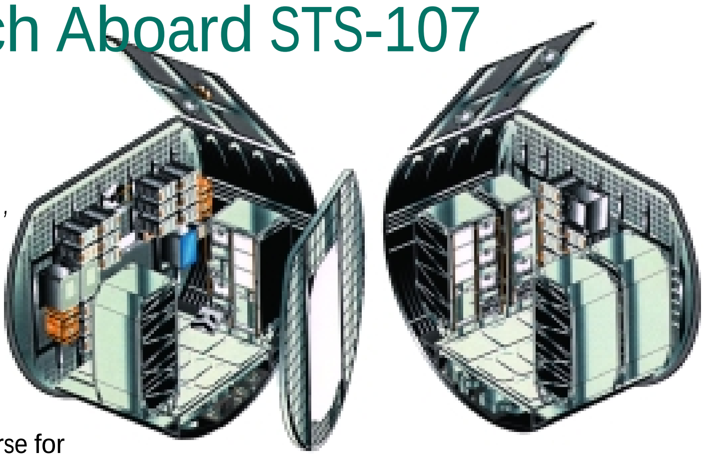
Bridging the Gap

ESA's Microgravity Research Aboard STS-107



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Introduction

For 15 years, Spacelab was the workhorse for western research in the life and physical sciences under microgravity conditions (10^{-5}-10^{-6} *g*), stretching from the first mission in 1983 to its last, Neurolab, in 1998. The international microgravity user community recognised early on that the International Space Station (ISS) would not be fully operational for its needs before 2005. It thus urged NASA to bridge the long gap in research opportunities by flying microgravity payloads on Shuttle missions.

Shuttle mission STS-107 will be a major flight for ESA's microgravity research programme...

The first, STS-95 in late 1998, included an ESA microgravity package with the Advanced Gradient Heating Facility (AGHF), Advanced Protein Crystallisation Facility (APCF), Biobox, Facility for Adsorption and Surface Tension (FAST) studies and Morphological Transitions in a Model Substance (MOMO) facility. STS-95 is perhaps better known as the John Glenn and Pedro Duque flight! After this mission, NASA agreed to include a series of research missions in the Shuttle manifest. These will use Shuttle *Columbia*, which is too heavy for ISS assembly or supply flights, but it has an extended duration operations kit for missions of typically 16 days. The commercial Spacehab pressurised module carries the research equipment.

STS-107

Launch: October 2001 (depends on higher-priority ISS and Hubble Space Telescope missions)
ESA payload: APCF, ARMS, Biobox, Biopack, ERISTO, FAST, COM2PLEX
Payload mass: 3630 kg (3300 kg in Spacehab & 330 kg in middeck), including 580 kg from ESA
Mission duration: 16 days (+2 days margin)
Orbit: altitude 280 km, inclination 39º
Crew: 7, working in two shifts

The STS-107 Mission

The Spacehab Research Double Module (RDM) will make its maiden flight on STS-107. NASA's rental agreement makes owner Spacehab Inc. and subcontractor Boeing fully responsible for payload integration in the RDM and in the Shuttle middeck, and for its operation during flight, controlled from NASA's Johnson Space Center (JSC) in Houston, Texas.

Payload integration, verification and test is underway in the Spacehab Payload Processing Facility (SPPF) in Port Canaveral, Florida, next to the Kennedy Space Center (KSC) launch site.

The ESA Payload

Spacehab missions are organised commercially, which means that access has to be contracted with Spacehab, Inc., normally on a US$/kg price basis. For STS-107, this applies to 230 kg of ESA's payload. But there are other ways to get aboard:

- 300 kg come from the barter arrangement with NASA in return for providing a Guppy transport aircraft;
- 50 kg are an ESA ergometer counted as NASA return for including a US experiment in Biopack.

ESA's payload encompasses seven separate facilities. Apart from the COM2PLEX technology facility of the Technology Flight Opportunities (TFO) Programme, they are all funded by the European Microgravity Research Programme (EMIR). In total, 37 ESA life and physical sciences experiments will be accommodated on STS-107.

