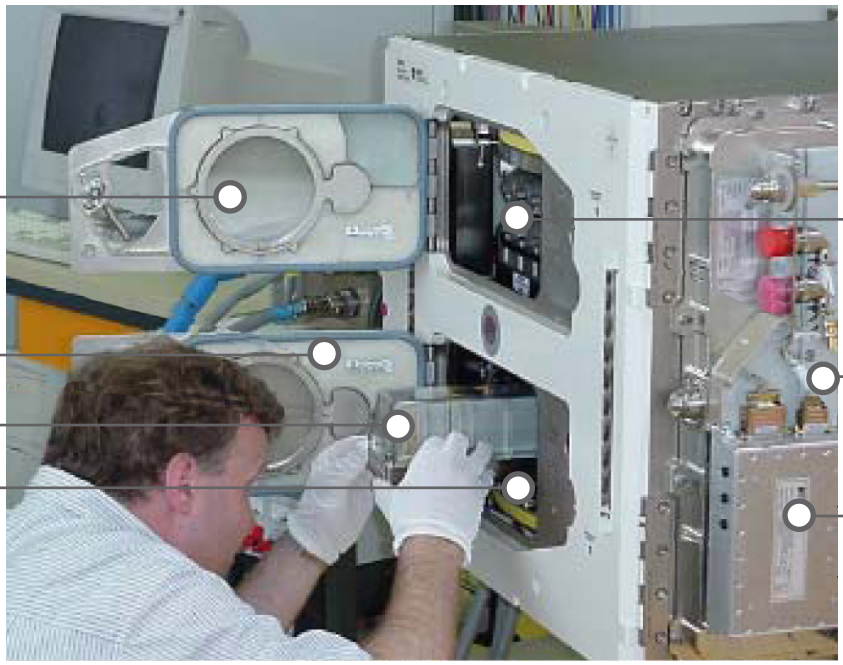
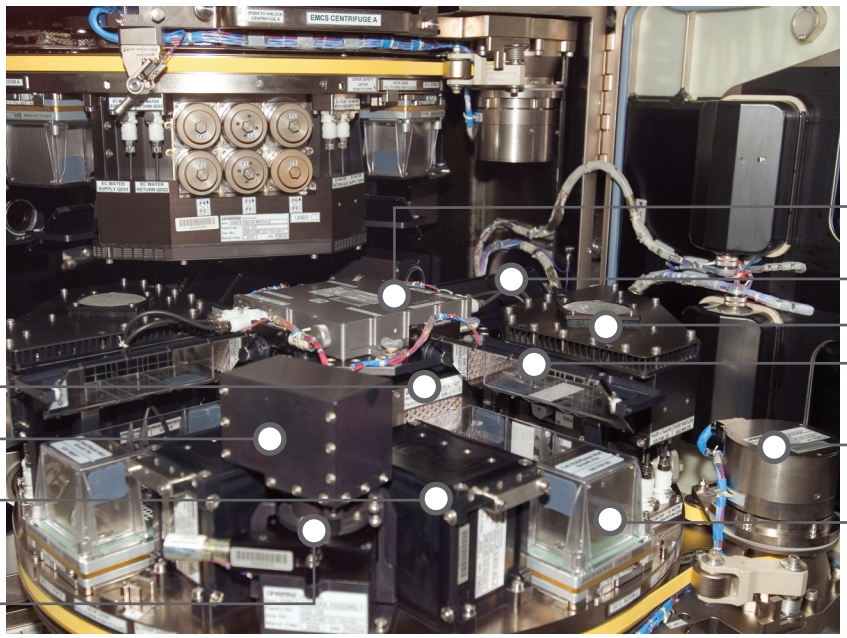
→ EUROPEAN MODULAR CULTIVATION SYSTEM (EMCS)

Experiment facility for plant biology research on the International Space Station

