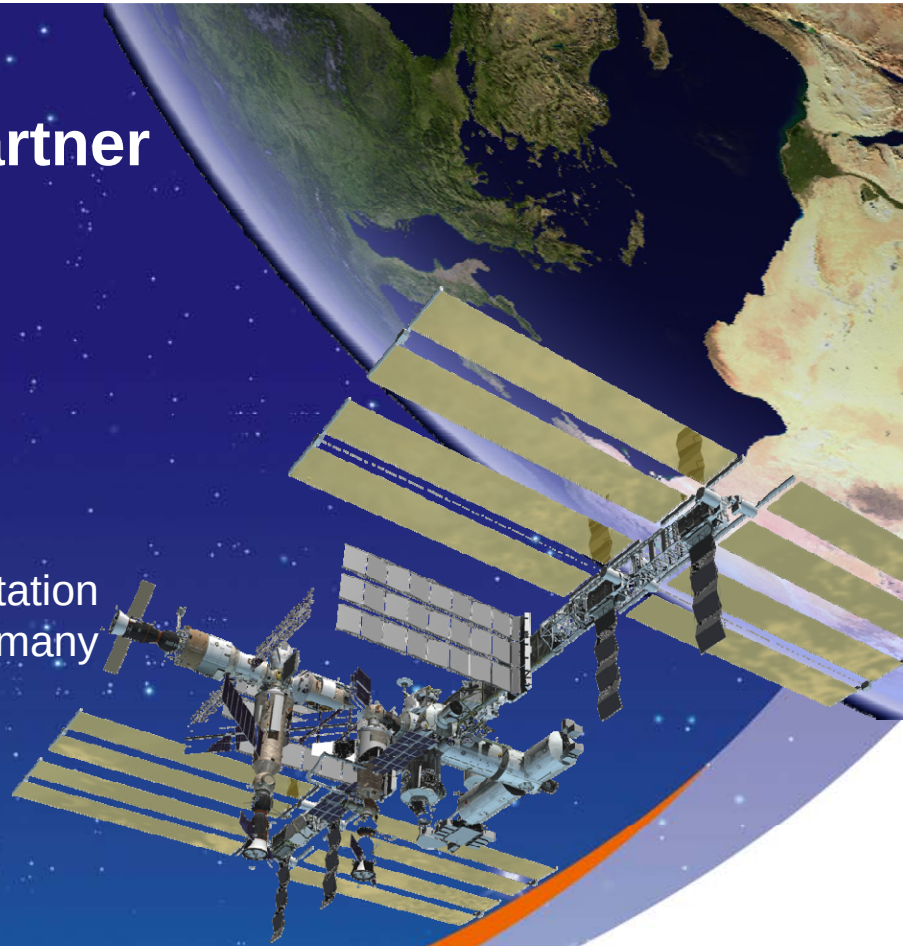
Implementation Partner

Astrium

Ulrich Kuebler
ISS Utilization Office
ASTRIUM Space Transportation
88039 Friedrichshafen/Germany



NASA ISS Research Academy and

Pre-application Meeting

August 3-5, 2010

League City, Texas

All the space you need

EADS astrium

Astrium a 100% subsidary of EADS

EADS

Commercial Aircraft		No.1
Helicopters		No.1
Missile Systems		No.2
Astrium		No.3
Military Transport Aircraft		No.3
Military Air Systems		No.4

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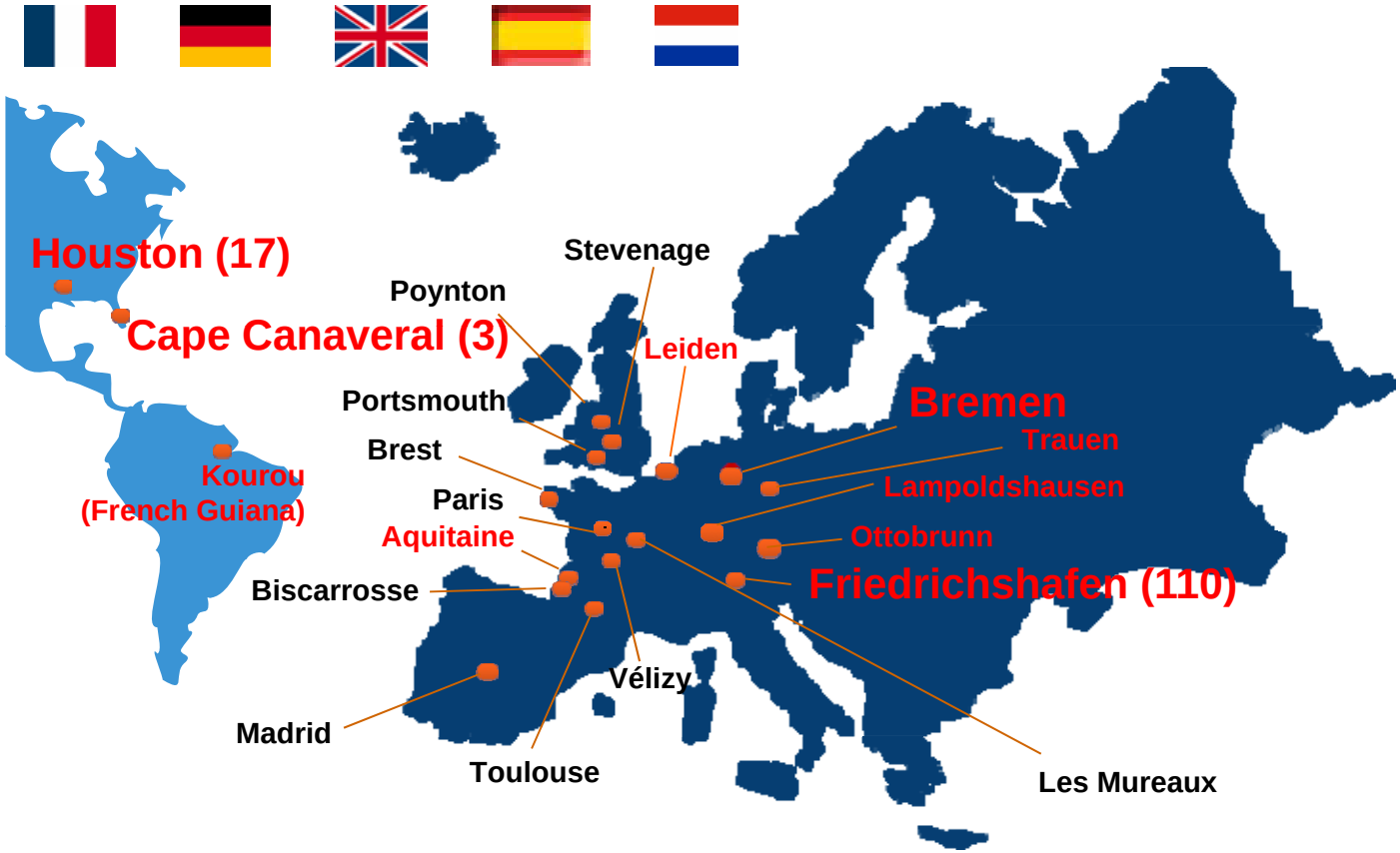
Astrium is the combined heritage and expertise of the leading European space nations



Astrium Space Transportation in red

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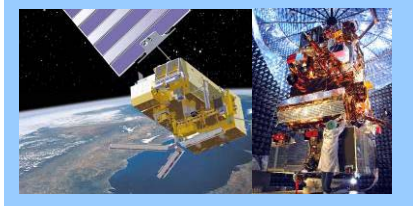
Astrium's activities are based in 3 key areas

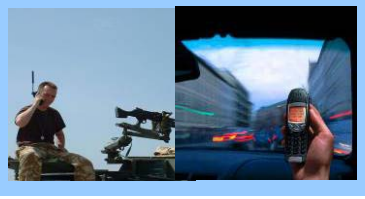
Astrium Satellites

A world leader in the design and manufacture of satellite systems



Astrium Services

At the forefront of satellite services in the secure communications, Earth observation and navigation fields



Astrium Space Transportation

The European prime contractor for civil and military space transportation and manned space activities

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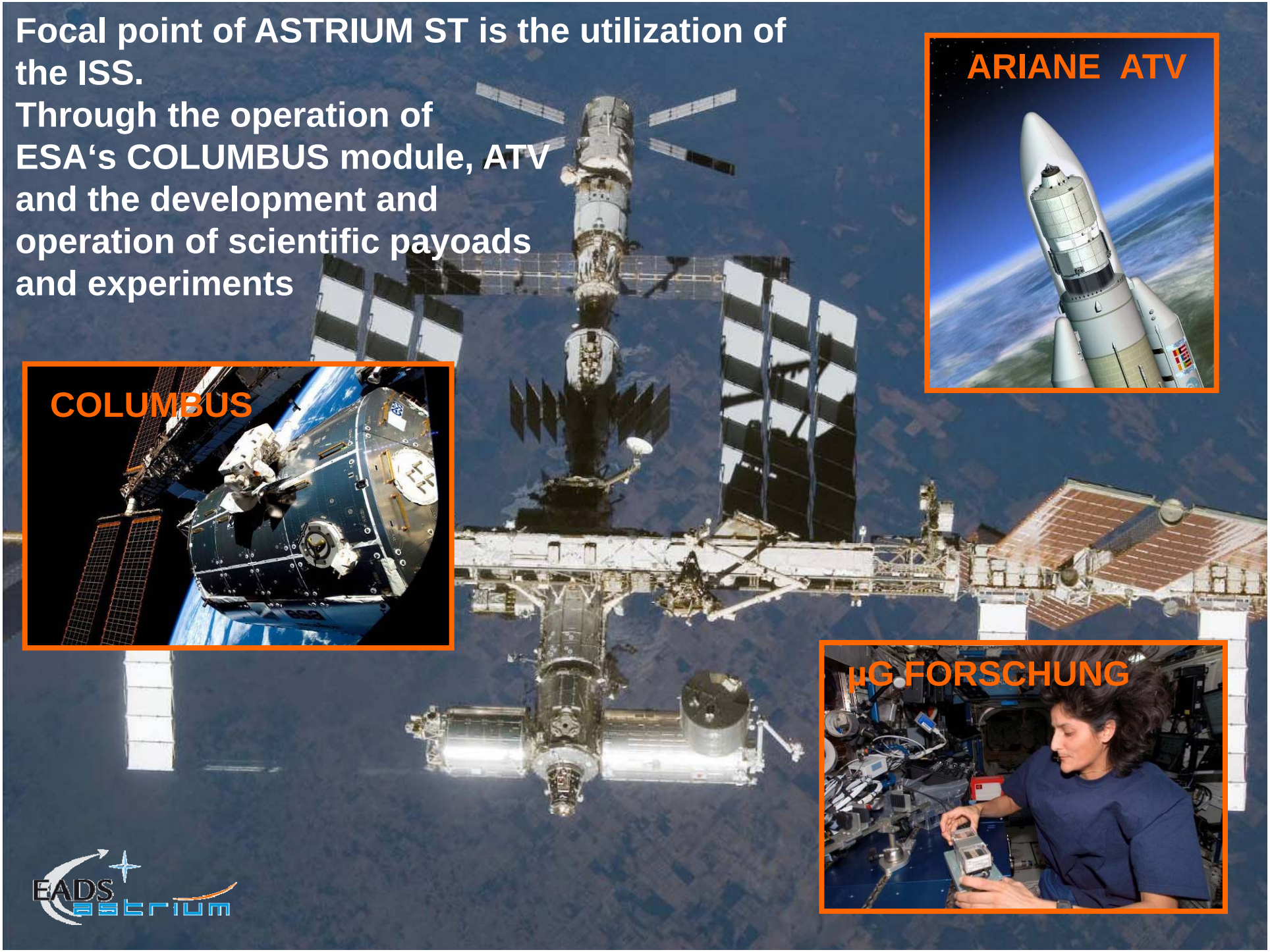
Focal point of ASTRIUM ST is the utilization of the ISS.
Through the operation of ESA's COLUMBUS module, ATV and the development and operation of scientific payoads and experiments



EADS astrium

ASTRIUM Payloads & Life Support

Astrium is expert for the development and operation of **Life Support Systems** as well as **Scientific Facilities**, and **Experiments** for**:**

Life Sciences

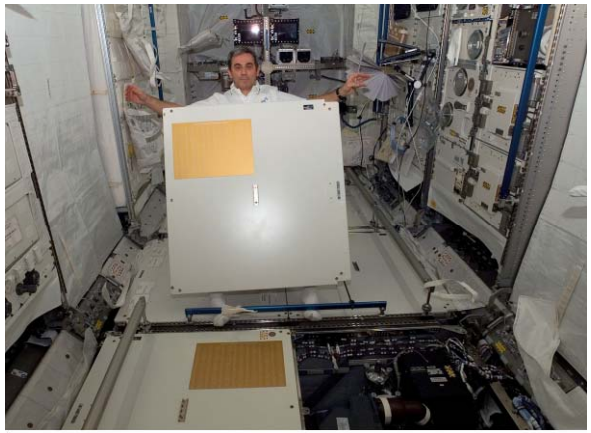
- biology
- human physiology
- Biotechnology
- protein crystallization

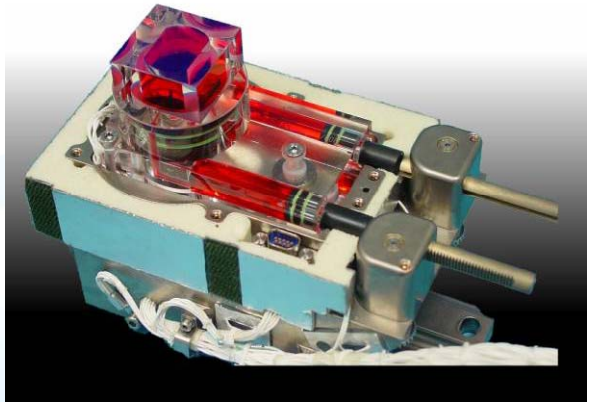
Physical Sciences

- materials science
- fluid physics
- fundamental physics

Lab Support Equipment

- Freezer/Cooler
- Microgravity Sciences Glovebox





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Activities in Payload Projects

Studies & Breadboarding

to get first hand experience of science and feasibility

Facility Development & Construction

to meet the scientific and space requirements for demanding research

Experiment samples & containments

fitting perfectly with the related facility

Crew Training

theoretical and hands-on training for astronauts

Operations

Refurbishment, Spares, Sust. Engin.