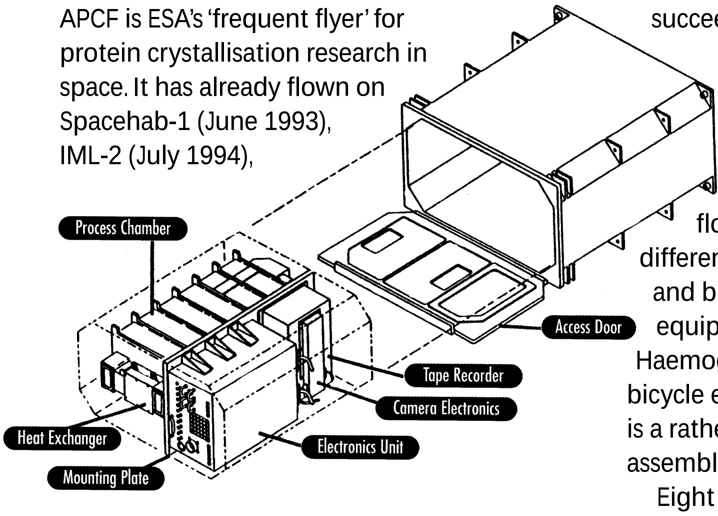
The experiment 'Choroidal regulations involved in the cerebral fluid response to altered gravity: water transports and serotoninergic receptors' requires rats to be housed in NASA's Animal Enclosure Module (AEM). As this is similar to a NASA experiment, ESA's researcher will receive her rat tissues from NASA within a day of landing.

Advanced Protein Crystallisation Facility

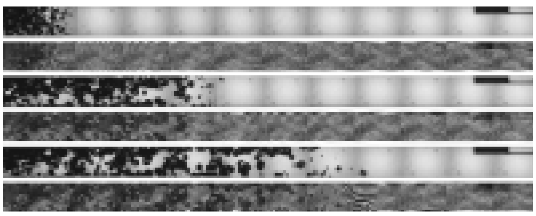
APCF is ESA's 'frequent flyer' for protein crystallisation research in space. It has already flown on Spacehab-1 (June 1993), IML-2 (July 1994), USML-2 (October 1995), LMS (June 1996) and STS-95/Spacehab (October 1998). ESA has two identical flight models that can each carry up to 48 individual and different experiment growth reactors, of which up to 12 can be observed by a video and a Mach Zender Interferometer subsystem. Protein growth temperatures can be selected between 4°C and 30°C (20°C for STS-107). APCF requires an astronaut to turn it on and off but it otherwise automatically follows a preprogrammed processing profile that includes the recording of up to 5000 video/interferometer stills.

APCF is designed for Shuttle Middeck Lockers (MDLs), which means it can fly on the actual middeck, Spacelab, Spacehab, ISS Express and ISS European Drawer Racks. MDLs allow late access before launch and soon after landing – a prerequisite for sensitive proteins, since some degrade rapidly after insertion into their growth reactors. On STS-107, eight experiments occupy 38 growth reactors.

The second APCF flight model will probably fly even earlier than STS-107: it is being prepared as ESA's first microgravity payload aboard the Space Station. It will be launched with ISS assembly flight 7.A1 in mid-2001 to be installed in an Express Rack in the US Destiny Lab, and returned on UF-1 in November 2001.



APCF design and accommodation in an MDL.

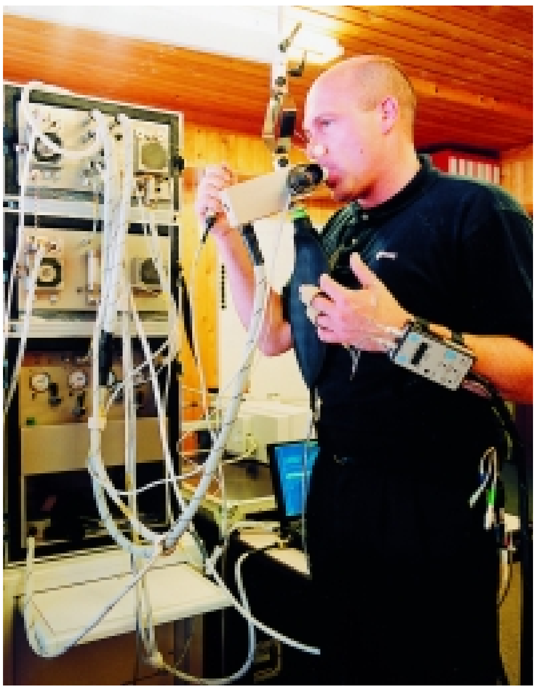


Protein crystals grown in APCF during STS-95. Interferometry shows the evolution of salt and protein concentration in the reactor chamber. (J.M. Garcia Ruiz et al.)

Advanced Respiratory Monitoring System

ARMS is a new development, mainly for pulmonary and cardiovascular research, succeeding instruments flown as part of Euromir and Anthrorack aboard Spacelab-D2. ARMS' core instruments are two Photo- and Magnetoacoustic Gas Analysers complemented by instrumentation such as valves, flowmeters, gas supplies with four different gas mixtures, blood pressure, ECG and breathing frequency measurement equipment, Infrared Pulse Oxymeter, Haemoglobin Photometer Spirovis and a bicycle ergometer to stress the subjects. ARMS is a rather complex set-up that astronauts assemble in orbit from many stowed items.

