A preflight view of JAXA's CubeSat **WARP-01**. The satellite, developed by the University of Tsukuba and Warpspace, was deployed during the JEM Small Satellite Orbital Deployer-16 (J-SSOD-16) micro-satellite deployment mission. NASA ID: jsc2020e049613.

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 space station 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. From the beginning of station to date, more than 600 articles have been published in the area of Technology Development and Demonstration.

Guatemala's **Quetzal-1** CubeSat satellite (Figure 21) was successfully deployed from the JEM Small Satellite Orbital Deployer-13 (J-SSOD-13) on space station. This investigation demonstrated passive magnetic attitude control capabilities using the Earth's magnetic field to nullify rotations in six degrees of freedom and accurately control attitude and pointing. The passive Attitude Determination and Control System (ADCS) was used to allow ground target imagery over the mission's geographical zone of interest, Guatemala. In order to reduce the size required for the hardware, the Quetzal-1 Satellite used two hysteresis rods and a 0.74 ampere-meter squared permanent magnet.

The Singular Value Decomposition (SVD) method was implemented for attitude determination together with a three-axis magnetometer and two photodiodes on each of the satellite's six sides with only the Z axis showing effects by other magnetic components within the satellite hardware. Attitude control was successfully accomplished after ± 25 degrees per second rotations on each axis immediately after deployment. Anomalies included the magnetometer occasionally transmitting zero data when the temperature dropped below 10 degrees Celsius and changes to the magnet torque and oscillation amplitude values during South Atlantic Anomaly (SAA) passes.

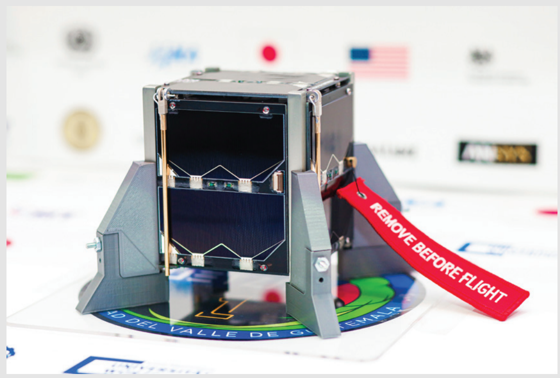

Figure 21. Photo of Quetzal-1 prior to spaceflight. Image obtained from Quetzal-1 research team.

The capability to control satellite attitude stabilization and pointing with minimal hardware is a critical factor for future orbiting satellite designs where weight and volume are limiting factors.

The NASA investigation **Spacecraft Fire Experiment-IV (Saffire-IV)** examines fire spread in different materials and under different conditions using the Cignus resupply vehicle after it leaves station.

The danger of uncontrolled fire on a spacecraft can have devastating if not fatal consequences. Materials that fly on station go through a rigorous screening process to characterize their fire hazard. However, since there is no way to properly simulate those characteristics on the ground, it is necessary to observe and study actual flame conditions

Alvarez D, Aguilar-Nadalini A, Bagur JA, Ayerdi V, Zea L. Design and on-orbit performance of the attitude determination and passive control system for the Quetzal-1 CubeSat. Journal of Small Satellites. 2023 May/June; 12(2): 1231-1247. Webpage.

in a microgravity environment. The Saffire-IV experiment provides the means to perform large scale studies of flames in microgravity conditions. The work published in the *Proceedings of the Combustion Institute* shows a methodology developed to determine the average temperature of flames spreading over a thin solid surface in microgravity using a testbed aboard a re-entering Cygnus spacecraft.

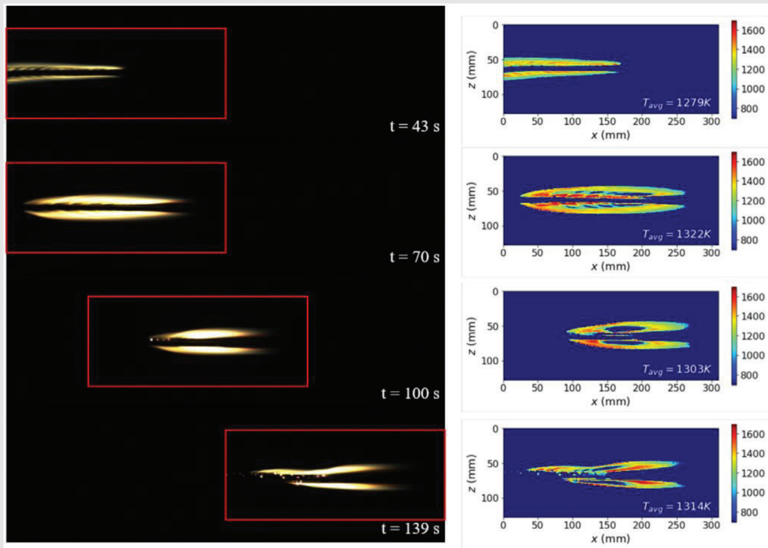

Figure 22. Camera snapshots at different times in the experiment and corresponding temperatures using broadband emissions pyrometry. *Image adopted from Thomsen, Proceedings of the Combustion Institute.*