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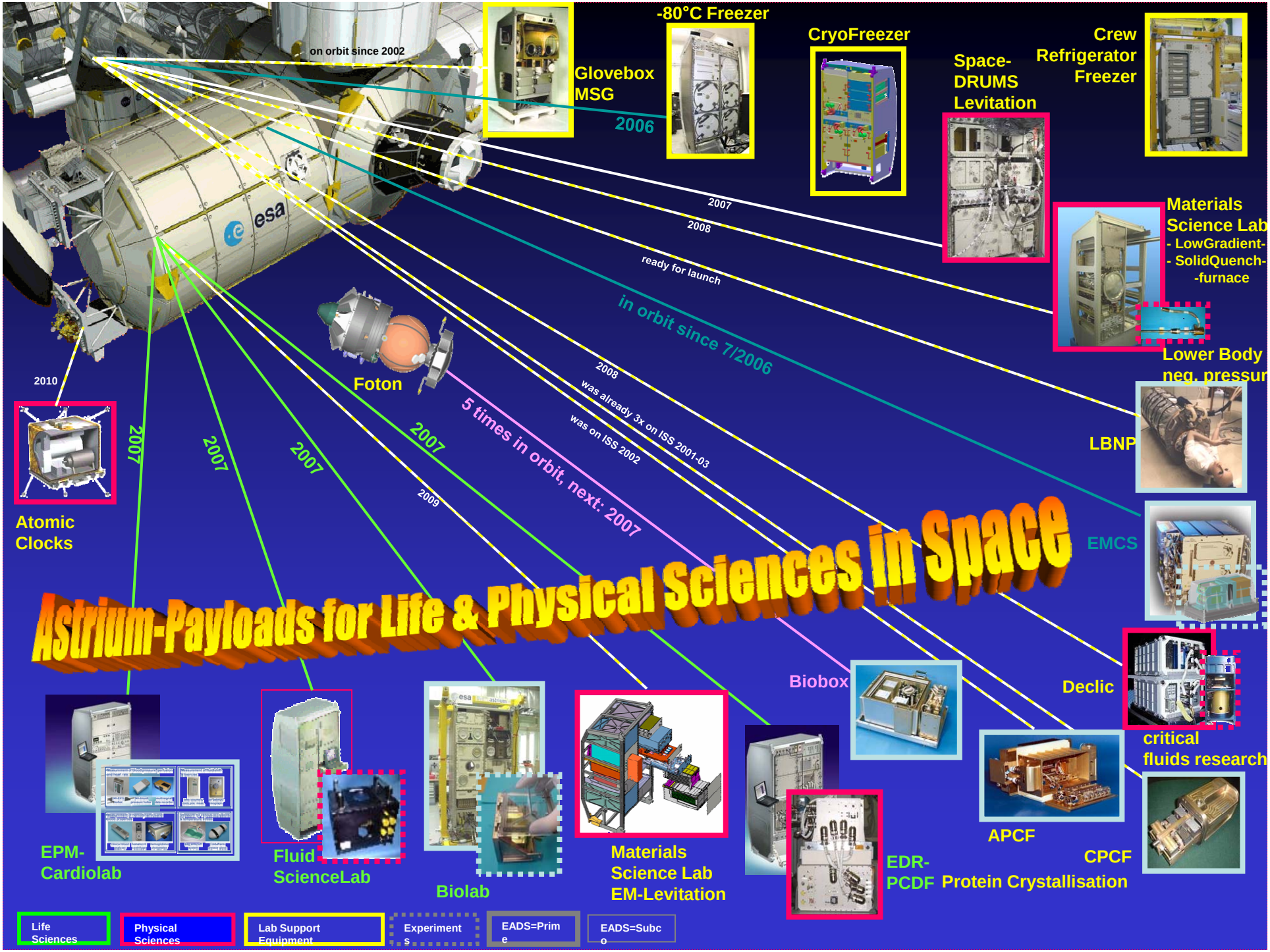

Astrium-Payloads for Life & Physical Sciences in Space
on orbit since 2002
Glovebox MSG
2006
-80°C Freezer
CryoFreezer
Space-DRUMS Levitation
Crew Refrigerator Freezer
2007
2008
ready for launch
Materials Science Lab
- LowGradient-
- SolidQuench-
-furnace
in orbit since 7/2006
Lower Body neg. pressur
Foton
2010
Atomic Clocks
2007
2007
2007
2007
5 times in orbit, next: 2007
2008
was already 3x on ISS 2001-03
was on ISS 2002
2009
LBNP
EMCS
Biobox
Declic
critical fluids research
APCF
CPCF
Protein Crystallisation
EDR-PCDF
Materials Science Lab EM-Levitation
Biolab
Fluid ScienceLab
EPM-Cardiolab
Life Sciences
Physical Sciences
Lab Support Equipment
Experiments
EADS=Prime
EADS=Subco

Multipurpose Facilities

MELFI Freezer

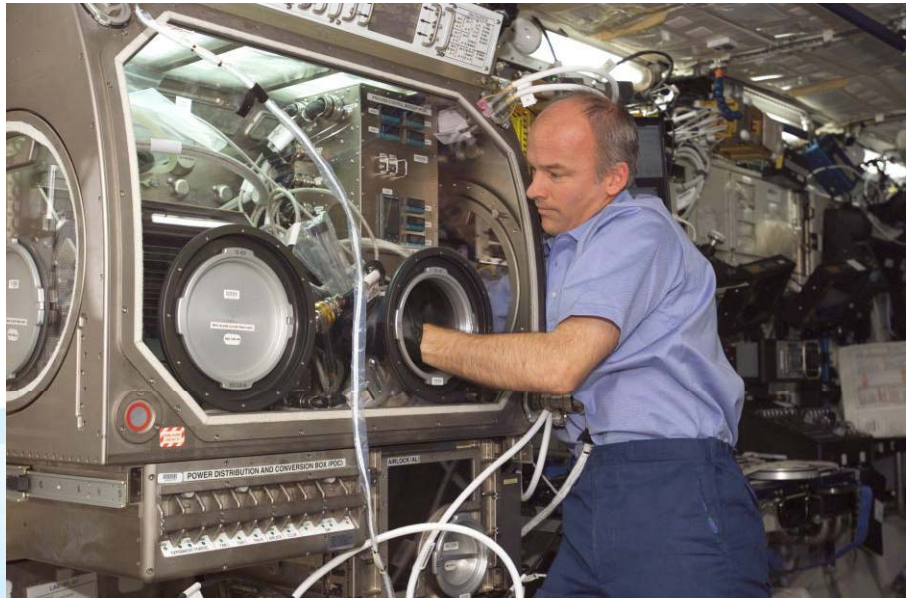
- **Objectives & features:**
  - Storage and preservation of life science and biological samples
  - Refrigerated volume of 300 liters in 4 identical enclosures (Dewars)
  - Cold temperatures individually controlled for each dewar:
    - -80°C, -26°C, +4°C
  - Provides a variety of receiving boxes and (vial) cards for sample accommodation

3x

MSG Glovebox

- **Objectives & features:**
  - allows for handling of critical substances in human space flight environment for experiments in the fields of

    - material science
    - fluid physics
    - biology
  - tele-science capabilities



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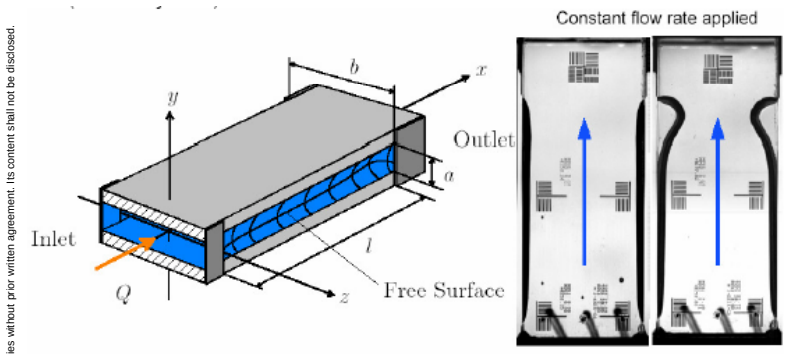
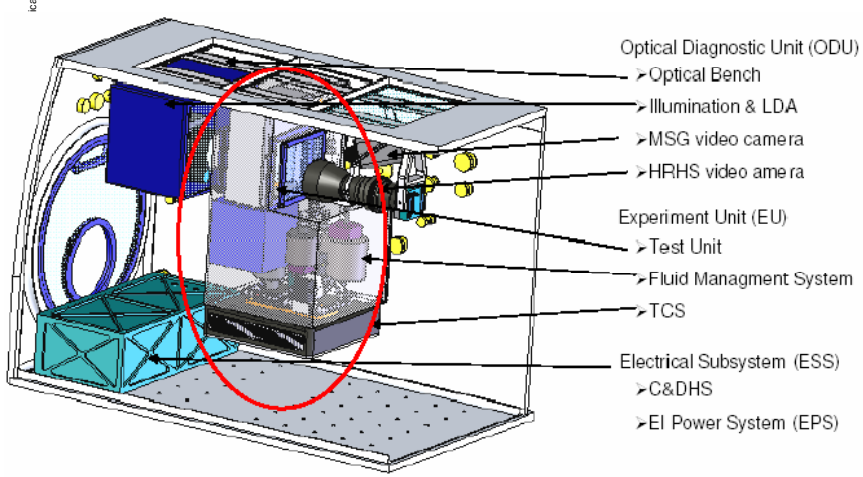
MSG inserts CCF and FASES

- **Science Objectives:**
  - Investigation of flow rate limitations in open capillary channels under low gravity conditions
  - phase separation capabilities of the wedge geometry channels



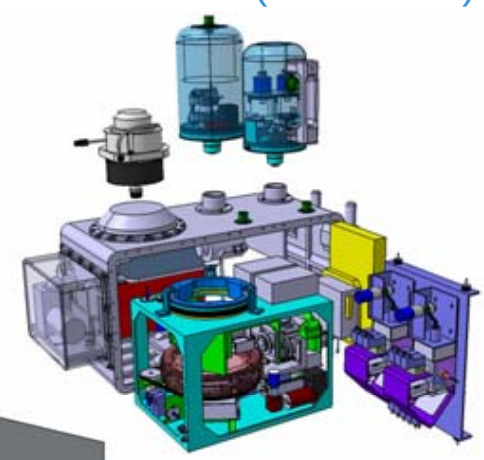
Example of a capillary channel
Liquid withdrawn at the outlet, liquid provided at the inlet

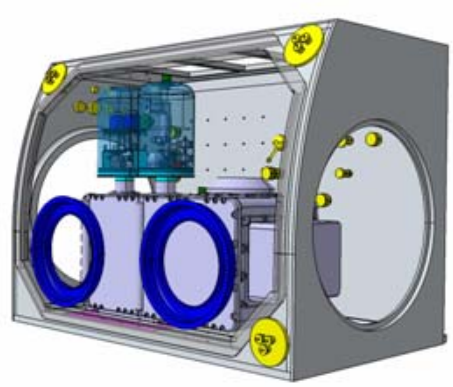


- **Science Objectives:**

Research facility for investigating physics and chemistry of aqueous and non aqueous foams:

  - Rheology: underlying bubble microstructure and dynamics of material
  - Drainage and stability: hydrodynamics of foam at high volume fraction (wet foams)





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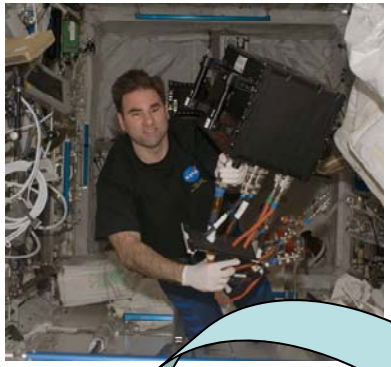
Fluid Science Lab (FSL)

The Fluid Science Laboratory (TAS-I) is a **multi-user facility** to study the dynamics of fluids in the absence of gravitational forces.