EMCS is an ESA experiment facility that is dedicated to studying plant biology in a reduced gravity environment. It supports the cultivation, stimulation, and crew-assisted operation of biological experiments under controlled conditions (e.g. temperature, atmospheric composition, water supply, illumination, observation, and gravity). The facility has performed multi-generation (seed-to-seed) experiments and studies the effects of gravity and light on early development and growth, signal perception and transduction in plant tropisms. Experiments with insects, amphibia, and invertebrates as well as studies with cell and tissue cultures are also foreseen in EMCS.





esa	PROJECT: International Space Station		
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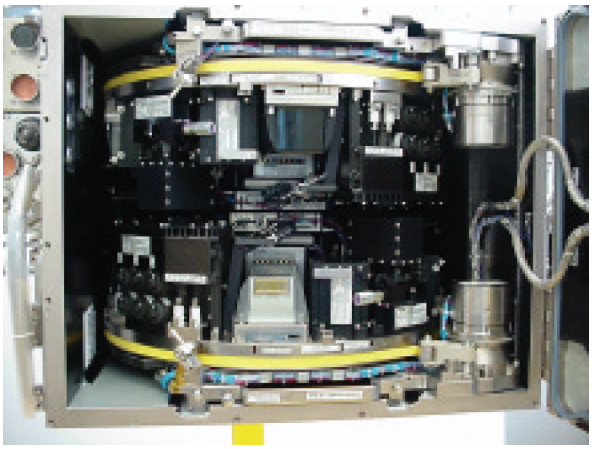
Facility Description

The EMCS facility contains an incubator with two slowly rotating rotors. Each rotor can accommodate up to four Experiment Containers (ECs), which house dedicated hardware that is unique to each experiment (Experiment Unique Equipment or EUE), based on its specific investigation. The rotors provide dedicated life support (including temperature, humidity, O2 and CO2) and water supply systems to the ECs, as well as illumination (white and infrared) and observation capabilities. In addition to the incubator, the EMCS facility has a Standard Payload Computer (SPLC), gas supply modules for atmospheric conditioning, a thermal control system, and a drawer containing control electronics and a video recorder.
The EMCS facility's data and command capabilities allow experiment control by the crew and from ground (telescience). The facility downlinks house-keeping, science, and image data.

Additional experiment services including glovebox, ambient stowage, refrigerator, and freezer access are available on the International Space Station.



View into the EMCS incubator with its two centrifuges.

SCIENTIFIC OBJECTIVES

The main research focus of the EMCS facility is plant biology. EMCS supports experimental investigation of:

- Long term growth stability in plants including multi-generation studies (seed-to-seed)
- Early development in plants
- Gravity influence on early development and growth (g-level threshold research)
- Influence of different wavelengths of light in plant phototropism
- Perception and signal transduction in plant tropism
- Possibility for research on small animals, tissues and cell cultures, also on radiation effects.

Plant biology experiments led by both ESA and NASA scientists have been successfully performed in EMCS, including Tropi, Gravi, Multigen-1, Tropi2, Genara-A, and Plant Signaling. EMCS provides a promising next step in the development of advanced facilities dedicated to biological research in space. It builds upon the experience gained by ESA in flying similar facilities over the last two decades.

INCUBATOR

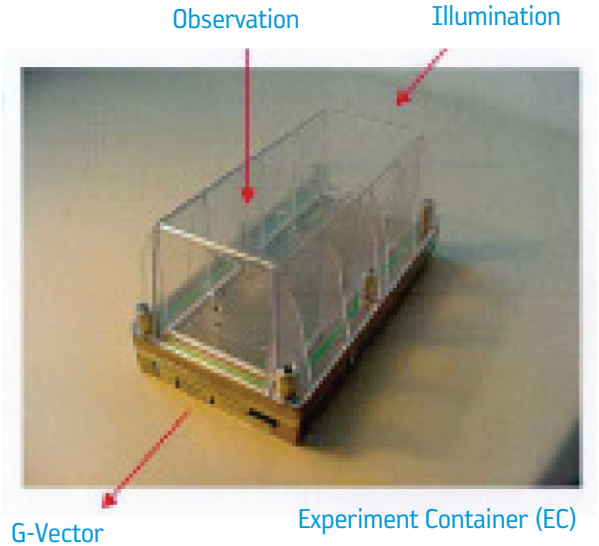
The incubator is housing all parts of EMCS and provides a gas tight, thermally controlled (+18°C to +40°C) enviroment to the Experiment Containers. The gas atmosphere is common to all 8 ECs and is composed of oxygen/nitrogen and carbon dioxide, stored in gas bottles, and of pure nitrogen, originating from the Space Station.

