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ESA research capabilities on board the International Space Station

Outreach Seminar on the ISS

United Nations - Human Space Technology Initiative (HSTI)

Vienna, 08-Feb-2011

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Utilisation Department
European Space Agency

Outline

- ESA contributions to ISS
- ESA research assets for a broad science community
- Utilisation achievements

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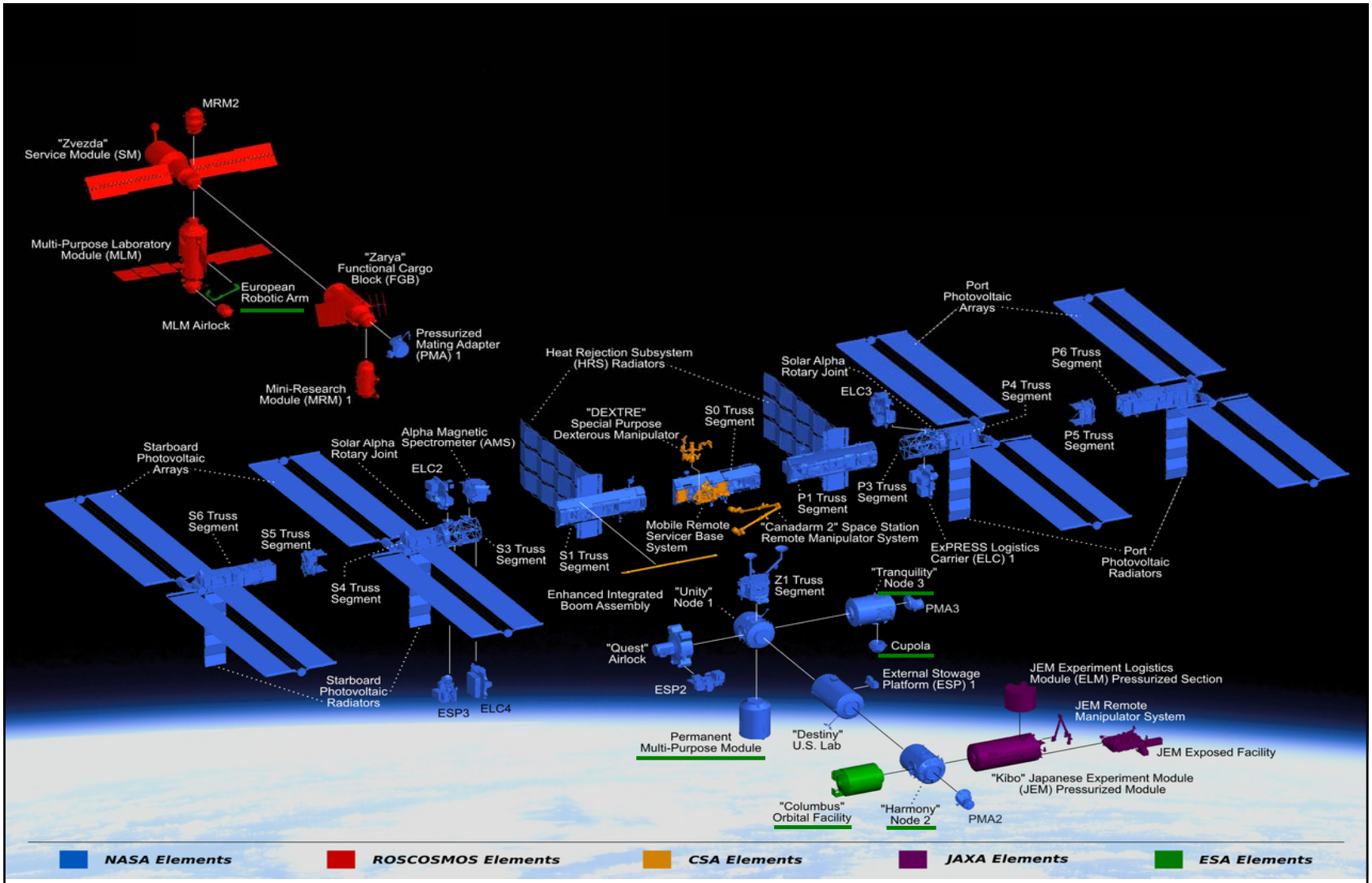
MRM2
"Zvezda" Service Module (SM)
Multi-Purpose Laboratory Module (MLM)
European Robotic Arm
MLM Airlock
"Zarya" Functional Cargo Block (FGB)
Pressurized Mating Adapter (PMA) 1
Mini-Research Module (MRM) 1
Heat Rejection Subsystem (HRS) Radiators
"DEXTRE" Special Purpose Dexterous Manipulator
S0 Truss Segment
Solar Alpha Rotary Joint
ELC3
Port Photovoltaic Arrays
P6 Truss Segment
P4 Truss Segment
P5 Truss Segment
P1 Truss Segment
P3 Truss Segment
Starboard Photovoltaic Arrays
Solar Alpha Rotary Joint
Alpha Magnetic Spectrometer (AMS)
ELC2
S6 Truss Segment
S5 Truss Segment
S4 Truss Segment
S3 Truss Segment
S1 Truss Segment
Mobile Remote Servicer Base System
"Canadarm 2" Space Station Remote Manipulator System
ExPRESS Logistics Carrier (ELC) 1
Port Photovoltaic Radiators
Enhanced Integrated Boom Assembly
"Unity" Node 1
Z1 Truss Segment
"Tranquility" Node 3
PMA3
Cupola
"Quest" Airlock
ESP2
External Stowage Platform (ESP) 1
JEM Experiment Logistics Module (ELM) Pressurized Section
JEM Remote Manipulator System
JEM Exposed Facility
"Kibo" Japanese Experiment Module (JEM) Pressurized Module
Starboard Photovoltaic Radiators
ESP3
ELC4
Permanent Multi-Purpose Module
"Destiny" U.S. Lab
"Columbus" Orbital Facility
"Harmony" Node 2
PMA2
NASA Elements
ROSCOSMOS Elements
CSA Elements
JAXA Elements
ESA Elements

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ESA contributions to ISS

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ATV

Automated Transfer Vehicle

DMS-R

ESA's Data Management System for the Russian Segment of the ISS. Located in service module Zvezda.

