. Data processing showed good agreement between in-space and Earth analyses, indicating accurate functioning of Mochii in low-Earth orbit.

An ISS-certified scanning electron microscope that reads trace element information from various materials is crucial to support mining efforts searching for fuels to power Moon surface and orbital operations. Mochii provides a remarkable capability for researchers interested in understanding the formation of planets and the origin of life in the universe.

Figure 20. Mochii system. NASA Image iss067e123927.

Own C, Thomas-Keprta KT, Clemett S, Rahman Z, Martinez J, et al. Electron microscopy and analysis of Martian meteorite ALH84001 with MochiiISS-NL on the International Space Station. Microscopy and Microanalysis. 2022 August; 28(S1): 2712-2718. DOI: 10.1017/S1431927622010224.

The ESA investigation Haptics-2: Real-time teleoperation experiment conducted by crew from Space to control robotic components on Earth with force-feedback (ESA-Haptics-2) assesses the ability of crew members to control robotic systems on Earth from the ISS. Understanding these crew capabilities enables remote operations from space stations to the Moon, Mars, asteroids, and other celestial bodies.

Hazardous conditions arise when automatic docking systems cease to function and manual input is required to guide spacecraft and manipulate large on-orbit modules. Knowing that task performance (i.e., pushing strength,

Figure 21. Cosmonaut operating the ESA Haptics-2 joystick and aiming task. Image adopted from Weber, Applied Ergonomics.

tracking, speed, and aiming) deteriorates during spaceflight due to the absence of Earth gravity, stress, sleep deprivation and altered proprioception, a focus on training is necessary to sharpen the crew's sensorimotor abilities and ensure successful human-machine interfaces.

In a new collaborative study between ESA and ROSCOSMOS published in *Applied Ergonomics*, researchers examined how aiming performance is supported or hindered by a variety of haptic settings before, during, and after spaceflight. Using a force feedback joystick that had different options for manipulating spring stiffness, motion damping (i.e., control), and virtual mass, three crew members controlled a cursor on a computer screen to match four different targets. A control ground study was simultaneously conducted to compare time performance differences.

Results showed faster reaction time from the first preflight session to the last postflight session. Similar faster times were observed for rapid motion, fine motion, and acceleration sign changes, demonstrating that microgravity did not impair the cosmonauts' ability to produce rapid movements or precise aiming, especially after a period of adaptation. However, some individual differences in sensorimotor skills emerged. While two cosmonauts showed decreased speed in rapid and fine movement during the early phase of adaptation relative to the ground study, the cosmonaut with above-average skill showed unchanged rapid and fine movement speed during the early phase of adaptation. Researchers concluded that the low stiffness of the joystick supports aiming precision in microgravity and individual sensorimotor skill facilitates machine operation.

This study provides critical information for the safe remote manipulation of robots and flight control systems during spaceflight operations.

Weber B, Schatzle S, Stelzer M. Aiming performance during spaceflight: Individual adaptation to microgravity and the benefits of haptic support. Applied Ergonomics. 2022 September; 103: 103791. DOI: 10.1016/j.apergo.2022.103791.

The ESA investigation Microbial Aerosol Tethering on Innovative Surfaces in the International Space Station (MATISS) examines how bacteria adheres to surfaces in microgravity to develop better cleaning products and antibacterial materials to reduce microbial contamination on surfaces aboard the ISS.