CENTRIFUGES

Two identical rotors (with a diameter of 600 mm) are fitted inside the EMCS Incubator. For both the rotational speed can be independently programmed to provide 0.001 g to 2.0 g, or microgravity level when not rotating. One typical experiment configuration is to have one rotor under microgravity conditions (no rotation) and the second one rotating at a speed of 59.5 rpm, which provides a resulting 1 g level and serves as an in-flight control for the microgravity experiment. However, g-levels on each rotor could be set to precisely meet the specific scientific requirements of the experiment, as an example to mimic the Martian gravity of 0.376 g, or any other level within the EMCS provided range (0.001 g to 2.0 g).

THE EMCS EXPERIMENT CONTAINER

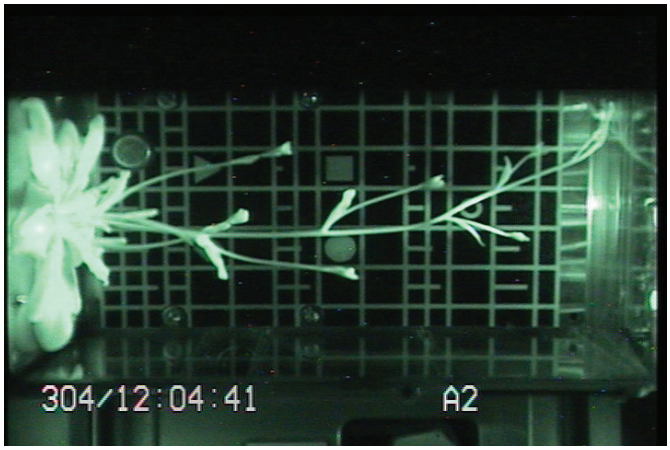
The EMCS EC is a standard container for all experiments integrated into EMCS. It provides an internal volume of 60 x 60 x 160 mm for the Experiment Unique Equipment (EUE) that serves the individual experiment. The EC provides a single level of containment and access to the EMCS gas and water services when mounted on the EMCS rotor. Particulates in the air and water loops are prevented from entering the EC air volume by membrane filters at the EC inlet. Each EC also has sensors for monitoring temperature, humidity and pressure. The EC is provided with power, data, and commanding capabilities via its interface with the EMCS rotor.