Node 3

Habitation Module

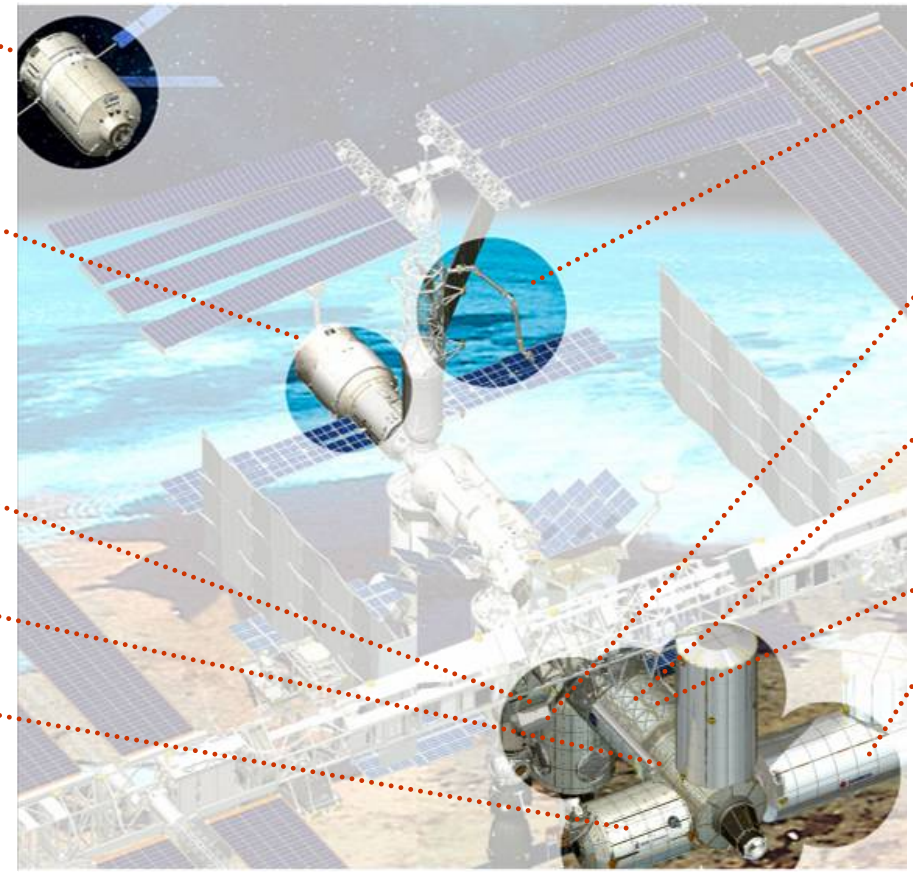
Node 2

Connecting Module

Columbus

Pressurized Facilities
(BIOLAB, EDR, EMCS, EPM, EDR, MARES)

Unpressurized Facilities
(SOLAR)



ERA

European Robotic Arm

Cupola

Pressurized observation and work area

US-Lab

Pressurized Facilities
(MSG, MSL, PFS)

MELFI

- 80°C Freezer for research specimens. Located in Japanese Research Module (Kibo) + US-Lab (Destiny)

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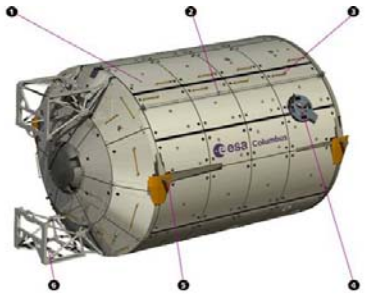
ESA contributions to ISS Columbus module



- Columbus laboratory technical dimensions:
  - net mass of 10.3 tons (incl. system racks);
  - internal volume of 75 m^3;
  - accommodation space for a total of 16 racks:
    - 5 ESA research racks;
    - 5 NASA research racks;
    - 3 system + 3 stowage racks;
  - accommodation of 4 unpressurized external payloads;
- Columbus is a compact ISS laboratory module offering a comparable payload volume, power, and telemetry as the Station's other laboratories.
- A significant benefit of the cost-efficient design is that Columbus was already outfitted for launch with 2500 kg of 5 rack facilities, additional outfitting hardware and 2 external payloads on a palette carrier. After commissioning phase, it is ready for science utilisation.