The fluid cell assembly (including the process stimuli and control electronics) is accommodated within an individually-developed Experiment Container.

EC Mass ~25-40 kg
Standard dimensions
400 x 270 x 280 mm.



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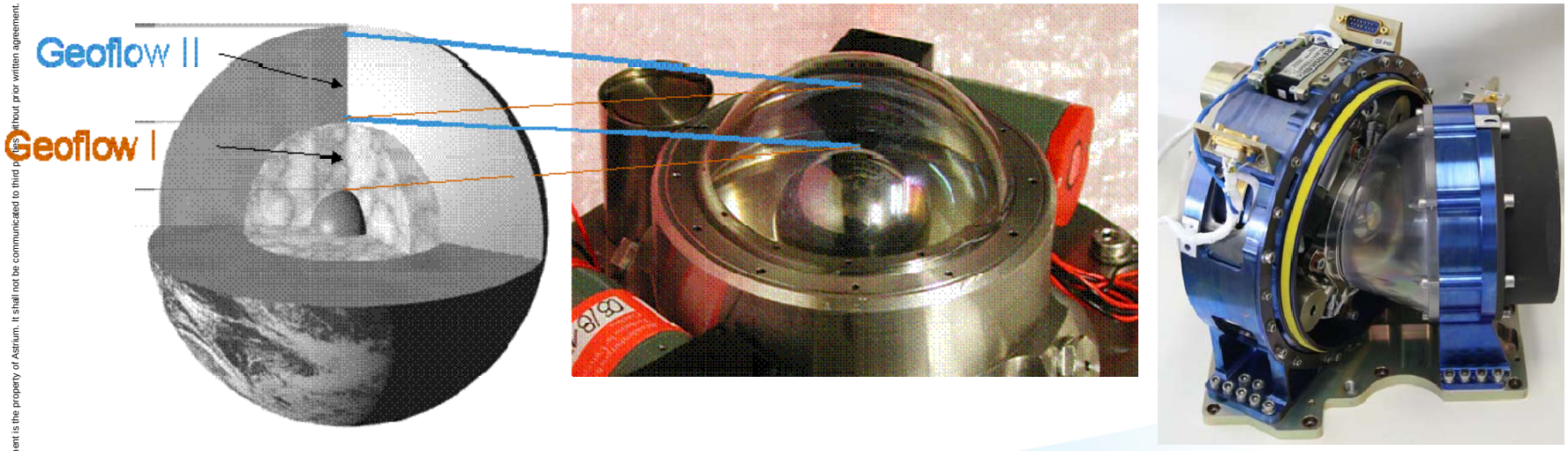
Scientific objectives of GeoFlow I & II

- Model for simulating geophysical motions in the Earth's liquid core
  - Thermal convection in a fluid, filling the gap between two concentric rotating spheres, kept at different temperature (gradient from 1 to 10 K over the gap)
  - Symmetric force field simulating gravity by high voltage (dielectrophoresis)
  - Experiment parameters: temperature, rotation, central force field, viscosity
  - Diagnostics: Optical measurement of temperature field (interferometry)



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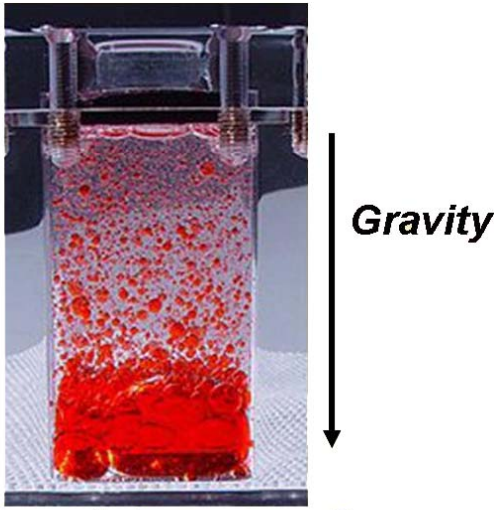
FSL Experiment FASES

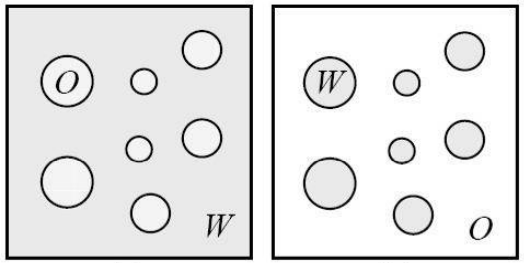


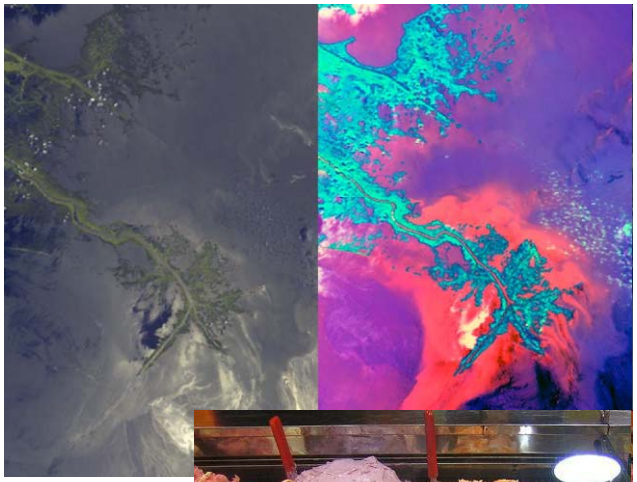
Oil emulsion on earth

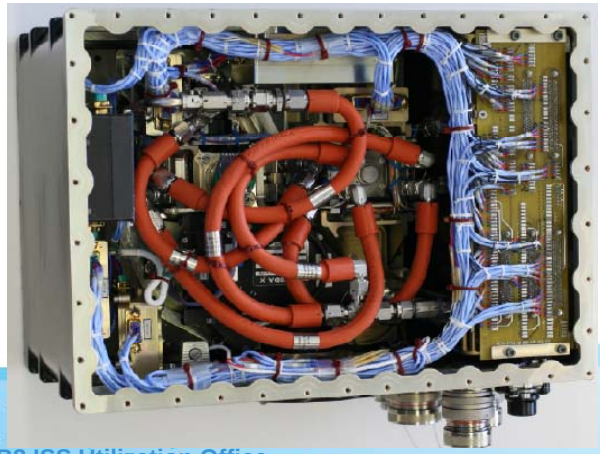
Specific objectives:

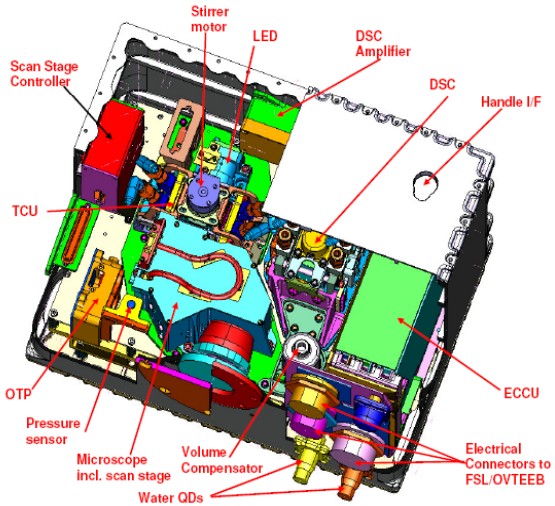
- Drop/drop interactions
- Mechanisms of emulsion dynamics
- Nano-particles effect on stability
- Models describing the evolution of the droplet size distribution

44 Experiment probes filled with ca.1cm^3 of liquid emulsions









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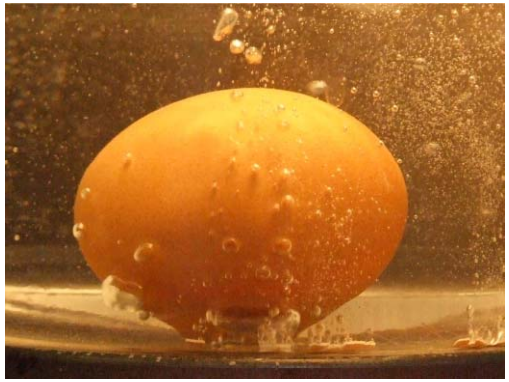
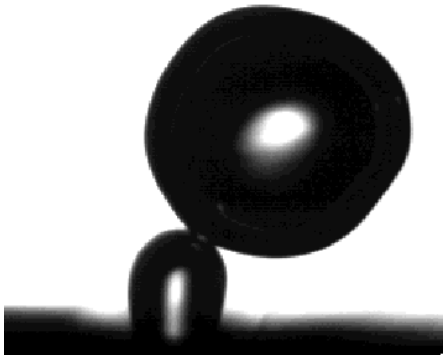
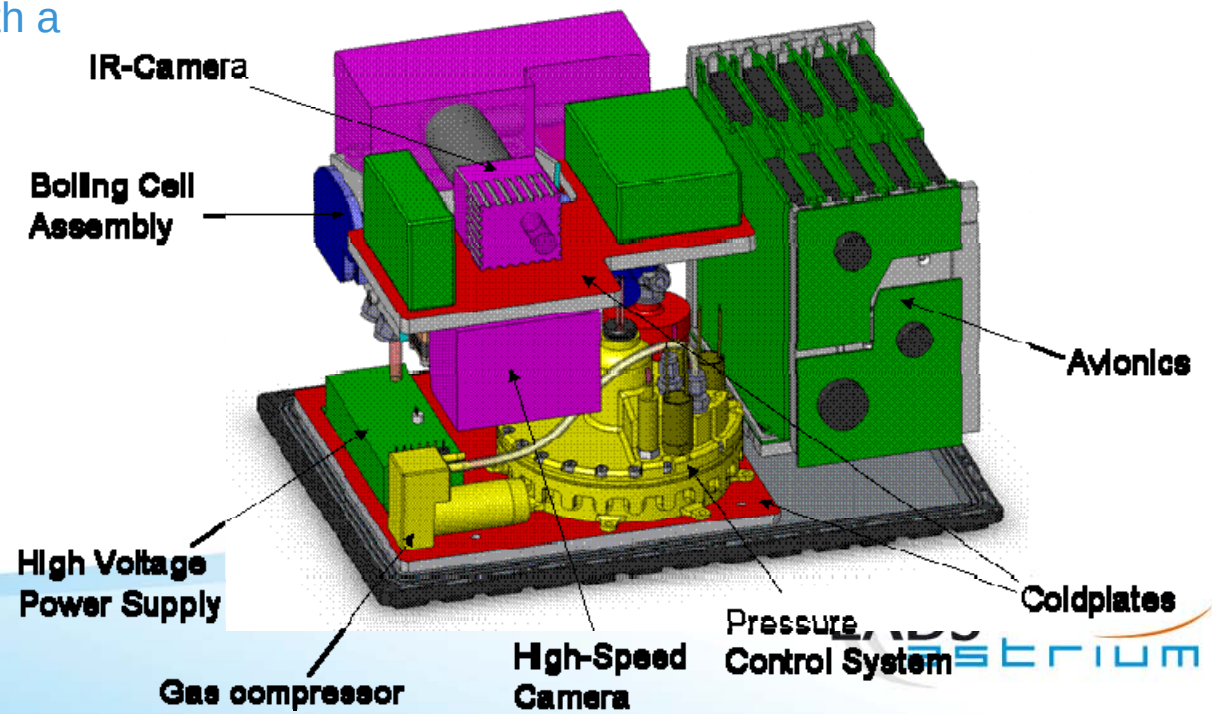
FSL Experiment RUBI

Reference mUlti-scale Boiling Investigation
short introduction into boiling





- Nucleate Boiling
  - High performance 2-phase heat transfer process
  - Latent heat transfer
  - Bubble motion induced forced convection
  - Highly dynamic process with a large number of involved mechanisms



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Material Science Lab

MSL is integrated in the right side of NASAs MSRR.