Many microorganisms on the ISS are brought there by crew members, with their origins coming from inside the body via mucus, or outside the body from bacteria and fungi on skin. The spread of these microbes is currently inevitable. When droplets containing small organisms land on a commonly touched surface on spacecraft, they attach themselves and eventually contaminate the surface. To inhibit prolific evolution of potentially harmful species, scientists are looking for ways to develop new surfaces that not only reduce surface-to-droplet interaction, but also reduce the possibility of microbial attachment. In order to find potential surface coatings that limit contamination,

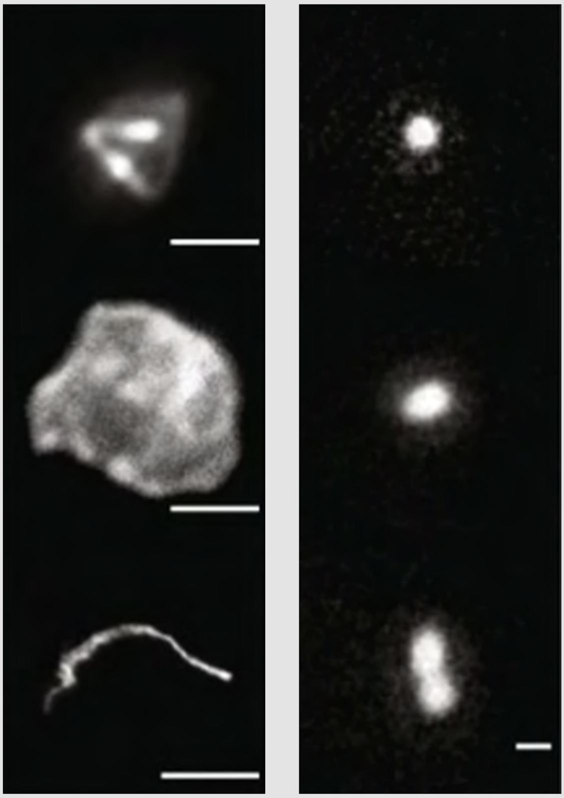

Figure 22. Optical images of course and fine particles observed on FDTS-coated surfaces. Image adopted from Lemelle, Npj Microgravity.

researchers used a special solvent called Perfluorodecyltrichlorosilane (FDTS) that has moisture-sensitive properties.

FDTS is a liquid chemical that bonds to surfaces such as glass. In a study published in *Npj microgravity*, glass holders were treated with FDTS, sterilized, and then placed in the Columbus module for periods varying from 40 days to nearly a year. Results show that FDTS is the most efficient hydrophobic coating that has been used to prevent the sticking of droplets and subsequently lessen surface contamination. Differences in sizes of particles collected within the holder offers a chance for further study on the movement of water droplets. Additionally, the data underscores the importance of developing air filtration systems that remove larger particles from the air that may otherwise be inhaled.

Through three different MATISS investigations, the size of particles captured by the microbial monitoring device greatly varied, but the environment was cleaner overall. However, it was noted that the number of crew members present on board has an impact on surface contamination measurements, with lower crew numbers having the lowest surface contamination data. It should be noted that the lowest contamination data was found during the Covid-19 pandemic, which directly limited the number of crew on board.

The development of surface materials and preventative measures improves spacecraft sterility and decreases biohazardous risks to astronauts.

Lemelle L, Rouquette S, Mottin E, Le Tourneau D, Marcoux P, et al. Passive limitation of surface contamination by perFluoroDecylTrichloroSilane coatings in the ISS during the MATISS experiments. npj Microgravity. 2022 August 4; 8(1): 1-8. DOI: 10.1038/s41526-022-00218-3.

The NASA investigation One-Step Gene Sampling Tool extracts ribonucleic acid (RNA) directly from plant or animal tissue for real-time analysis aboard the ISS.

Assessing gene expression changes in response to spaceflight allows researchers to understand adaptation processes in different organisms. Understanding the adaptation mechanisms of plants is critical because as crews become more independent in future missions to the Moon and Mars, they will need to rely on space-based plant cultivation for self-sustenance and survival.

Until the development of the One-Step Gene Sampling Tool, all plant genetic analyses were performed on Earth after spaceflight due to crew time limitations, reduced working area on ISS, and liquid handling concerns in microgravity.