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ESA contributions to ISS Columbus module

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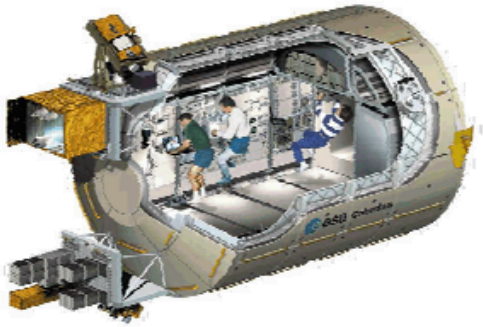
- COLUMBUS was launched with STS-122 (07-Feb-2008);
- The Columbus laboratory is the cornerstone of ESA's contribution to the International Space Station (ISS) and is dedicated to long-term research in space;
- During its projected lifespan of 15+ years on-orbit, Columbus will support sophisticated multi-disciplinary research, having internal and external accommodation for dozens of experiments in life and physical sciences, space and earth science, technology, commercial R&D, education and finally human exploration preparation.
- Since accommodation and check-out of COLUMBUS, ESA is entitled to a resources allocation envelope (up-/down-mass, crew time, power, data transfer). ESA carries out its ISS activities in cooperation with NASA, FSA, JAXA and CSA.



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ESA contributions to ISS
Automated Transfer Vehicle (ATV)

- ATV is an unmanned servicing and logistics vehicle to be used for the periodic re-supply of the International Space Station.
- The ATV provides the following services to the International Space Station:
  - Delivery of cargoes to the Station (such as experiments, food, compressed air and water);
  - Refuelling of the Station (i.e. the transfer of propellant to the Zarya (FGB) module);
  - Re-boost and attitude control of the whole Station.

- ESA contributions to ISS
- ESA research assets for a broad science community
- Utilisation achievements

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Research Facilities initially deployed with Columbus

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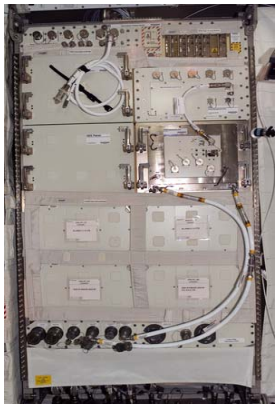


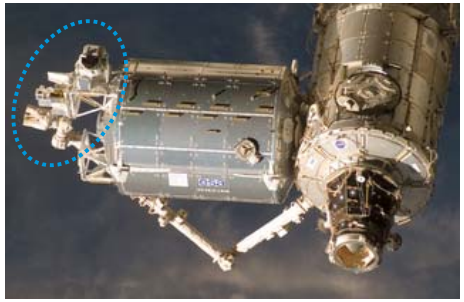
EDR

EPM

- **BIOLAB**, which supports experiments on micro-organisms, cell and tissue cultures, and even small plants and animals;
- **Fluid Science Laboratory (FSL)**, looking into the complex behaviour of fluids, which could lead to improvements in energy production, propulsion efficiency and environmental issues;
- **European Physiology Modules (EPM)**, which supports human physiology experiments concerning body functions such as bone loss, circulation, respiration, organ and immune system behaviour in weightlessness;
- **European Drawer Rack (EDR)**, which provides a flexible experiment carrier for a large variety of scientific disciplines;
- Unpressurized platforms, which provide Sun observation (**SOLAR**) and exposure technology platform (**EuTEF**)

SOLAR

EuTEF



BIOLAB

FSL

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Research Facilities transferred to Columbus at a later stage

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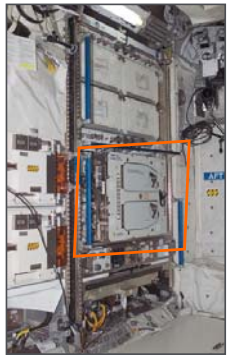
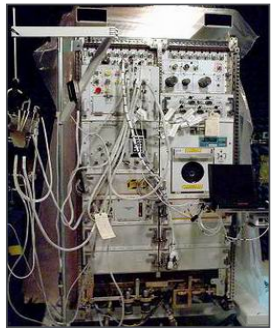
The ESA research facilities in Columbus have been complemented by 3 NASA racks transferred from US-Lab, and 1 additional ESA rack:

- **EXPRESS Rack#3 and European Modular Cultivation Systems (EMCS)**, which provides gas- and temperature-controlled environment, centrifuge and video capability to cultivate plants on orbit (transferred to Columbus in 2008)
- **Human Research Facilities (HRF-1 and HRF-2**), which support experiments in human physiology (transferred to Columbus in 2008);
- **Muscle Atrophy Research and Exercise System (MARES)**, which supports research on musculoskeletal, biomechanical, and neuromuscular human physiology (uploaded in 2010)

HRF-1 (2002)