2 Furnace Inserts are uploaded:

the Low Gradient Furnace (LGF)

the Solidification and Quench Furnace (SQF)

First experiments have been performed on Sample Cartridges for the directional solidification of Aluminum-Silicon-Iron alloys (with and without rotating magnetic field)

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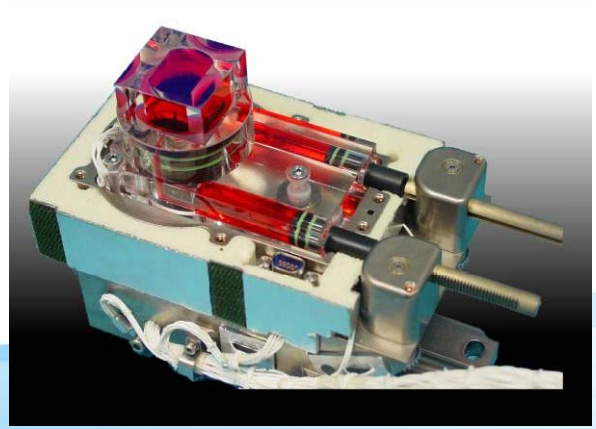
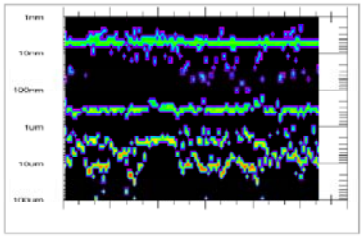
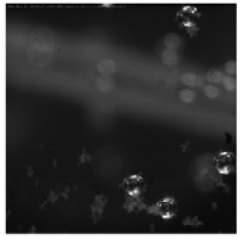
Protein Crystallisation Diagnostics Facility

The PCDF PROTEIN Mission that took place in ISS during four months in the first half of 2009. PCDF allowed in-situ observation of nucleation and crystal growth behaviour of in microgravity via microscopy and interferometry

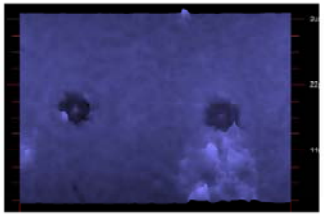
The instrument was used to investigate the crystallization properties of the glucose isomerase (D-xylose ketol isomerase) protein from *Streptomyces Rubiginosus.*







The nucleation behavior of the glucose isomerase protein in microgravity is followed with photon correlation spectroscopy. As soon as precipitant is added to the protein, the particle size distribution is very complicated. Analysis is ongoing



Concentration gradients are observed with the on board Mach-Zehnder interferometer. Fast-growing crystals like ours are supposed to establish a depletion zone in microgravity. During the PROTEIN mission, depletion zones were not stable, being established and destroyed in a cyclic fashion. Analysis is ongoing and will need the development of new tools to investigate the role of vibrations and temperature gradients.

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BIOLAB

- **Science Objectives:**

Biological experiments in the field of cell cultures, micro organisms, small plants and invertebrates

- **Key Technical Features:**

➢ Based on Experiment containers
60 x 60 x 100 mm³

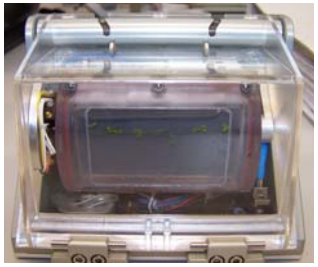
➢ Incubator, 18°-40°C with
- 2 centrifuges, 10^{-3} g to 2g
- Automatic gas composition & control

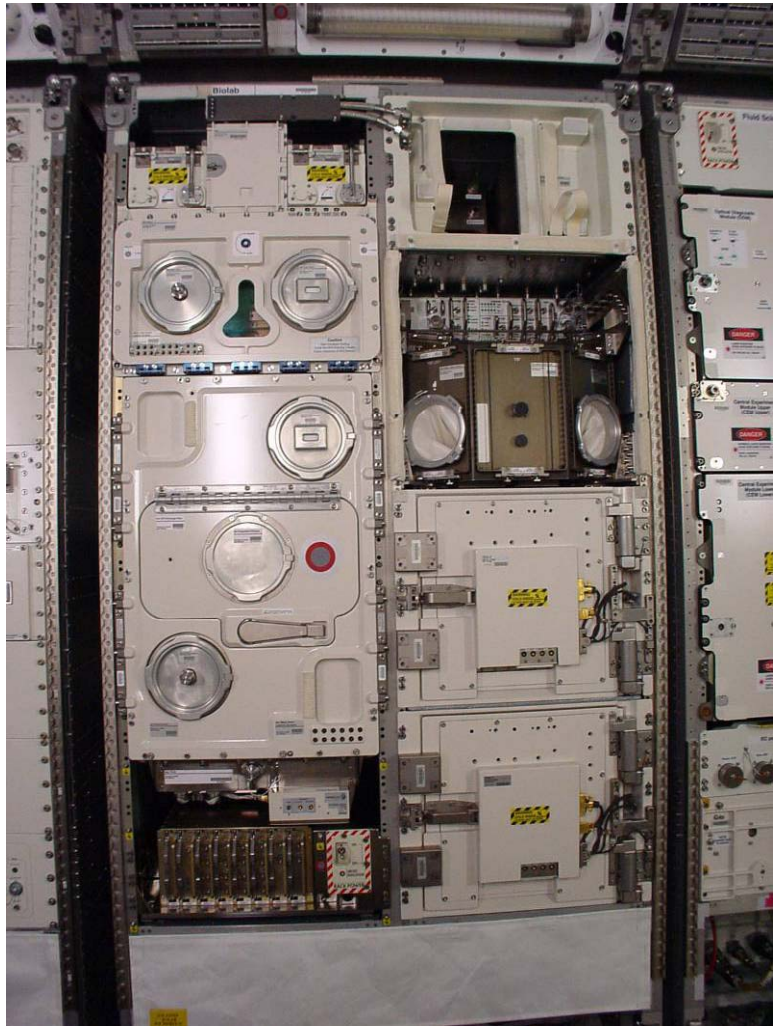
➢ Automatic fluid handler

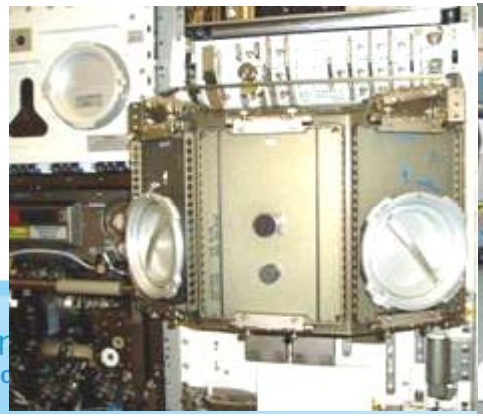
➢ Integrated freezer, cooler

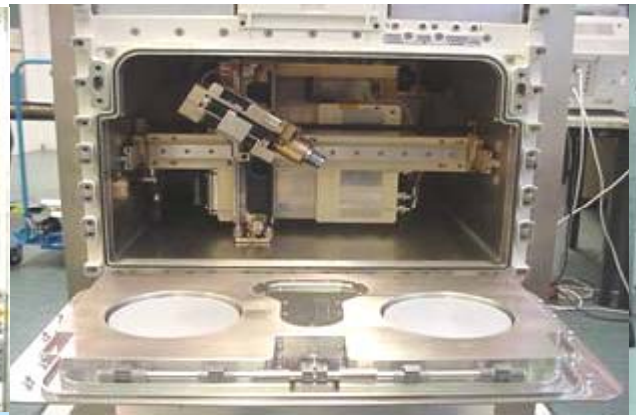
➢ Integrated glovebox with sterilisation capability

➢ Integrated microscopy & spectroscopy









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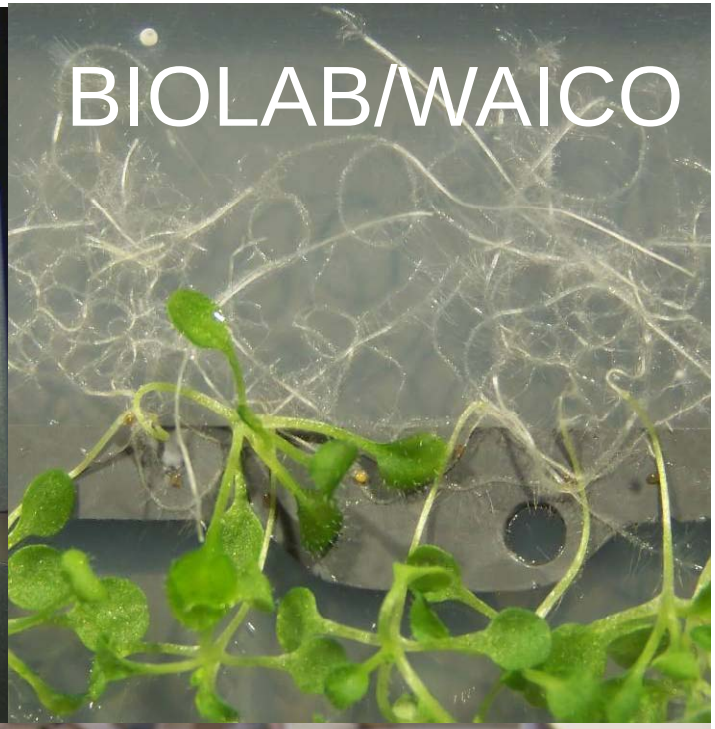
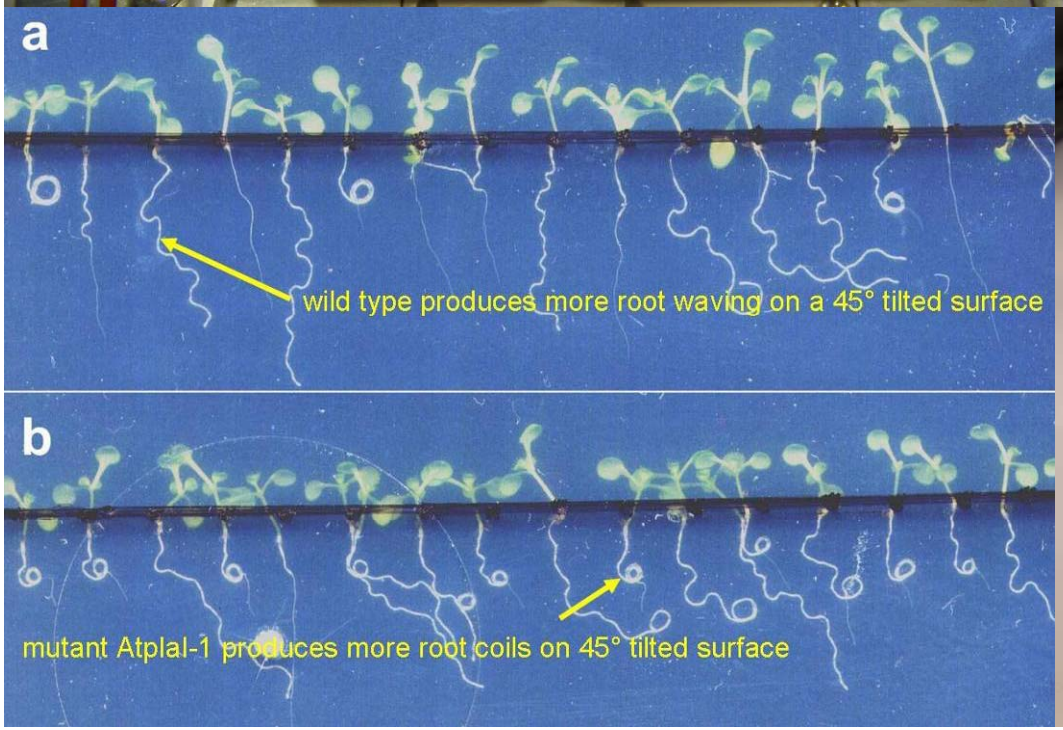
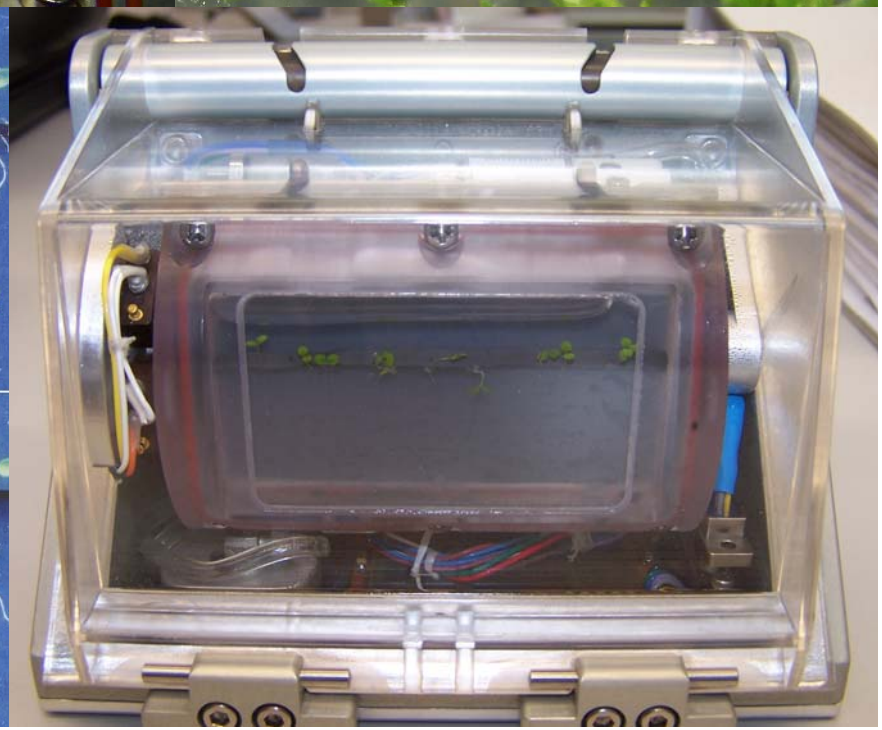

BIOLAB/WAICO


a
wild type produces more root waving on a 45° tilted surface
b
mutant Atplal-1 produces more root coils on 45° tilted surface