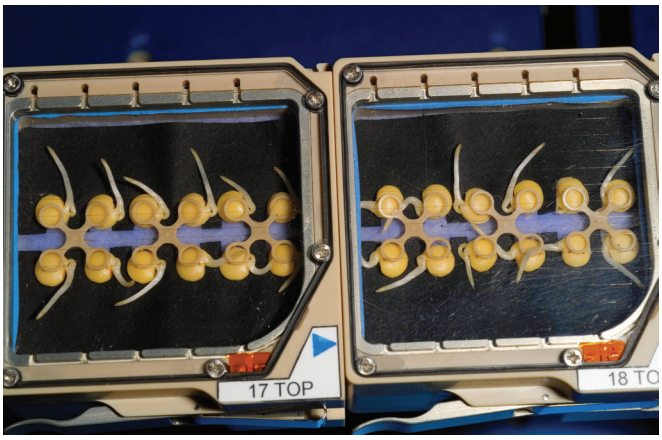
Specifications

- Experiment locations for up to 8 Experiment Containers (ECs) on 2 rotors inside the incubator
- Available experiment volume per EC: 160 x 60 x 60 mm³
- The EC provides one level of containment
- Air and water filters (0.2 µm pore size)
- Standard EC sensors: temperature, humidity, and pressure
- Single shot valves to close ECs hermetically (e.g. after fixation)
- Artificial gravity: 0.001 g to 2 g (independently controlled on both rotors)
- Incubator temperature: 18°C to 40°C
- Incubator atmosphere: O_2: 15% to 22%, CO_2: ≈0.2%* to 5.5 % (rest: N_2)
  * lower limit determined by concentration in Columbus module
- Incubator flushing with N_2 for atmosphere setup
- Ethylene removal from experiment
- Air flow through EC (controlled relative humidity: 30%, 50% to 90%, flow rate: 0.2 to 0.4 l/min)
- Water supply to and removal from EC: 0.4 to 0.8 ml/min
- Power supply to EC: +/-12V, 5V
- Data channels per EC: 2 analog out, 4 digital in/out, 1 serial (RS485), 1 NTSC video
- Illumination of experiment: white (2 intensities) or infrared LEDs
- Video observation of experiment through transparent cover: analog NTSC video or digital still images
- Housekeeping and science data sampling rate: 1 Hz
- Downlink of analog video and digital still images

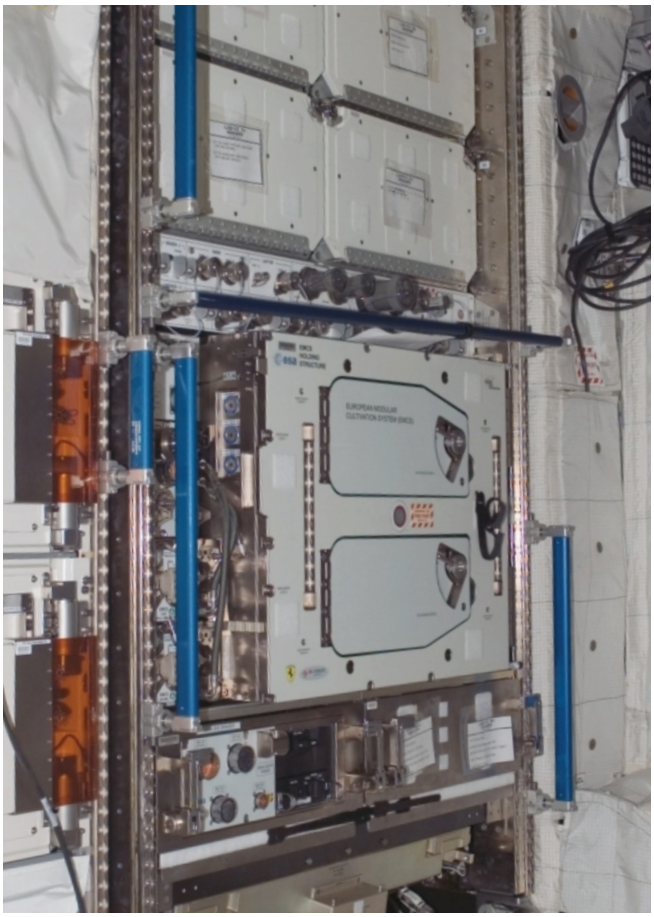
SAMPLE PICTURES FROM PERFORMED EXPERIMENTS



MULTIGEN-1 with Arabidopsis



GRAVI Cultivation Chambers (CC) with the space-grown lentil (*Lens Culinaris*) seedlings



EMCS in Express Rack-3 inside ESA Columbus Module (since April 2008)

EXPERIMENT PREPARATION

Standard Experiment Containers (ECs) are provided by ESA for each experiment, and prepared on ground prior to launch of the experiment. Preparation of the experiment and its integration into ECs is usually performed by the Payload Developer and the Principal Investigator (PI).