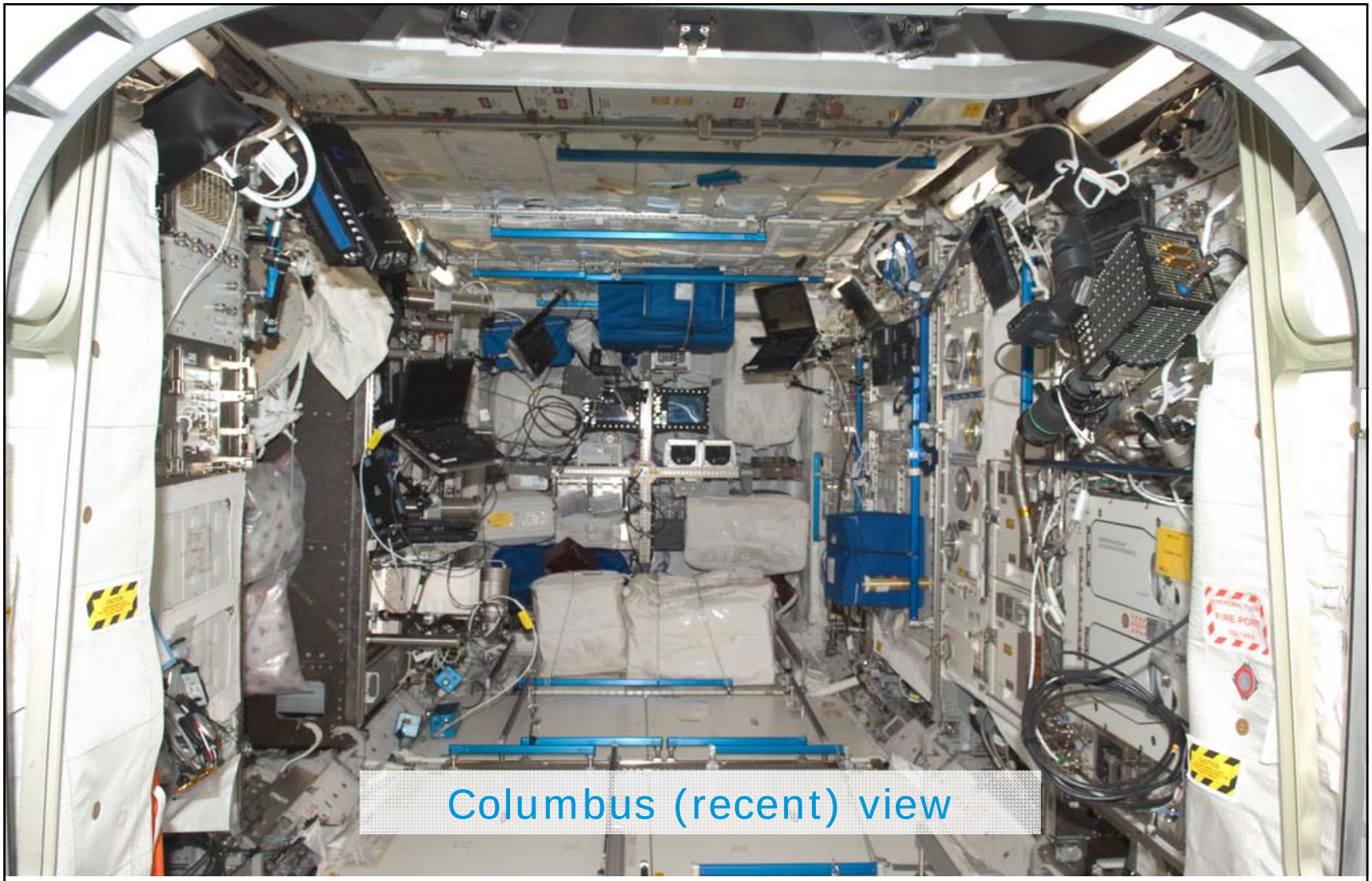
ER#3 / EMCS (2005)



HRF-2 (2005)

MARES (2010)

➔ With these racks, ESA is able to serve a large science community in both Life and Physical Sciences, and Exploration research fields.



Columbus (recent) view

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Future: outlook on new research facilities

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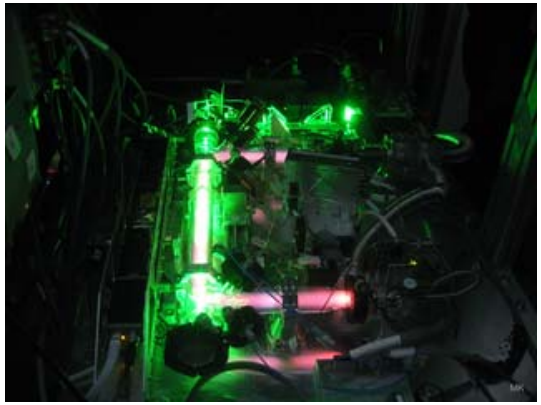
Future pressurized facilities

- **Electro Magnetic Levitator (EML)**
  - EML is a multi-user facility that provides containerless melting and solidification of electrical conductive, spherical samples, under ultra-high vacuum and/or high gas purity conditions. Heating and positioning of the sample is achieved by electromagnetic fields generated by a coil system;
- **Physics of Plasmas (Plasma-Kristal 4)**
  - PK-4 is a scientific laboratory-style payload for performing research in the field of 'Complex Plasmas'. These are low-temperature gaseous mixtures composed of ionized gas, neutral gas and micron-sized particles. The micro-particles become highly charged in the plasma and interact strongly with each other through the Coulomb force.

EML (principle)



PK4 (breadboard)

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Future: outlook on new research facilities

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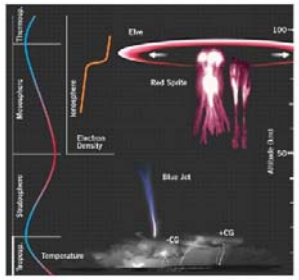
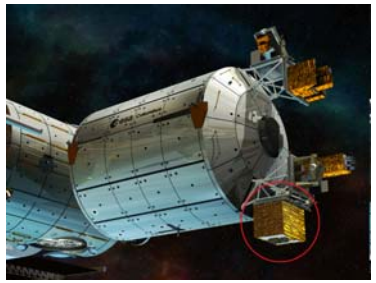
Future External payloads

- **Atmosphere Space Interaction Monitor (ASIM)**
  - observatory-type platform which will study giant electrical discharges (lightning) in the high-altitude atmosphere above thunderstorms and their role in the Earth's climate. The instrument payload is composed of light detectors, sensitive in the optical range (cameras, photometers) and in the X-ray to Gamma-ray ranges (imaging spectrometer).
- **Atomic Clocks Ensemble (ACES)**
  - Dual high precision clock assembly: Projet d'Horloge Atomique par Refroidissement d'Atomes en Orbit (PHARAO), Space H-Maser (SHM)
- **European Technology Exposure Facility (EuTEF-2)**
  - Provides a platform for further experiments in open space for Exploration preparation
- **Climate Change Monitoring Platform (TBC)**