The next BIOLAB experiments are TRIPLELUX A, B & C
In Triplelux cellular responses will be translated into chemo-luminescence (A/B) and bio-luminescence signals (Part C)

TRIPLELUX A for Measuring phagocytosis of mammalian cells
PI: Prof. Dr. O. Ullrich, University of Magdegburg, Zurich and Munich
TRIPLELUX B for Measuring phagocytosis of oyster or mussel cells
PI: P.-D. Hansen. TU-Berlin
TRIPLELUX C for the Aggravation of radiation effects and DNA repair on genetically modified bacteria PI: P. Rettberg, DLR-Cologne

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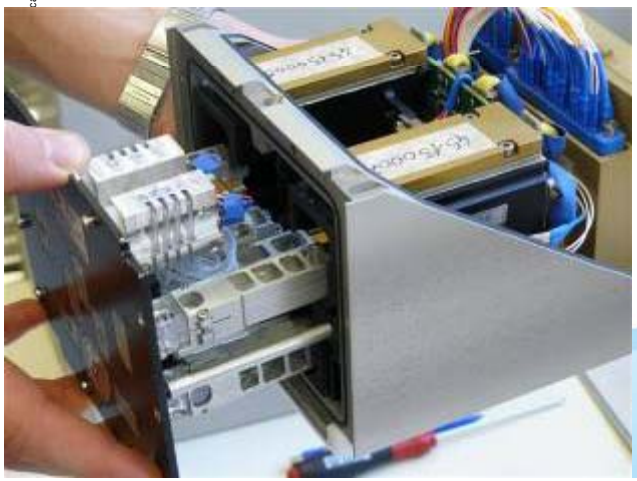

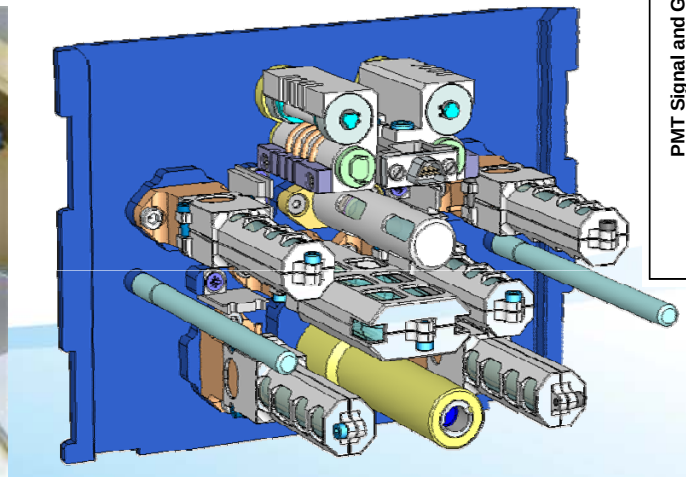

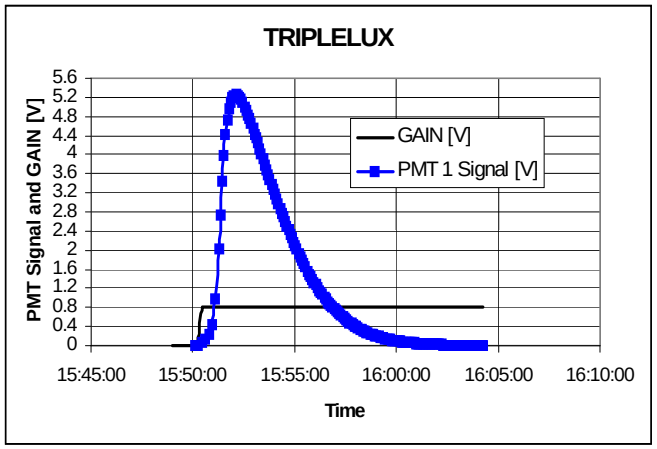

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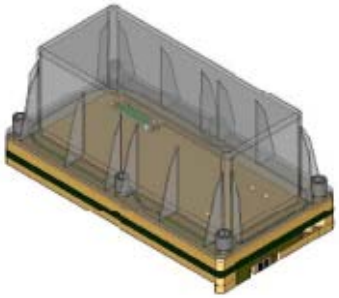
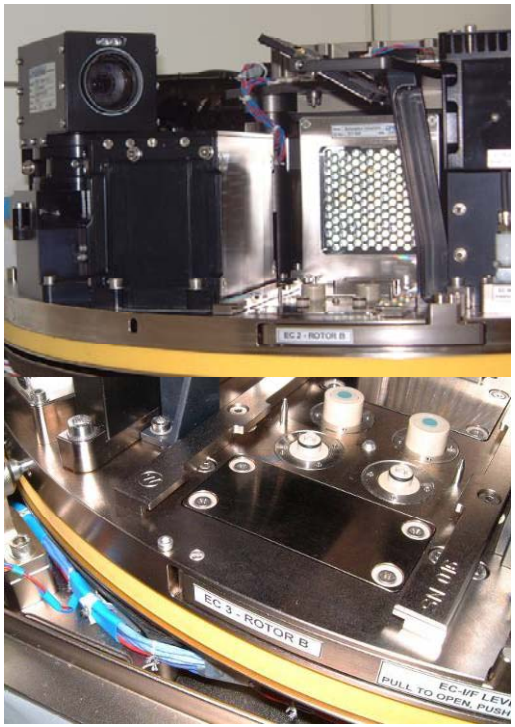
European Modular Cultivation System

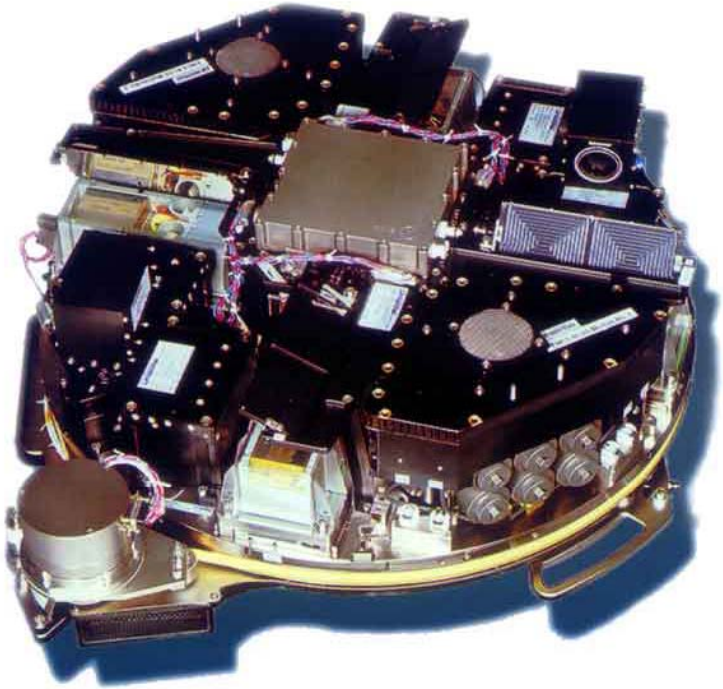
EMCS is a multiuser Facility for gravitational biology experiment with 2 exchangeable rotors providing:

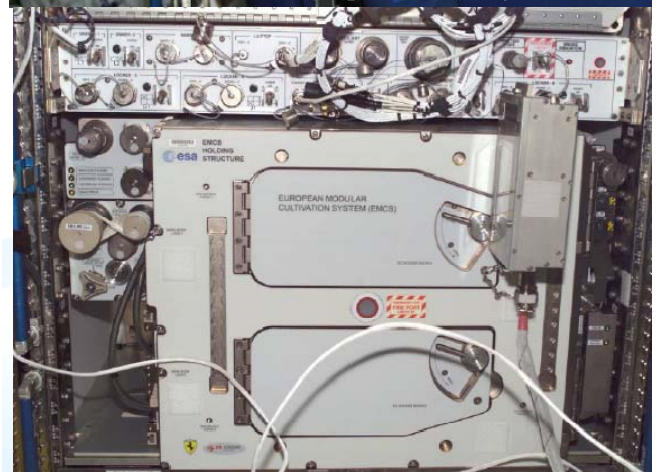
- Environmental control
- Variable g level from 0.1g to 2g
- Illumination and Observation
- Data aquisition and commanding
- Water reservoirs
- Interface to 4 Experiment Containers (60x60x160)



Thomas Reiter installing EMCS, Expedition 13







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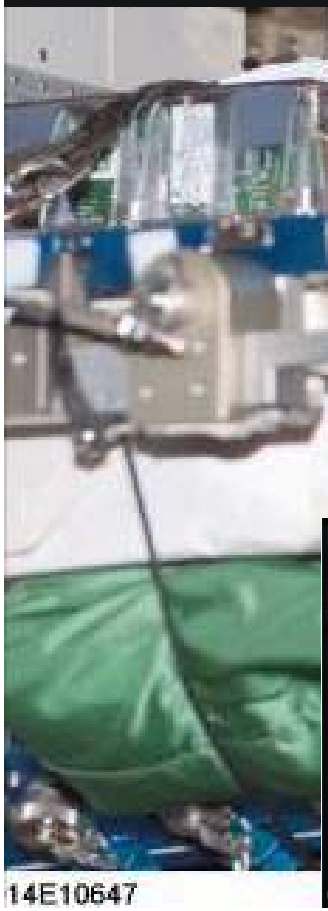
J. Z. Kiss, Miami University, Oxford, USA

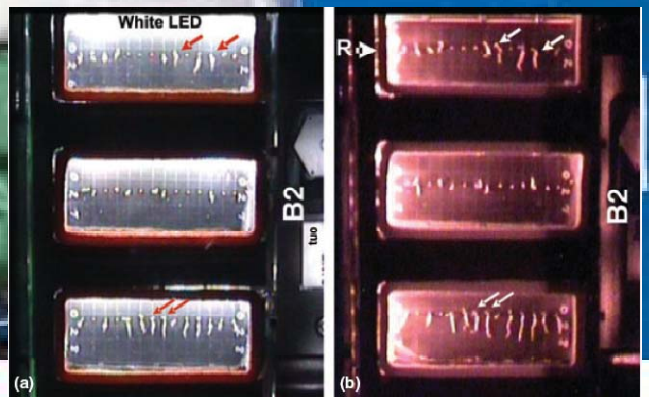
Analysis of novel sensory mechanism in root phototropism

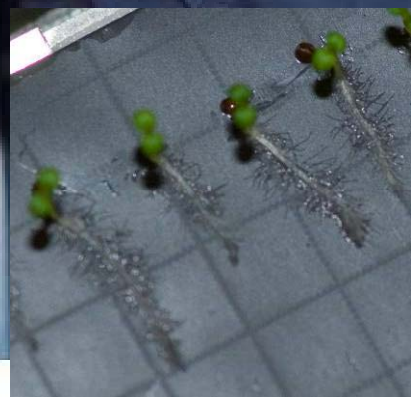
The major goals of the TROPI experiments are to better understand cellular mechanisms of phototropism in plants and to determine the effects of gravity on light perception in plants. Specifically, microgravity is used to study phototropism in roots and hypocotyls of *Arabidopsis* seedlings.