Eight groups of investigators will use ARMS during STS-107, although one will make measurements on the whole crew only before launch and after landing. The research fields cover heart control and regulation, pulmonary physiology (including both lung mechanics and gas exchanges) and orthostatic intolerance. The experiments will be performed at the mission's beginning, mid-point and end



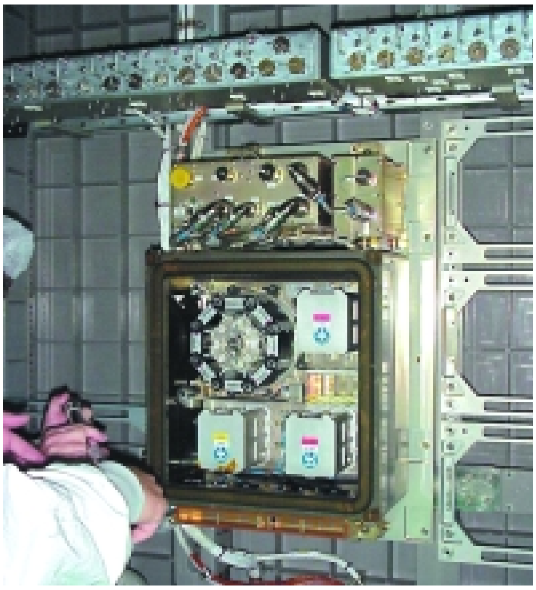
ESA astronaut Andre Kuipers tries the ARMS Training Model.

to study both the early adaptation and the achieved steady-state. This requires a total crew time of about 78 hours.

In addition, an important part of the research is done on the ground: pre-flight to establish the individual reference baseline of each of the four ARMS astronauts, and post-flight to study the return to 1 *g*. Both fast- and slow-recovery systems will be studied after return (landing +2 hours) until a month and a half later.

Training is an important part of the mission preparation. The crew has to learn to set-up, stow and use the equipment, and to perform the different breathing 'manoeuvres', such as controlling inspiration or expiration flow at 0.5 litre/s.

Biopack: the top compartment carries the refrigerator/freezer; the incubator and centrifuges are in the bottom.



Biobox, with the lid removed, is installed in Spacehab.

Biobox

The multi-user Biobox was originally designed to fly on Russia's Foton and Bion retrievable capsules. After three flights in 1993, 1995 and 1997, it was adapted for Spacehab and made its first flight on STS-95.

Biobox is essentially an incubator (6-38°C) that can accommodate 24 experiments in static (microgravity) positions and six in a 1 *g* reference centrifuge. Biobox works 'hands-off' – it runs automatically from installation in Spacehab until landing. The temperature and centrifuge speed can be adjusted by ground control by telecommand.

During STS-107, four experiments will use bone cell cultures (osteoblasts, haemopoietic cells and osteoclasts) from humans and mice. A second Biobox will operate on the ground as a 1 *g* reference.

Biopack

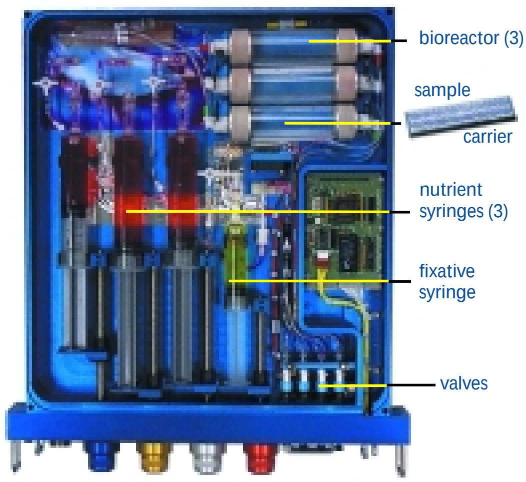
Biopack is now finishing development for its debut on STS-107. It is designed to fit in any double-MDL position in the Shuttle, Spacehab, ISS Express Rack or ISS European Drawer Rack. Biopack is an incubator (22-37°C) with static (microgravity) and dynamic (three centrifuges controllable 0-2 *g*) accommodation positions for standard experiment containers of Type 1/E (65 ml internal volume) and Type 2/E (385 ml). For storing experiment containers, Biopack includes a refrigerator/freezer (4°C or -15°C) and a freezer (-15°C).

Apart from astronauts handling experiment containers, Biopack can be run fully automatically with telescience control from the ground. However, all functions can also be monitored and controlled from its Control and Monitoring Panel by the astronauts. On STS-107, Biopack will be used for eight experiments in 78 containers on mammalian cell and tissue cultures, and bacteria.

As for other biology facilities, the Biopack engineering model will run on the ground during the mission as a 1 *g* reference.