ASIM



ACES

EuTEF-2

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ESA strategy: Basic and Applied Oriented Research

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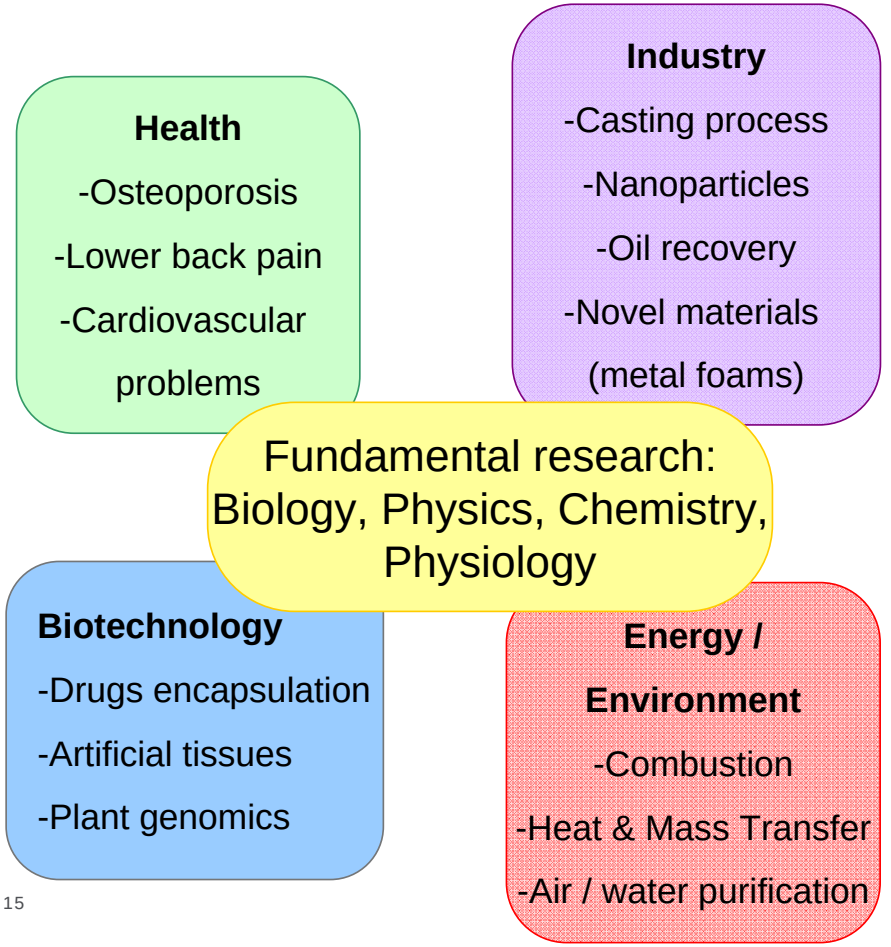
- Besides traditional “fundamental research”, ESA promotes application-oriented projects which:
  - regroup large multi-disciplinary science teams (coordinators and team members…rather than PIs);
  - include both Space and namely non-Space related European industries in R&D;
  - are supported by National Agencies, various Institutes or even the European Commission.
- A broad range of scientific and technology problems are investigated through a cross-disciplinary research strategy…



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ESA strategy: Multidisciplinary / Interdisciplinary approach

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– ESA is regularly asking for scientific feedback by independent reviewers (e.g. from the European Science Foundation), in order to:
  - Get an objective evaluation of the implementation status of research projects;
  - Collect novel ideas / concepts in the various Research Cornerstones;
  - Foster interdisciplinary approach;
  - Adapt the research strategy if necessary;

This feedback loop ensures that ESA can pursue a coherent strategy which matches the available research capabilities on orbit (and on ground)…

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ESA strategy: Multidisciplinary / Interdisciplinary approach