EMCS/TROPI

Experiment H/W developed by NASA Ames





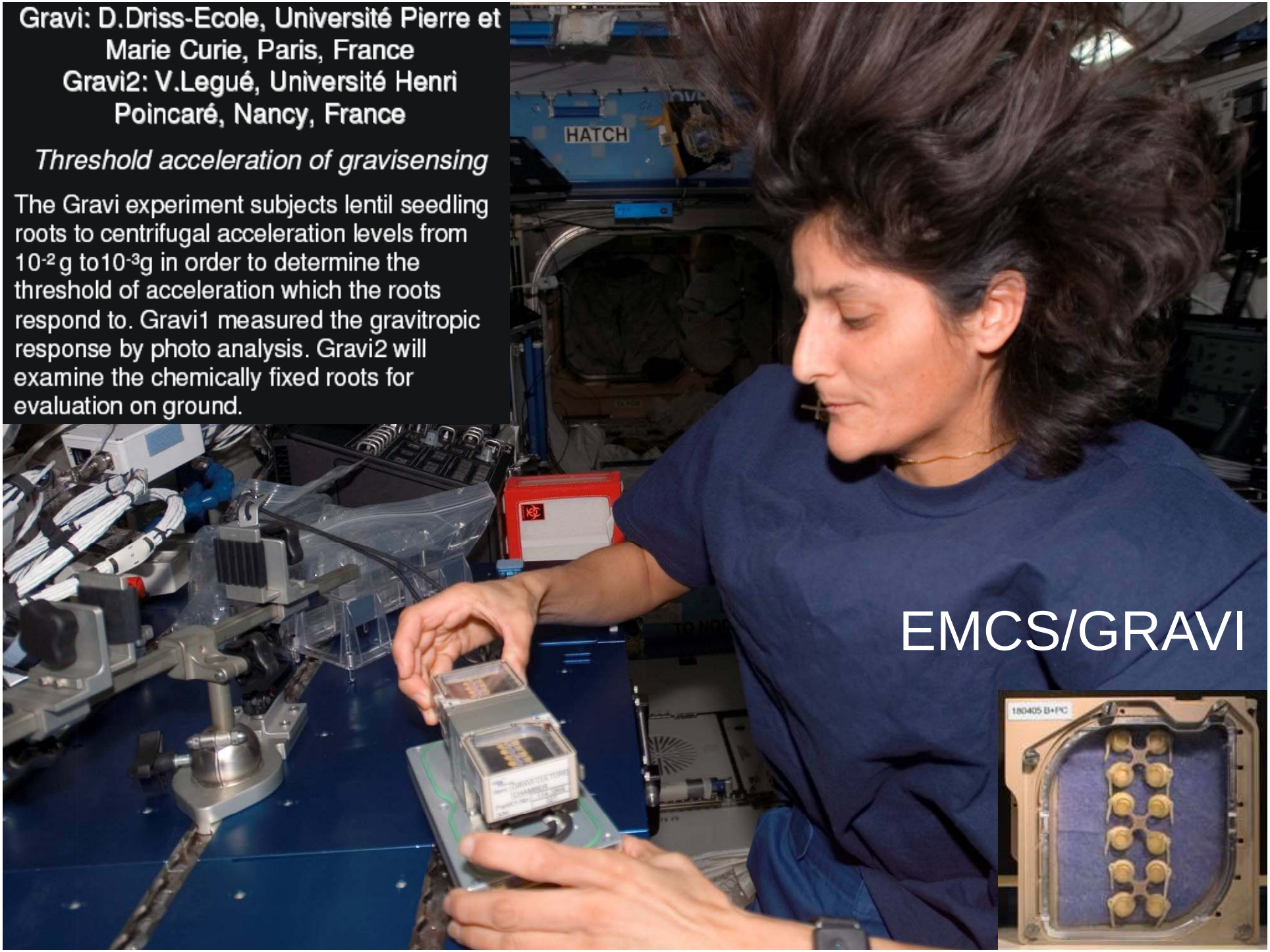


14E10647

Gravi: D.Driss-Ecole, Université Pierre et Marie Curie, Paris, France
Gravi2: V.Legué, Université Henri Poincaré, Nancy, France

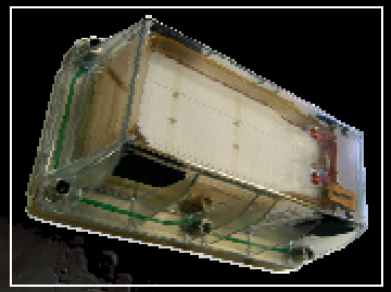
Threshold acceleration of gravisensing

The Gravi experiment subjects lentil seedling roots to centrifugal acceleration levels from 10^{-2} g to10^{-3}g in order to determine the threshold of acceleration which the roots respond to. Gravi1 measured the gravitropic response by photo analysis. Gravi2 will examine the chemically fixed roots for evaluation on ground.



GENARA A
Gravity regulated genes and
Protein synthesis

GENARA A

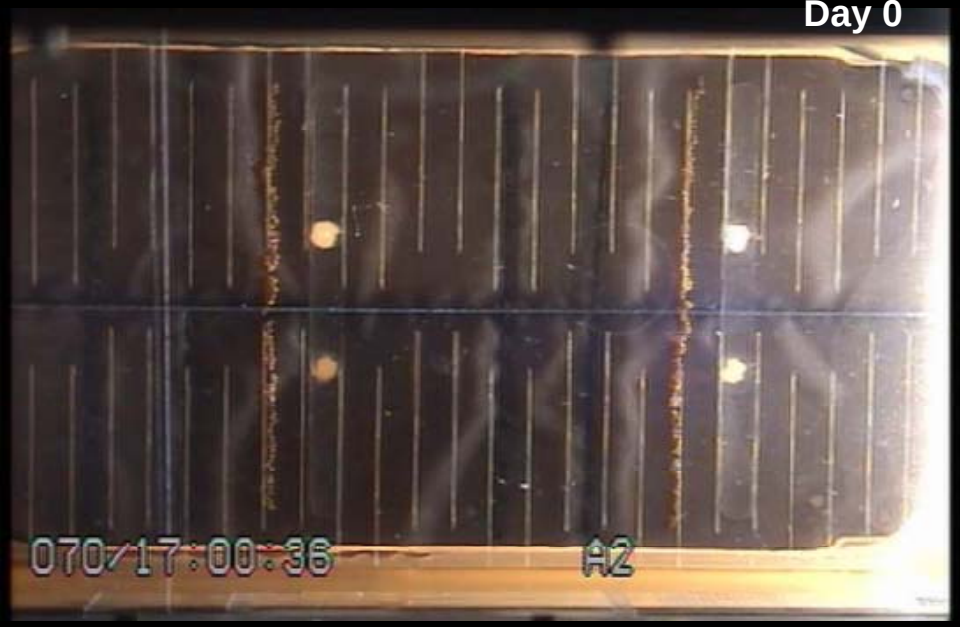


E. Carnero-Diaz, Université Pierre et Marie Curie, Paris, France

Gravity regulated genes in Arabidopsis thaliana

GENARA A aims at identifying gravity regulated genes and assessing protein synthesis expression grown under microgravity conditions in *Arabidopsis thaliana* seedlings, compared to 1-g controls.

Day 0



Day 14

CW/RW (JAXA)

K. Nishitani

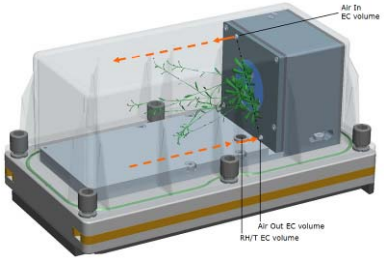
T. Hoson

The Cell Wall/Resistance Wall experiment explores the molecular mechanism by which the cell wall construction in *Arabidopsis thaliana* is regulated by gravity. It determines the importance of the structural connections between microtubules, plasma membrane, and the cell wall as the mechanism of gravity resistance.

CW/RW uses the same hardware concept as Multigen1 but is supplemented by additional harvesting and fixation equipment from Bionetics, to return preserved stem material. For safety reasons the harvesting uses MSG.

Due to technical problems the experiment could not be executed as planned and is waiting for a new start.

MULTIGEN 1



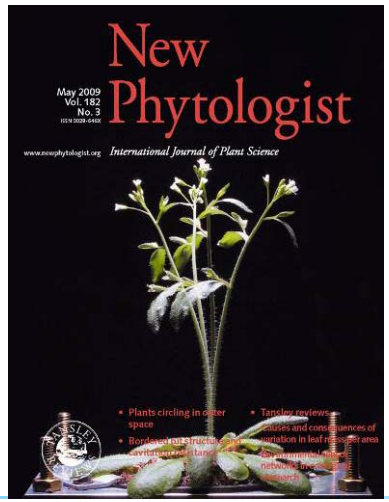
T. H. Iversen, Norwegian University of Science and Technology, Trondheim, Norway

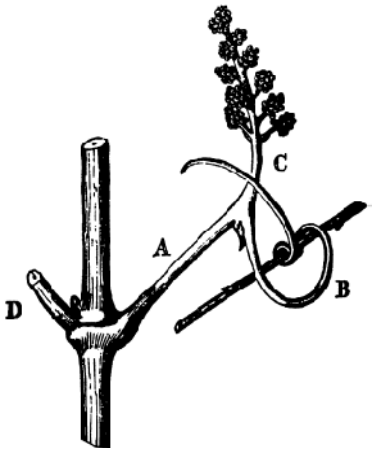
Molecular and plant physiological analyses of the microgravity effects on multi-generation studies of Arabidopsis thaliana

The MULTIGEN experiment was designed to examine the possibility of sustainable plant growth for long duration space exploration by growing several generations of plants in orbit. A model plant, Arabidopsis thaliana, was used to study seed production and viability in microgravity.

Side Effects

A 200 year old question, could be decided in favour of a theorem by Darwin that the movement of plants is ancered in their genes and not caused by gravity.

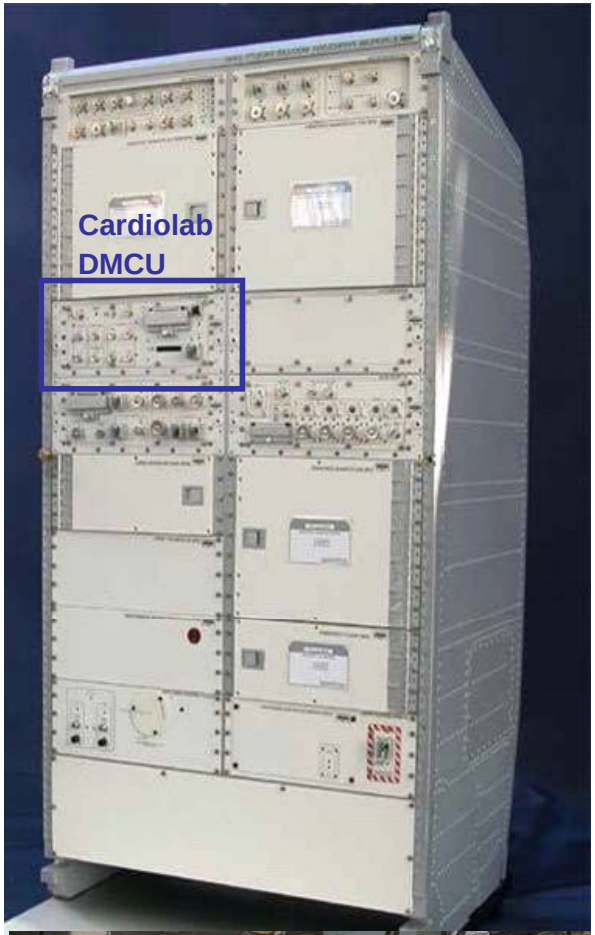




CARDIOLAB

is a modular physiological research facility, jointly developed by CNES and DLR for the investigation of the Cardiovascular System.

Astrium has developed a set of 10 sensor & 2 stressor modules, mostly derived from commercial instruments.



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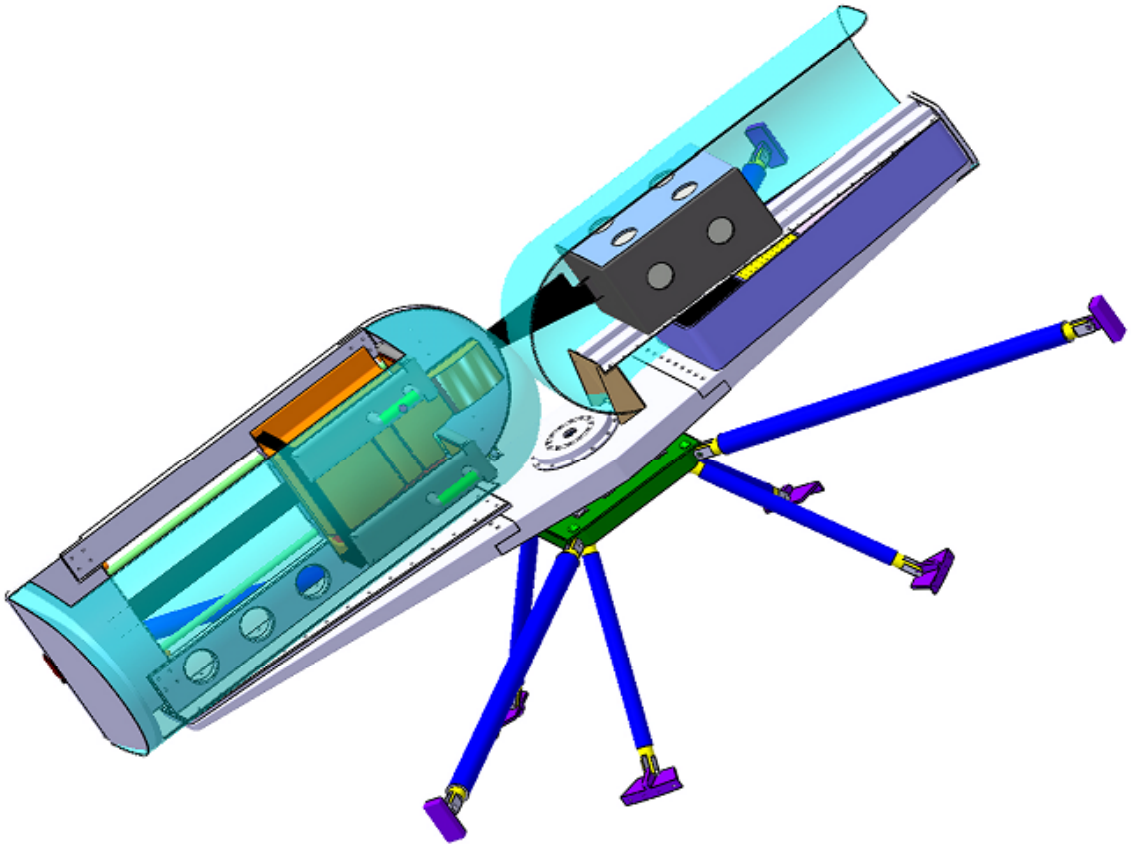
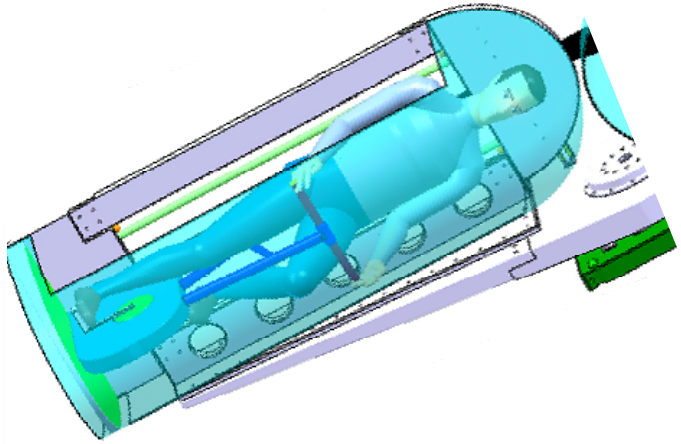
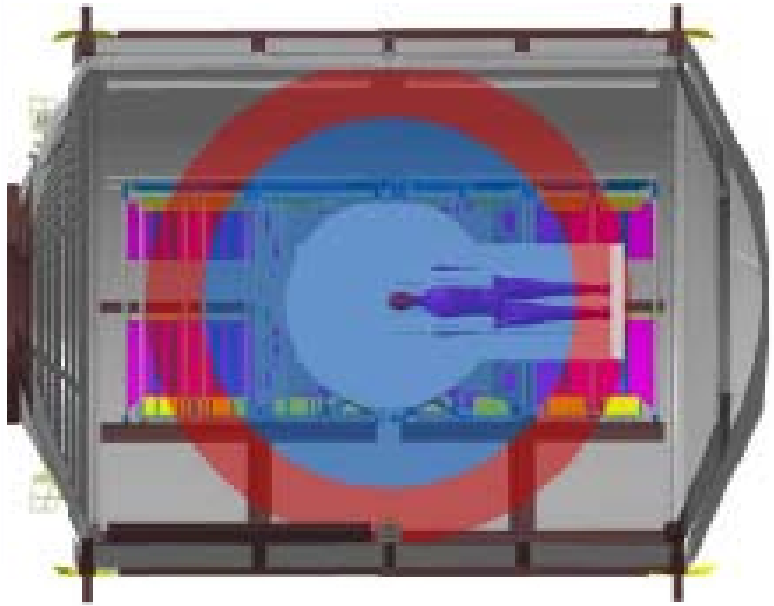
Short Arm Human Centrifuge