The Norwegian User Support and Operations Center (N-USOC) in Trondheim, Norway, is responsible for the operation of EMCS and supports the development and verification of the experiment and its specific operational products.

For an autonomous experiment run, a programming tool is available to define command and control sequences (so-called 'schedules'). N-USOC prepares those based on the experiment requirements. Typically these schedules may include event-triggered or time-based day/night cycles, imaging sessions or gravity threshold settings.

Once experiment verification testing is complete, the EC undergoes a set of tests on the EMCS Engineering Model before it is ready for flight: (1) a function and interface test, (2) a 'Schedule Test' to verify the EMCS commanding strategy, and (3) an 'Experiment Sequence Test', which is an end-to-end validation test that assures flight readiness of the experiment.

Flight preparation of the EMCS ECs with their experiments installed is performed by the EMCS Engineering team in cooperation with the experiment developer and the N-USOC. Since EMCS performs biological experiments, late access to the launch vehicle is typically requested for the hardware at the launch site.

OPERATIONAL CONCEPT

During execution of the experiment on the ISS, the EMCS facility is commanded by the N-USOC with the support of EMCS Engineering. The PI is able to monitor the experiment from the N-USOC (for ESA experiments) or the NASA Ames Research Center (for NASA experiments). Both N-USOC and Ames provide the PI with all requested science (e.g. images) and facility data (e.g. g-level, atmosphere and temperature data). All experiment operations including launch, on-board stowage, use of glovebox and cold stowage facilities, landing, and ground transport are handled by the EMCS Payload Integration Manager (PIM).

After landing, the experiment samples are transported to the PI's laboratory for evaluation.

GROUND MODELS FOR EXPERIMENT PREPARATION

Two models support experiment verification and ground control experiments for studies in EMCS: the Experiment Reference Model (ERM) and EMCS Engineering Model (EM).

Two Experiment Reference Models (ERMs) are available to scientists for experiment development and ground control experiments; one facility is available at N-USOC in Trondheim, Norway, and a second facility residing at NASA Ames Research Center at Moffett Field, California (USA). The objectives of the ERM are:

- Experiment definition studies
- Testing and verification of EMCS experiment protocols with biological samples
- Validation of experiment specific software running on an EUE internal microcontroller
- 1-g ground reference experiments parallel to flight experiments

To achieve these objectives, the ERM is equipped with flight identical features (temperature, humidity, gas composition, pressure, water supply, illumination, observation, power and data handling). However, the system configuration is different due to the direction of the g-vector on ground. The ECs are not mounted on rotors, but instead they stand vertically on a static shelf in-line with the Earth's g-vector.

The EMCS EM is situated at N-USOC in Trondheim, Norway, and offers the same functionality as the EMCS FM. It contains two rotors, and all the functionality of the FM in terms of temperature, humidity, gas composition, pressure, water supply, illumination, observation, power and data handling. The only difference from the flight model is the presence of Earth's gravity. For this reason, the EM is not used for science tests on ground, but for interface, schedule, and experiment sequence tests.

In addition, several Experiment Container Development Kits (ECDKs) exist to support the PIs in experiment development and validation of their experiment's interface to the EMCS Experiment Container.

MAIN CONTRACTOR

EMCS was developed under ESA contract by EADS-ST Friedrichshafen, Germany.

SCHEDULE

EMCS was launched from Kennedy Space Center on board of Utilisation Flight ULF 1.1, with ESA astronaut Thomas Reiter on 4 July 2006. EMCS was operated during a two-year period on board the US Destiny Laboratory after it was transferred within Express Rack 3 to ESA's Columbus Laboratory. EMCS will be regularly maintained to provide full service to experiments.

NASA Astronaut Clay Anderson, Expedition 15 flight engineer, works with the European Modular Cultivation System (EMCS) in the Destiny laboratory of the International Space Station.

Illustrations: ESA/D. Ducros