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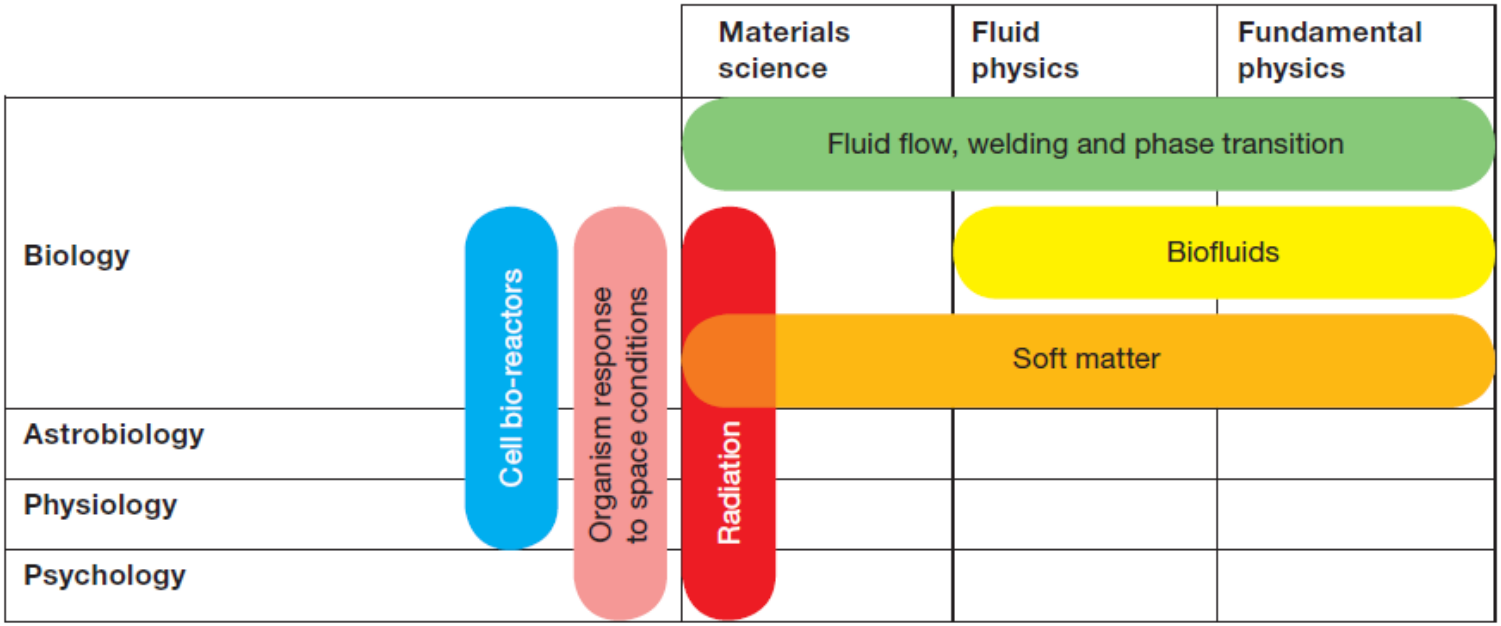
– New cross-discipline research fields are emerging, i.e. regrouping between Life / Physical Sciences research fields to tackle specific problems:



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ELIPS-3 program: current Research Fields

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Latest programmatic status: the ELIPS-3 program intends to provide Europe with a solid basis for achieving major progress in:

- Focused Fundamental Research in Life and Physical Sciences in Space within the following 6 main research disciplines:
  - General Physics;
  - Materials sciences;
  - Physics of fluids and combustion;
  - Exobiology;
  - Biology;
  - Human adaptation and performance.
- Applied Research, addressing societal needs in:
  - Diagnostics and novel treatments for age-related human diseases;
  - Lightweight and advanced materials for reducing energy needs and climate change;
  - Environment monitoring and control systems based on biotechnological components;
  - Advanced heat exchangers and boilers for energy savings.

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ELIPS-3 program: current Research Fields

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Latest programmatic status: the ELIPS-3 program intends to provide Europe with a solid basis for achieving major progress in:

- Industry-driven R&D and Technology Demonstrations, being the logical next step in the area of Applied Research, making end-user industries key stakeholders and investors in research exploiting microgravity conditions available in Columbus and other platforms.
- Enabling Research for Exploration in the areas:
  - Radiation biology and physiology;
  - Health care and human performance under extreme conditions;
  - Life-support and thermal control systems;
  - Food production in space;
  - Fluids processing in space;
  - Materials exposure and advanced materials;
  - Technology testing.
- Educational activities, exploiting the ISS and using the European astronauts as ambassadors of science towards the younger generations.

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ESA and European Commission: Cross-disciplinarity Life Sciences Matrix

EU policy / ESA R&D	Fundamental research	Environmental and clean technologies	Information and Communications technologies	Safety/Security	Health
Human Protection		Pollution monitoring	Telemonitoring Telemedicine	Environmental Hazards - detection, protection, monitoring, and mitigation	Tele-diagnostics Health monitoring
Inactivity and Isolation	Exercise Physiology Blood Pressure research Risks of a sedentary life style		Psychological support from remote locations		Osteoporosis Heart diseases Psychology support
Life Support	Recycling using biological systems	Air control and revitalization		Food, Water, and Air Quality Control	Food, Water, and Air Quality
Evolution and Ecosystems	Exobiology	Radiation biology, atmosphere, soil analysis		Biosensors and standoff detectors	

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ESA and European Commission: Cross-disciplinarity Physical Sciences Matrix

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EU policy / ESA R&D	Fundamental research	Energy	Environmental and clean technologies	Transportation	Information and Communications technologies	Safety/Security	Health
Dust, complex plasmas and quanta	- General physical principles - Relativity tests - Planetary physics	Plasma processes for advanced solar cells	Dust particulate monitoring and control	- Cold-atoms based space sensors - Time referencing	- Diamond p-n junctions via plasma processing - Quantum computing;	Quantum-based cryptography	- Aerosol monitoring and scavenging - Plasma medical sterilization
Materials and processing	- Self-organization of matter - Coupling with convection - Structure of molten alloys	- Fuel cell technology - Turbine technology	- Catalytic material - Insulation materials	- Nuclear power generators - Light weight materials - High-density batteries	- High performance sensors - Miniaturized systems	- Reliable structural materials; - Shock / sound damping structures - Advanced non-destructive testing systems;	- New biomaterials; - Optical diagnostics subsystems - Radiation shielding materials
Fluids and interfaces dynamics	- Fundamentals of diffusive processes - Dynamics of fluids - Vibrations in heterogeneous media - Phase transition	- Advanced heat exchangers - Cryogenic fluids - Efficient oil exploitation technique	- Supercritical fluid chemistry - Soil remediation - Waste treatment	- Cryogenic rocket engine subsystems - Power generators	- Data treatment systems for high data rate diagnostics	Disposal of chemical weapons	- Life support systems - Water treatment

- ESA contributions to ISS
- ESA research assets for a broad science community
- Utilisation achievements

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ESA ISS utilisation: Past achievements (2001-2005)



- Focus on (short-duration) Soyuz Missions: 10 days scientific program, nationally sponsored by individual ESA member states – more than 100 experiments performed;
- Since 2004, progressive ESA research activities build-up, with the involvement of US astronauts and Russian cosmonauts as test subjects / operators during ISS Increments;
- Steep (but paying off) learning curve with the ISS complex operations environment;
- Valorisation of the ESA Astronaut Corps.