Astrium has been contracted by ESA to study the accommodation of a short arm human centrifuge onbord ISS







Red circle

- Max. SAHC Ø of ~ 3.9 m

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External Payload on Columbus
Atomic Clocks Ensemble in Space - ACES

Science Objectives

- Clock comparison experiments between space and ground atomic clocks for fundamental physics tests with unprecedented accuracy (e.g. test of Einstein´s theory of relativity),
- applications in time and frequency metrology, geodesy, global positioning and navigation.

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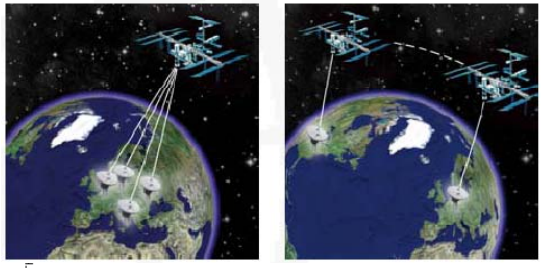
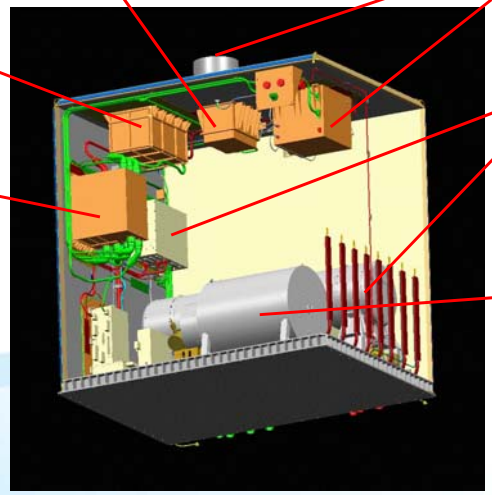


Frequency Comparison and Distribution Package (FCDP)
- on-board frequency distribution
- on-board phase comparison

Microwave Link (MWL)
- space-to-ground time & frequency distribution

Power Distribution Unit (PDU)

External Payload Computer (XPLC)

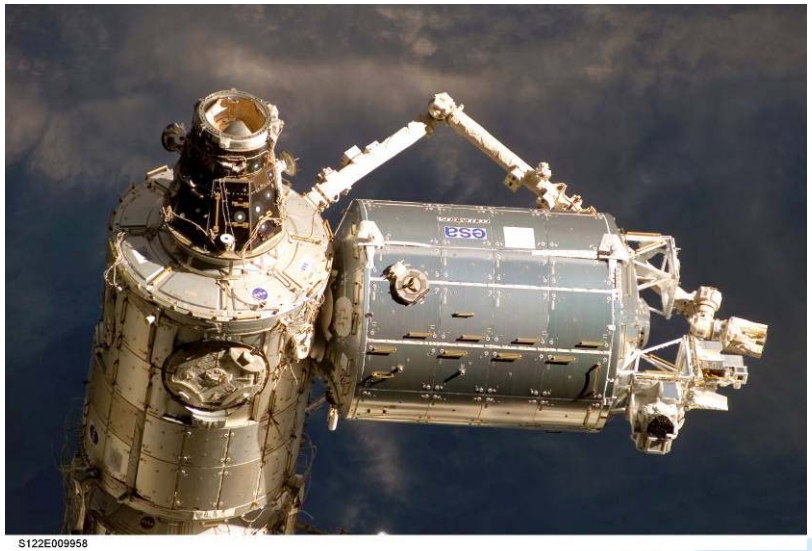


PHARAO Cs Clock
- high accuracy
- high medium and long term stability

Space Hydrogen Maser (SHM)
- high short and medium term stability

Mounted on CEPA

ISS Operations - Scope of Work (1)



S122E009958

- Columbus - Launch Feb 2008
  - Biolab
  - Fluid Science Laboratory
  - European Physiology Module
  - European Transport Carrier
  - European Drawer Rack
  - SOLAR
  - EuTEF

ISS016E029896

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Scope of Work (2)

- Operations and maintenance for
  - EMCS - launched Jul 2006
- Sustaining engineering for
  - Data Management for Svezda - launched Jul 2000
  - Microgravity Science Glovebox (NASA) - launched Jul 2002
  - Minus 80 degree Freezer (MELFI) - launched Jul 2006
  - Node 2 - Launch Oct. 2007
  - Material Science Laboratory
  - ERA – Dec 2009
  - Node 3 – Jan 2010
  - Cupola – Jan 2010
- ATV Operation:
  - ATV operations tasks are being integrated
  - Launch of ATV-2 : end of 2010 (planned)
  - ATV-3, ATV-4 & ATV-5 are planned to be launched 1 per year (2011-2013)

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www.nasa.gov/mission_pages/station/science/experiments/Gravi.hmtl

http://www.nasa.gov/mission_pages/station/science/experiments/Gravi.html

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People Who Rea

International Space Station

Fact Sheet

Text Size

Threshold Acceleration for Gravisensing (Gravi)

Overview | Description | Applications | Operations | Results |

Experiment/Payload Description

Research Summary

- This experiment is designed to determine the minimum amount of artificial gravi lentil seedling roots to start growing in a new direction.
- The artificial gravity (from 1/10th - 1/100th of Earth gravity) is created by using the (European Modular Cultivation System) to control the amount and duration of the experienced by the plants.
- Experience in growing plants in partial gravity environments is basic research th plant cultivation by human explorers on the Moon and Mars.

Description

On Earth, plants respond to gravity so that stems grow up and roots grow down; lack c problems in space. The goal of the Threshold Acceleration for Gravisensing (Gravi) st parameters of the gravitropic response (a tendency to grow toward or away from gravit perception of the gravistimulus (reorientation within the gravity field) during initial plant

- presentation dose (minimum quantity of stimulation to provoke a significant curvature)
- gravisensing threshold acceleration (minimum acceleration which can be perceived)
- minimum deviation from the gravity vector, which leads to a reorientation of the root.

Gravi uses lentil seedling roots subjected to centrifugal acceleration levels from 10^{-2}g to 10^{-3}g in microgravity in order to determine the threshold of acceleration to which the roots respond.

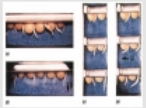
Gravi is divided into two phases to be operated on board the International Space Station. Gravi-1 was completed during Expedition 14 and was the observation only phase of the investigation. The development of roots by the lentil seeds during acceleration was videotaped by the European Modular Cultivation System (EMCS) for a designated period of time. The tapes were returned to Earth for analysis. Gravi-2 is the second phase of the Gravi investigation; Gravi-2 is scheduled for future operation on ISS and will allow for automated fixation of the lentil roots after the acceleration is complete. The videotapes and the preserved roots of Gravi-2 will be returned to Earth for analysis.

^ back to top

- Perbal G, LeFranc A, Jeune B, Driss-Ecole D. Mechanotransduction in root gravity sensing cells. Physiologia Plantarum. ;120:303-311. 2004

^ back to top

Images



In a previous study, lentil roots grown in microgravity on Spacelab (a) were oriented randomly, whereas roots grown in space on a 1g centrifuge (b) grew in the direction of the gravity. Roots grown in microgravity (c) were disoriented but did not seem to lose their ability to perceive gravity because when placed on 1g centrifuge (d), they grew in the direction of accelerations that simulated gravity. Image courtesy of NASA.

+ View Larger Image

Ground study of lentil seeds at 28 hours (left) and 30 hours (right) after initiation of growth by injection of water. The experiment containers were positioned vertically in an incubator with no light source at 22 degrees C. Image courtesy of NASA.

+ View Larger Image

NASA Image: ISS014E12278 - Cultivation chambers belonging to the Threshold Acceleration for Gravisensing (Gravi) experiment performed in the Destiny laboratory module by the Expedition 14 crew. This experiment will grow lentil seedling roots under various gravity conditions (generated by the centrifuge in the European Modular Cultivation System (EMCS)) on ISS, to determine the amount of acceleration force sufficient to stimulate the direction of root growth.

+ View Larger Image

NASA Image: ISS014E12135 - Astronaut Sunita Williams,Expedition 14 Flight Engineer,works with the upper and lower walls of cultivation chamber on Rotor A of the Threshold Acceleration for Gravisensing (GRAVI) experiment in the Destiny laboratory module.

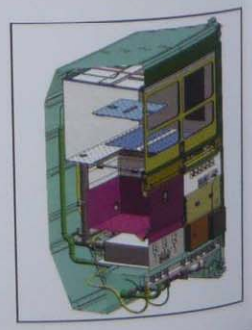
+ View Larger Image

Multipurpose Facilities

European Drawer Rack (EDR) [ESA] is a multidiscipline facility to support up to seven modular experiment modules. Each payload will have its own cooling, power, and data communications, vacuum, venting, and nitrogen supply. EDR facilitates autonomous operations of subrack type of experiments in a wide variety of scientific disciplines.

The Protein Crystallization Diagnostics Facility (PCDF) *is the first ESA experiment performed with the EDR rack. Its main science objectives are to study the protein crystal growth conditions by way of non-intrusive optical techniques like Dynamic Light Scattering (DLS), Mach-Zehnder Interferometry (MZI) and classical microscopy. Understanding how crystals grow in purely diffusive conditions helps define the best settings to get organic crystals as perfect as possible. Later on these crystals will be preserved and analyzed via X-rays on Earth to deduce the three-dimensional shape of proteins.*

Multipurpose Small Payload Rack (MSPR) [JAXA] has two workspaces and one workbench and can hold equipment, supply power, and enable communication and video transmission. With such general characteristics, MSPR can be used in various fields of space environment use not only for science, but also for cultural missions.



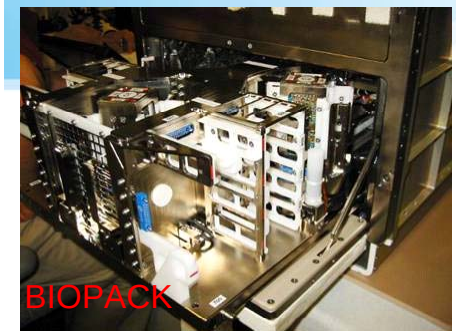
Expedite the Processing of Experiments to Space Station – (EXPRESS) Racks [NASA] are modular multipurpose payload racks that store and support experiments aboard ISS. The rack provides structural interfaces, power, data, cooling, water, and other items needed to operate the science experiments on ISS. Experiments are exchanged in and out of the EXPRESS Rack as needed; some subrack multi-user facilities (like European Modular Cultivation [EMCS]) will remain in EXPRESS for the life of ISS, while others are used for only a short period of time.