The testbed is safely ignited while the Cygnus spacecraft is undocked and safely away from the space station as it enters the Earth's atmosphere prior to burning up during re-entry. The burn sample was 40.64 centimeter wide by 50 centimeter long and was mounted on a metal frame in the center of the flow tunnel and consisted of a thin fabric made of cotton and fiberglass called Sibal. Images of the testbed burning were taken along with data from four thermocouple and radiometers. The raw imagery was analyzed using two-color broadband emission pyrometry (B2CP) as a method to measure high temperatures. The results from imagery analysis showed an average temperature of 1300 Kelvin, which remained constant during the flame spread (Figure 22).

This study provides a better understanding of flame properties in microgravity essential to validate numerical models and develop methods to prevent and respond to the occurrence of fire accidents that could endanger the success of a mission and the safety of the crew.

The NASA investigation **Astrobee Maneuvering by Robotic Manipulator Hopping (Astrobatics)** aims to develop robotic hopping capabilities in an orbital environment (i.e., space station or artificial satellites). While robotic hopping has already been demonstrated on an asteroid surface, robotic hopping in challenging environments where the surfaces are made of different materials or there are obstacles such as tools and wiring had not been tested until now.

In a recent study published in *Acta Astronatica*, researchers tested motion theory and methodology previously developed. In the applied study on station, the robots self-tossed from a grasped handrail or a free-floating condition to another distal or proximal surface using a mechanical arm that opens and closes the robot's gripper (Figure 23).

Thomsen M, Cruz JJ, Escudero F, Fuentes A, Fernandez-Pello AC, et al. Determining flame temperature by broadband two color pyrometry in a flame spreading over a thin solid in microgravity. Proceedings of the Combustion Institute. 2023 June 7; 39(3): 3909-3918. DOI: 10.1016/j.proci.2022.07.237.

Results showed that proximal self-toss maneuvers on the space station had a greater range of motion, and displacement compared favorably to simulation models. However, tests on station showed a greater value of angular displacement, causing the robots to tumble off-axis compared to the simulation. While improvements in hardware and modeling are needed to fix this discrepancy, the results of this study demonstrate, for the first time, the successful self-toss locomotion of robots in a spacecraft.

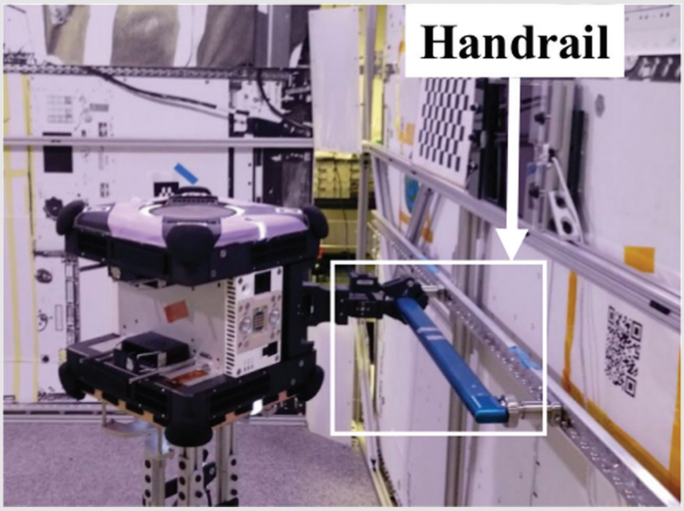

Figure 23. Test of Robot's gripper at NASA Ames Research Center. *Image adopted from Kwok-Choon, Acta Astronautica.*

Self-toss or hopping maneuvers allow robots to go across a spacecraft or celestial body surface to reach a work site without the need for propellant. These hopping maneuvers in microgravity represent a major step toward developing autonomous robots that can perform important and potentially dangerous tasks in space, reducing the risks to astronauts.

Kwok Choon ST, Romano M, Hudson J. Orbital hopping maneuvers with Astrobee on-board the International Space Station. Acta Astronautica. 2023 June; 207: 62-76. DOI: 10.1016/j.actaastro.2023.02.034.