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ESA ISS utilisation: Past achievements (2006-2007)

- Before Columbus Laboratory availability:
  - Comprehensive research program in cooperation with Russian entities (FSA, IBMP);
  - Experiments performance in ISS Russian Segment and US Segment;
  - ESA Long Duration Mission (LDM) – Astrolab: a very different mission than the Soyuz missions successfully performed between 2002 and 2005;
  - First long-term ESA astronaut on ISS (T. Reiter) and first operations from COL-CC in Germany;
  - Cooperation with Malaysian Space Agency (Angkasa);
  - Preparation for COLUMBUS activities;
  - Preparation of ESA Automated Transfer Vehicle (ATV).

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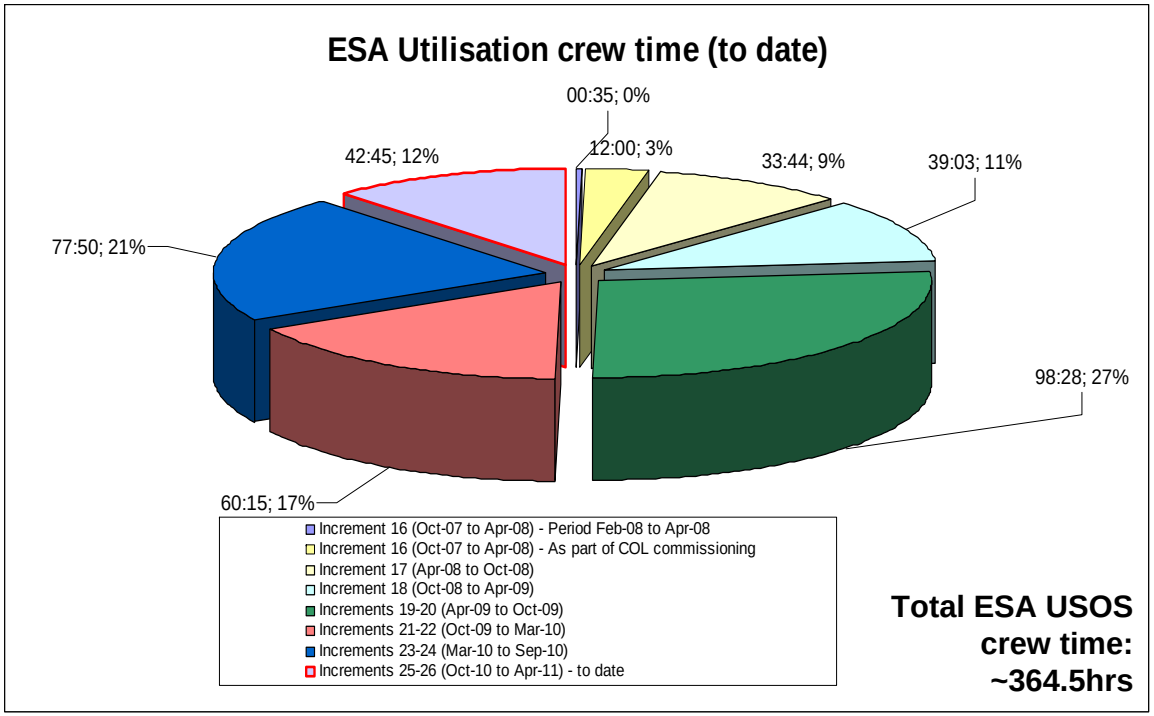
ESA ISS utilisation: Columbus deployment (2008-2010)

Deployment of COLUMBUS:

- Full use of the new research capabilities provided by the instrumentation racks;
- New possibilities to carry out simultaneously several experiments, thanks to a decentralized network of User Support Operation Centres across Europe;
- Progressively harvest the long-awaited science results with the telescience-operated payloads.



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ESA ISS utilisation: Columbus deployment (2008-2010)