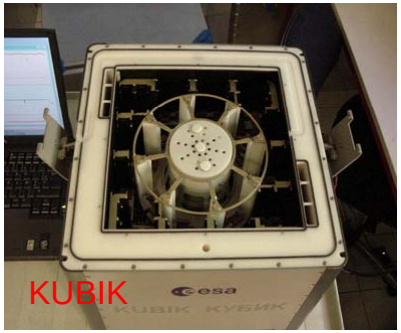
Outlook

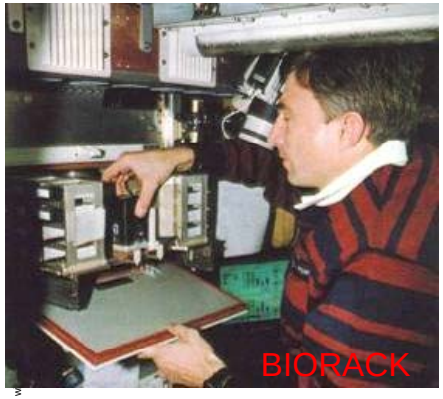
Astriums first multiuser facility for gravitational biology BIORACK was launched in Oct. 1985.

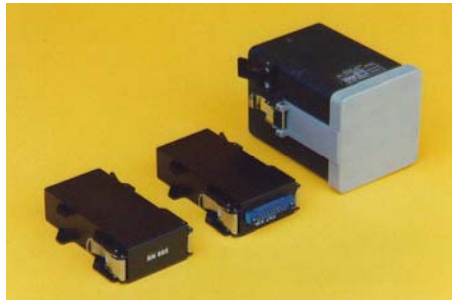
Until 1997 it flew 6 times, the last 3 missions as an ESA/NASA joint venture to the russian space station MIR.

This was for us the first working example for a truly international cooperation in space.









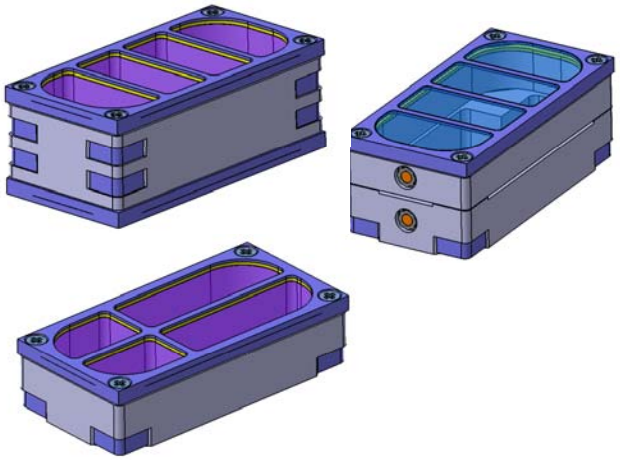
The BIORACK experiment standard, continued today, delivered so far to the impressive record of >25 Missions in 25 years with approx. 120 experiments and >300 publications in peer reviewed journals. This stands also for a huge variety of existing and flight proven experiment designs, which are available to the scientific community.

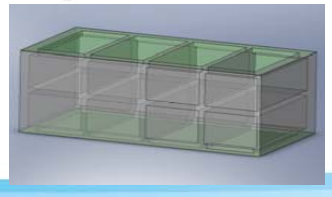
This docu
to third parties w

Astrium has started together with other payload developers to prepare a payload catalogue to make these designs available to potential users for a:

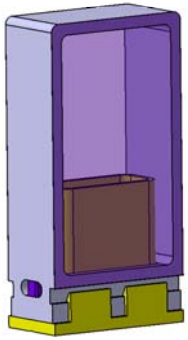
- reduction of cost and development schedules
- increase of comparability between experiments
- early availability of test hardware
- reuse of existing units, components and/or modification for specific needs.
- acceleration of discussion and ideas for new designs.

Type: Miniaquaria
(for Nematodes, Drosophila, Algae, Mikro-organism)

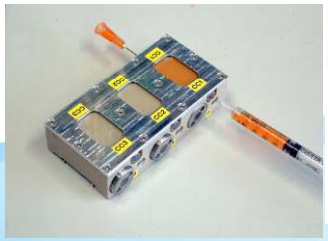


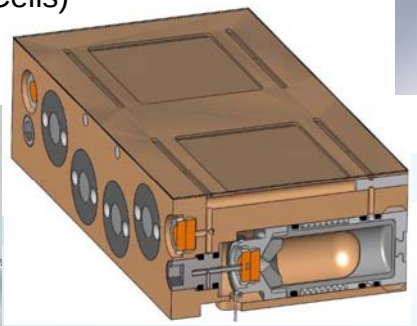


Plant Cultivation Type:
(for Rice and Arabidopsis)

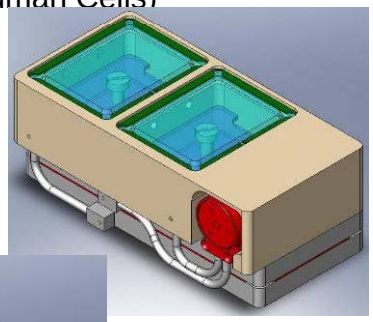


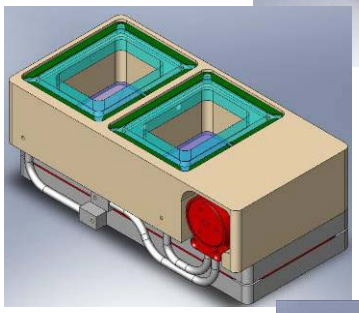
Type: Plunger box:
(for human Cells)

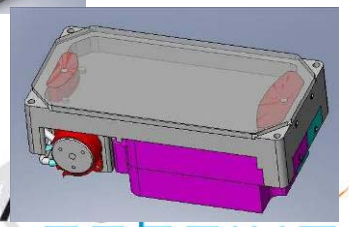




Type: Cell cultivation/fixation
(for plant Calli, human Cells)







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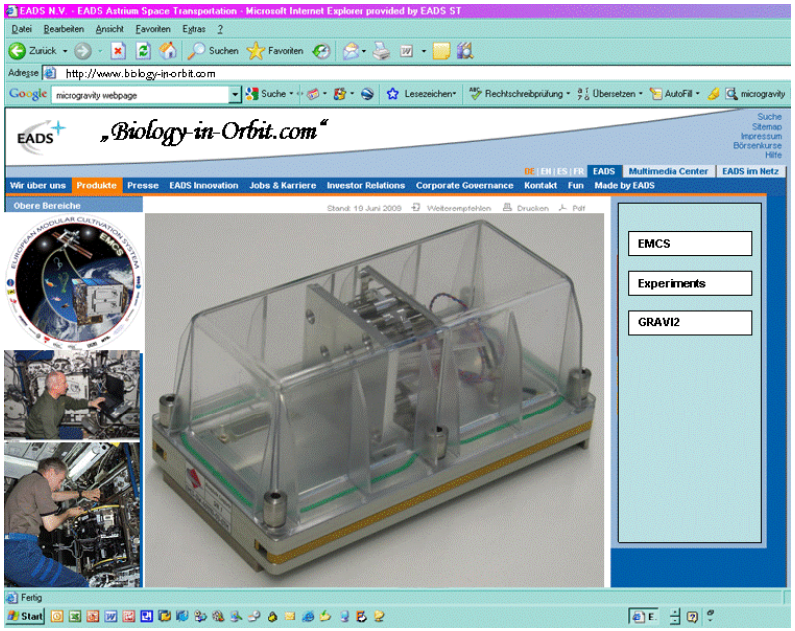
(…any time)



Contact:
Ulrich Kuebler
ISS Utilization Office
ASTRIUM Space Transportation
Claude-Dornier-Str.1
88039 Friedrichshafen/Germany
ulrich.kuebler@astrium.eads.net

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Backup Charts for Astrium operations servicew

- The industrial service to ESA covers
  - To prepare the missions and in-orbit activities
    - Mission integration, mission planning, preparation of system and payloads, astronaut and ground control teams training; software and hardware development and maintenance, configuration management, logistics and sustaining engineering, etc.,
  - To perform the mission
    - Mission control (COL-CC), engineering support, support to astronauts for on-orbit activities, launches, support to users
  - To operate and maintain the ground segment
    - Control centers, support to user centers and industrial ground infrastructure to support the missions
- The Multinational Industrial Consortium
  - with more than 30 companies / organizations in 10 ESA member states including Thales Alenia Space & DLR for the Columbus Control Center
  - set up as integrated service teams with collocation at the various centers and the customer

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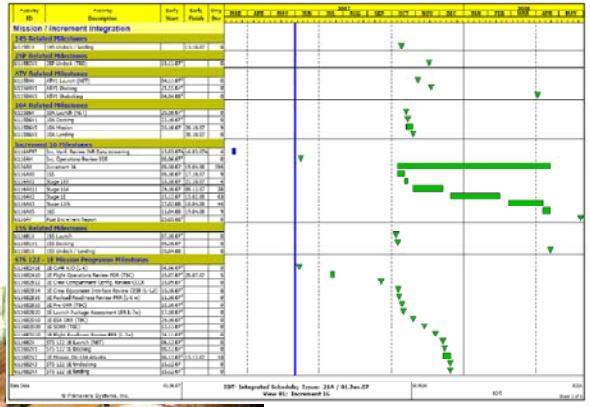
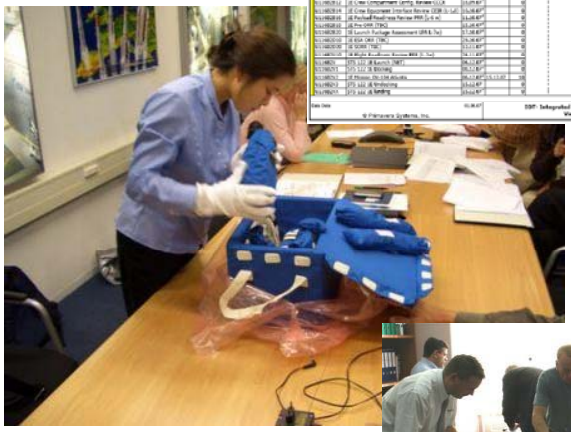
Increment Integration Team

- Supports the customer for the definition of the increment objectives
- Coordinate the technical implementation of the agreed increment objectives through the contribution of the affected IOT functions, USOC's and EAC
- Facilitates lessons learned process and coordinates the post increment report
- The team is located in **Bremen, Leiden/ESTEC, Turin, and Houston**





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Engineering Support

- Develop and verify operations products (ESA ODF and displays) and data sets
- Software system preparation and maintenance, software cycles
- At the engineering support centers (ESCs)
  - Maintain and operate the engineering models of the flight configuration
  - Perform maintenance of Columbus system hardware and software configuration and interfaces
  - Provision and retention of expertise, including systems documentation
  - Support to operations, including real time, anomaly handling and trouble shooting, in-depth anomaly investigation, problem resolution, and generation of near-real time updates e.g. system SW patches. It includes end-to-end troubleshooting
- ESCs are in Bremen and Turin (ALTEC)
- At the control centers
  - On site engineering support team and in support of the operations teams and mission safety function

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Payload Engineering & Operations Integration

- Stage Integration, i.e. support to increment requirements definition and feasibility, Columbus element level stage analyses for the different stages including ESA and International Partner pressurized and un-pressurized payloads in Columbus. The tasks are:
- P/L engineering and operations integration on Columbus element and facility Class 1 and Class 2 level, both flight and ground models for ESA and NASA payloads in Columbus
- Columbus Payload complement-level integration of ESA PODF procedures and flight and ground databases
- Establishment, maintenance and update of the ESA Payloads flight and ground SW Databases
- Provision of engineering expertise on payload level to handle anomalies, i.e. trouble shooting, in-depth anomaly investigation, problem resolution and generation of near-real time updates including end-to-end troubleshooting
- Maintenance of the Columbus payload requirements baseline
- Support to User Centres for
  - familiarisation with payload facilities and development of P/L operations products and science/experiment integration
  - Maintenance of ESA Payload hardware and software configuration and qualification status including interfaces

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Mission Operations

- Mission Operations
  - The Flight Director Office (FDO) provides the "Project Management" and FCT/GCT team lead.
  - Increment Operations Preparation (for several increments in parallel)
  - Increment Operations Execution
  - Post Increment Evaluation

- Flight Control will be available for 24/7 in the Control Center. It will support in general full shift during Columbus activities and reduced shifts during nights and weekends
- This task is performed at the COL-CC in Oberpfaffenhofen
- The Execute level Planning, performing the mission planning Columbus Mission, is also located at COL-CC

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Training

- The training team provides an integrated service covering the whole increment / mission training for the European part of ISS, i.e.,
  - Crew Training (Columbus Systems, ATV and Payloads)
  - Ground Support Personnel (GSP) Training (Columbus Systems and Payload operations) including simulations (e.g. ES, JMSTs).
  - Mission independent training for ESA elements to be implemented in the course of basic, advanced, proficiency training and ESA Training Academy.
- The majority of the industrial team is collocated at European Astronaut Center (EAC) in Cologne, where also the training infrastructure is provided
- Some team members are also located in Bremen and Turin, two instructors work in Houston for joint station training and operating the ESA contribution to the ISS Training Facility

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