NASAfacts

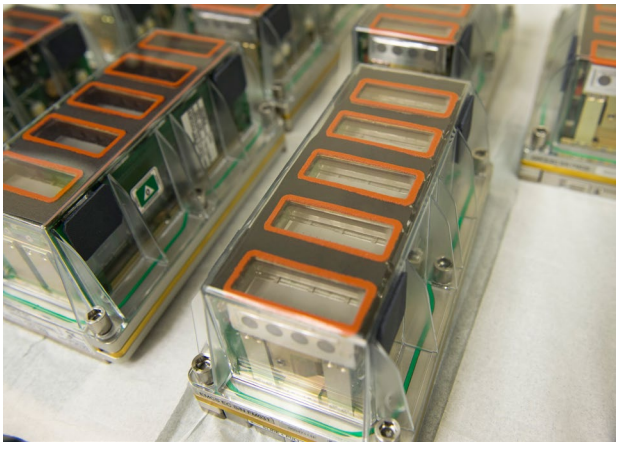
Variable Gravity Plant Biology Spaceflight Research

Studying plant growth and development responses aboard the International Space Station at multiple gravity levels

NASA and the European Space Agency (ESA) are collaborating to perform plant biology research aboard the International Space Station using the European Modular Cultivation System (EMCS) facility. Working with multiple U.S. and international investigators, NASA's Ames Research Center in Moffett Field, Calif., is conducting variable gravity plant experiments in space, including TROPI-1 (2006), TROPI-2 (2010), Plant Signaling (2011), Plant RNA Regulation (2016) and Seedling Growth (2013–2017).

The EMCS Facility
The ESA-developed EMCS is a unique incubator system that provides dedicated, controllable life support for biological experiments in a multi-gravity environment. Two independent centrifuge rotors inside the EMCS create gravitational forces ranging from 0 *g* (static rotor) to 2 *g*. This range includes the fractional g-forces found on the moon and Mars.

The basic modular component of the EMCS is an experiment container with an internal volume of 6-by-6-by-16 centimeters that mounts onto the centrifuge rotors. These experiment containers hold experiment-specific hardware and provide gas, water, electrical and data connections to their contents from the EMCS.



NASA experiment containers integrated with experiment-unique equipment for a spaceflight plant biology study.

The EMCS provides lighting and control of temperature, humidity and gaseous atmosphere composition, including ethylene scrubbing. Rotor-mounted camera systems capture images for near real-time downlink to the ground.

Although research conducted in the EMCS has historically focused on plant biology, the system can accommodate experiments involving various organisms, such as cell and tissue cultures, and small invertebrates or aquatic specimens. Payload and experiment developers must design, test, and integrate new "experiment unique equipment" to fit within the EMCS experiment containers.

Ames Plant Biology
To support spaceflight studies of germination and early growth of the plant *Arabidopsis thaliana*, experiment-unique equipment was designed and developed by the Space Biosciences Division at Ames. First used for the TROPI-1 mission in 2006, this equipment includes seed cassettes, and lighting, hydration and air circulation systems. A heating system also eliminates condensation on the surface of the seed cassettes, ensuring that clear views of seedlings are available for real-time imaging by the EMCS rotor-mounted camera. Seed cassettes are large enough to support *A. thaliana* growth for up to eight days. White, blue and red LEDs supply light for plant growth and photo-stimuli, according to experimental protocols.

Each spaceflight study uses experiment containers that are prepared on Earth and transported to the space station aboard a SpaceX Dragon capsule.

Prior to the start of an experimental run, an astronaut mounts the loaded experiment containers onto one or both EMCS rotors. From this point the experiment runs without further crew intervention. The EMCS is controlled by a combination of ground commanding and automation software. Experiment runs begin with a command to hydrate that releases water into the specimen chambers to initiate growth. When each run is completed, an astronaut removes the

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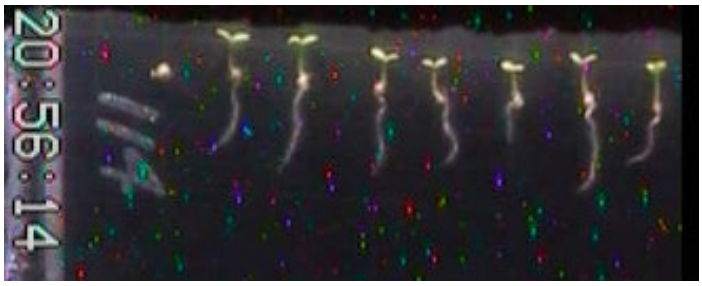
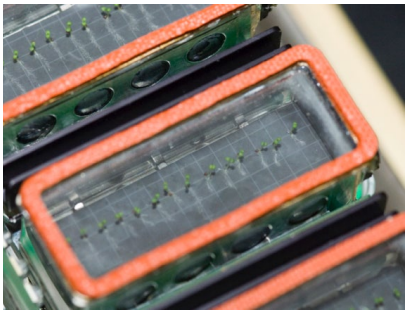
experiment containers from the EMCS. At this time, the biospecimens may be frozen or chemically preserved.



Images of four-day-old *Arabidopsis thaliana* plants were downlinked to Earth in near real time during the Seedling Growth-1 experiment.

Video and still image data are downlinked during the experiments. Frozen or preserved samples are returned to Earth aboard a SpaceX Dragon capsule for biochemical and genomic analysis.

Plant RNA Regulation Experiment
The Plant RNA Regulation experiment studies responses of the plant model organism *Arabidopsis thaliana* to the space environment, focusing on the role that molecules known as small regulatory RNAs play in these responses. The principal investigator is Imara Perera, Ph.D. of North Carolina State University. Dr. Perera's 2011 flight experiment, Plant Signaling, revealed novel regulatory mechanisms that provide a foundation for the Plant RNA Regulation experiment. The long-term goals of Dr. Perera's research are to understand the molecular mechanisms by which plants sense and adapt to changes in their environment and to characterize the regulatory networks that mediate these responses.



Arabidopsis thaliana seedlings are visible growing inside NASA seed cassettes during a ground test.

Seedling Growth Experiments
The Seedling Growth program involves three spaceflight studies of *A. thaliana* and is jointly supported by NASA and ESA. The principal investigators are Dr. John Z. Kiss, University of Mississippi, Oxford, Miss. (NASA) and Dr. F. Javier Medina, Centro de Investigaciones Biologicas at Universidad Complutense de Madrid, Spain (ESA). Major goals of the Seedling Growth experiments are to determine how gravity and light responses in plants interact, and to better understand the cellular signaling mechanisms. This research will help us understand light and gravity-sensing systems that are conserved throughout the plant kingdom.

NASA Astronaut Thomas Marshburn at the EMCS facility with one of the experiment containers that was used for the Seedling Growth-1 experiment.

Scientific results of these projects are broadly relevant; both for improving plant cultivation on Earth and also for employing plants in bio-regenerative life support systems aboard spacecraft during long duration space missions.

NASA's Space Biology Project at Ames manages the Seedling Growth and Plant RNA Regulation projects. Funding for Space Biology comes from the Space Life and Physical Sciences Research and Applications Division within the Human Exploration and Operations Mission Directorate at NASA Headquarters. Funding to support use of the EMCS facility for U.S. investigators is provided by the International Space Station Program at NASA's Johnson Space Center, Houston.

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