European Research in Space and Terrestrial Osteoporosis (ERISTO)

ERISTO, one of more than 40 ESA Microgravity Application Projects (MAP), makes use of the OSTEO facility developed and already flown by the Canadian Space Agency on STS-95.



An ERISTO payload tray.

ERISTO's long-term goals are a better understanding of the role played by mechanical stress in osteoporosis and to help develop countermeasures against bone-loss on long space missions. It is hoped that the results can be adapted to fight osteoporosis on Earth.

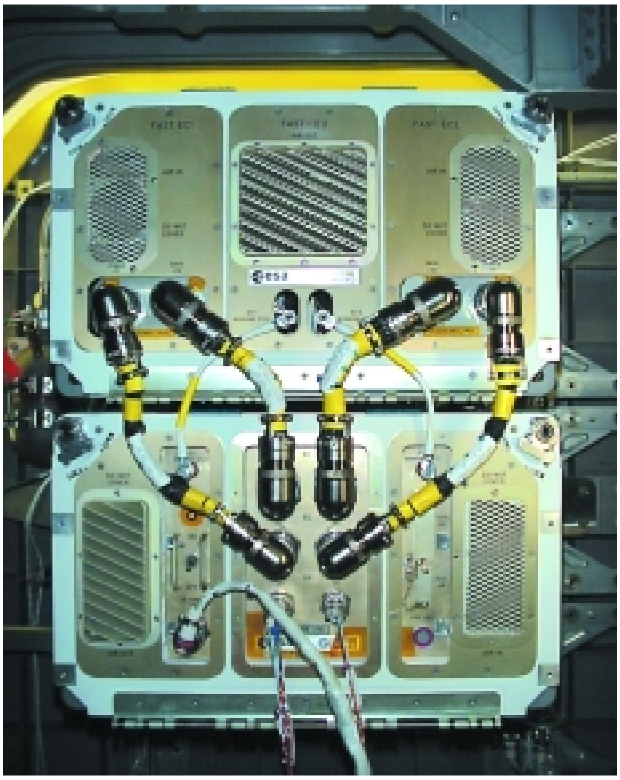
Two ERISTO experiments will study the responses of osteoblasts (bone-forming cells) and osteoclasts (bone-resorbing cells or cells that break down bone) to various drugs and growth factors under microgravity conditions (i.e. under reduced mechanical stress).

ERISTO consists of an incubator housing four identical trays with three experiment specimens each. The Spacehab locker will be installed only 40 hours before launch. In orbit, the crew will follow a precise procedure in operating valves, syringes with nutrients and syringes with fixatives. The same will be done with the 1 *g* reference ERISTO unit on the ground.

Facility for Adsorption and Surface Tension

Following its debut on STS-95, FAST will run a series of experiments to measure the response of surface tension to carefully controlled dynamic changes in surface area, free from the perturbing effects of buoyancy and convection that limit ground-based investigations. While executing its three experiment programmes semi-autonomously, FAST will send science and housekeeping data to the ground by video and telemetry. Telescience will allow the investigators to modify experiment parameters and experiment sequencing by telecommands, if required, after a preliminary analysis of the science results.

FAST is carried in two adjacent lockers on Spacehab's aft bulkhead: one for the Facility Controller and the other for the two Experiment Units. The Principal Investigators are involved in ESA's MAP on Fundamental and Applied Studies of Emulsion Stability that foresees FAST flying aboard Columbus.



FAST installed in Spacehab for Interface Verification and Testing.

COM2PLEX

The COMbined European 2Phase Loop EXperiment has integrated three different loop heatpipes into one technology experiment, mounted outside on Spacehab's flat roof. Loop heatpipes – highly efficient heat transport systems using an evaporation/condensation cycle inside a closed loop (similar to classical heatpipes) – have been developed in the last few years and are key technology elements for deployable radiators, thermal control of laser-based instruments, and heat transfer from remote equipment to radiators. Two-phase phenomena (evaporation, condensation, two-phase flow) behave differently in 1 *g* and low-*g*, so testing and in-orbit qualification are mandatory to mature this new technology.

Outlook

The only major uncertainty with STS-107 is its launch date, which could be between September 2001 and April 2002. This is because NASA awards higher priorities to Shuttle flights for the Space Station and Hubble Space Telescope than to microgravity research missions.

Another microgravity research mission is already being planned: STS-118 is assigned in the manifest. As our two agencies plan to refly part of STS-107's payload, a minimum gap of 15-18 months is required for refurbishing the experiment facilities. This means that STS-118/Spacehab is not expected to fly before spring 2003.

An unmanned microgravity mission is also in preparation: the 14-16 day Foton-M1 flight in late 2002. Negotiations with Rosaviakosmos are almost completed.