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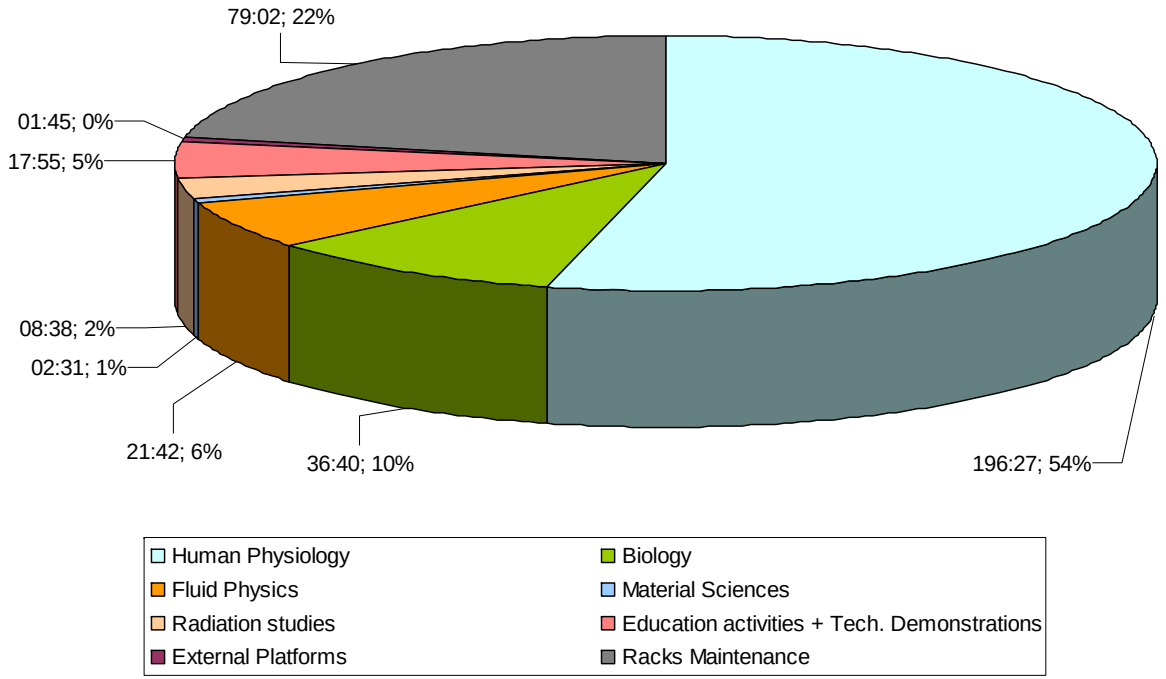
ESA Utilisation break-down per discipline (to date)



Total ESA USOS crew time: ~364.5hrs

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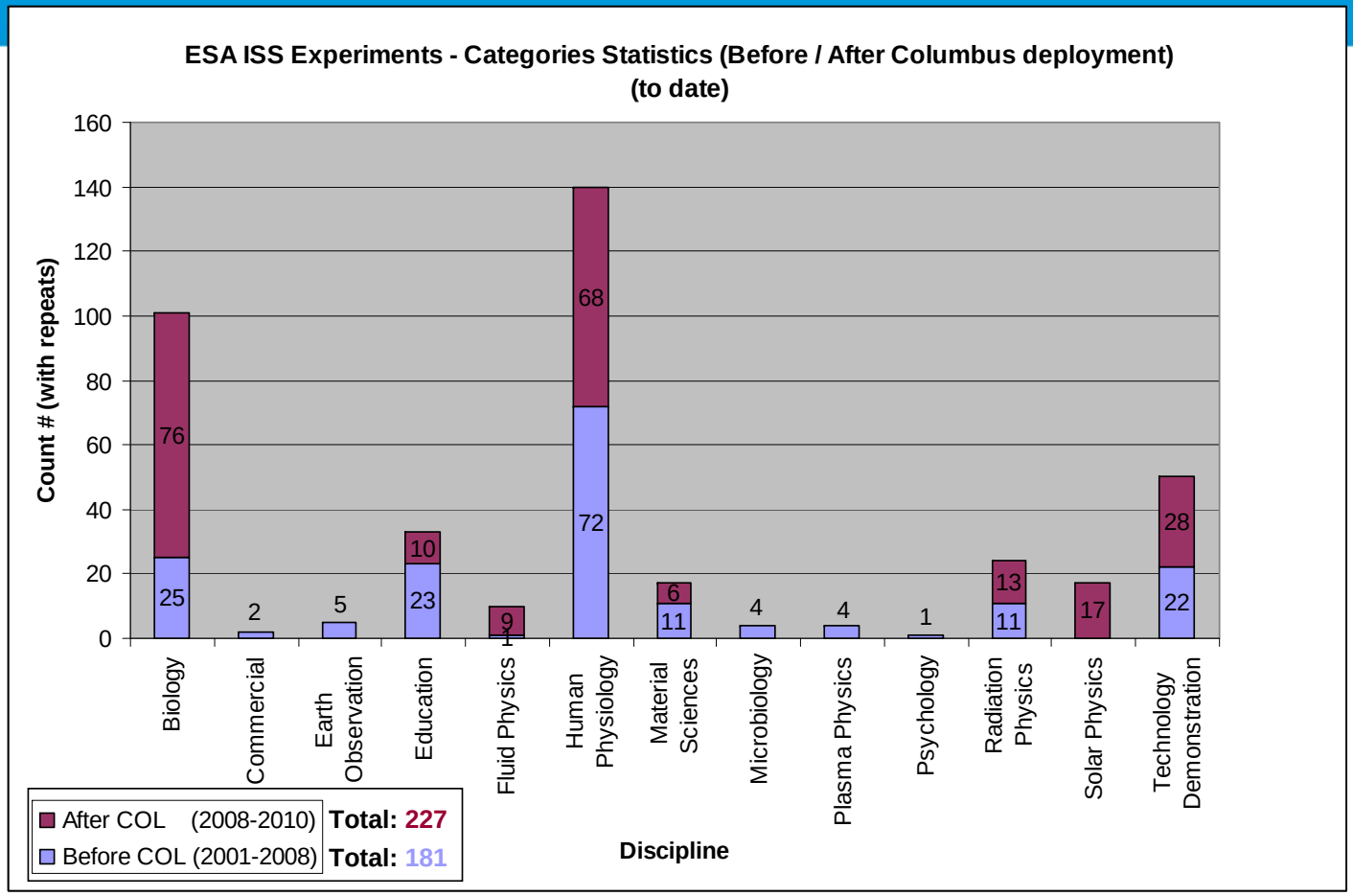
ESA ISS utilisation: Columbus deployment (2008-2010)



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ESA ISS Investigations statistics (2001-2010)