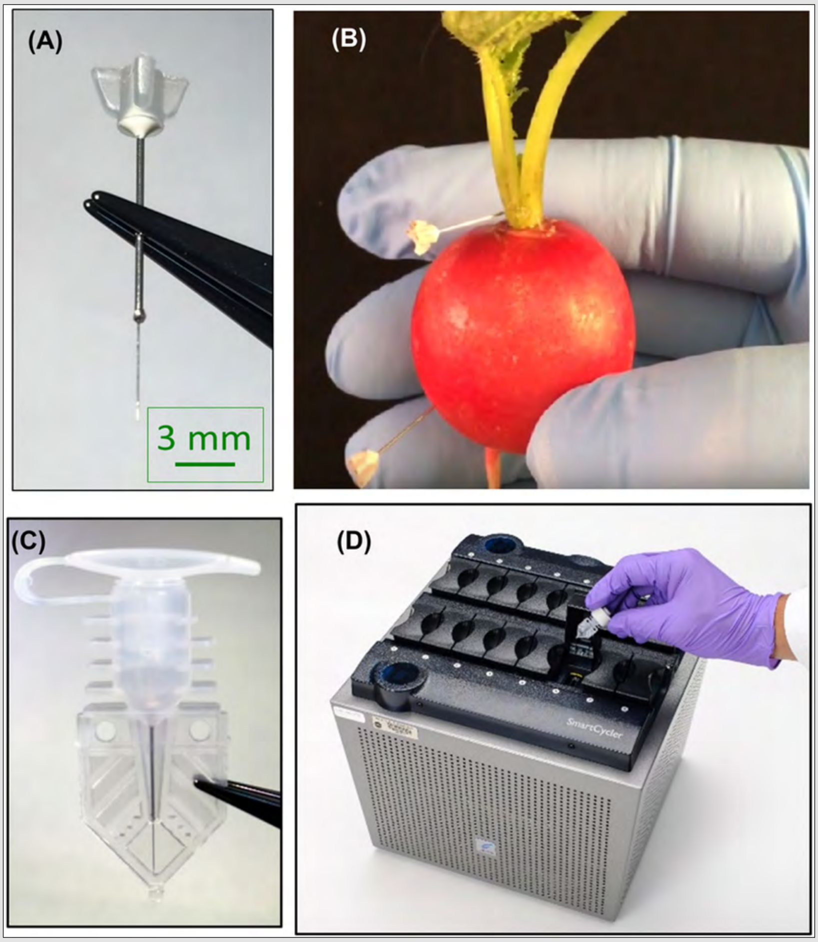

Figure 23. One-Step Gene Sampling Tool process. The small pin obtains plant tissue which is placed in the SmartCycler for the extraction of RNA. Image adopted from Nestorova, Acta Astronautica.

Unfortunately, long waiting periods between testing and analysis, few biological replicates, and changes associated with plant freezing or fixation can impact results. Therefore, a new technology that requires minimal liquid handling and power consumption is needed to conduct adequate plant genetic analysis in microgravity.

In this validation study published in *Acta Astronautica*, researchers report on-ground and spaceflight validation of this user-friendly and efficient technology for RNA extraction from plant or animal tissue without the use of liquids. An RNA capture pin (RCP) selects and purifies high-quality mRNA from biological material without requiring pre-processing steps. This method is faster than the previous RNA prep protocol aboard the ISS and is completely dry, allowing collection of multiple samples of the same specimen and repeat genomic analysis with high spatial resolution. Using Cherry Bell radishes, researchers found that the ground control test showed similar results to the experiment onboard the ISS.

This new tool simplifies the procedures for genetic screening onboard the ISS, enhances analyses without destroying specimens, and creates new opportunities for assessment of long-term plant and animal adaptation responses to microgravity in real-time.

Nestorova GG, Crews N, Schramm AK, Aquilina RA, Parra MP, Chin M, Chinn T, Hee L. Spaceflight validation of one-step Gene Sampling tool for genetic analysis on the International Space Station. Acta Astronautica. 2022 September 1; 198: 225-232. DOI: [10.1016/j.actaastro.2022.05.023](https://doi.org/10.1016/j.actaastro.2022.05.023).