human spaceflight

esa

Human spaceflight:
Life and physical science in space

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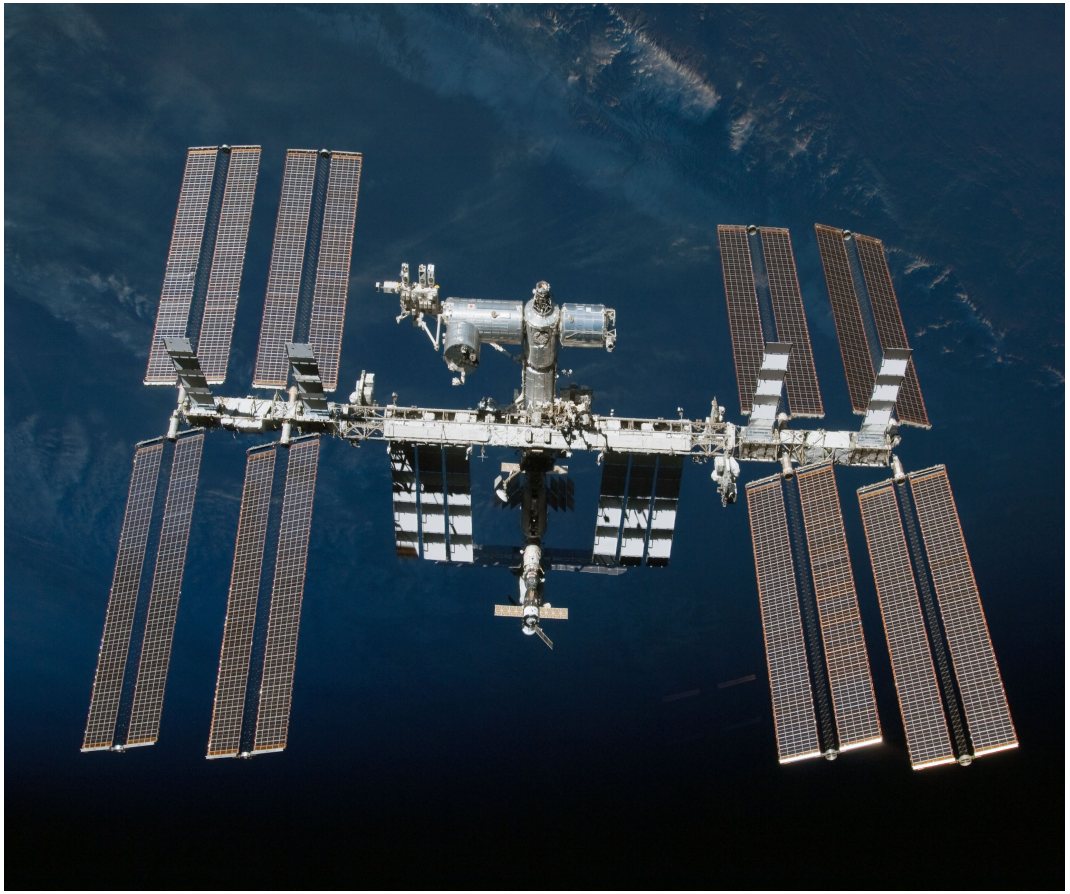
ELIXIR training School, ESTEC, 19-20 May 2011

Overview

- The International Space Station
- Overview on ELIPS: when, where, how
- Physics and life science experiments in space

The International Space Station

- Joint project of USA, Russia, Japan Europe, Canada, started in;
- Research laboratory *assembled* in low Earth orbit (300-400 Km);
- Home to a crew of six astronauts;
- Research laboratory, test bed for space exploration technology, manned outpost in space.

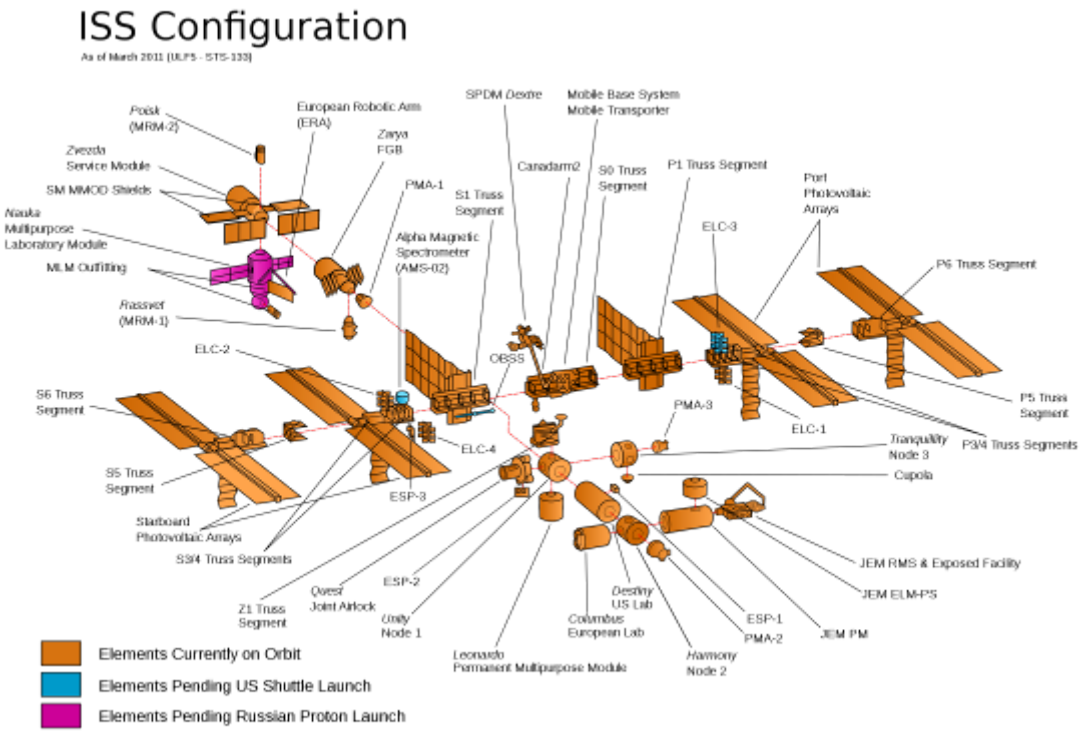


How does it work

–ESA contributes to the ISS infrastructure: Columbus laboratory, Automatic Transfer Vehicle (5), …;

–In return, ESA has a 8% share of resources for utilisation;

–ISS is NOT the only platform for science in space (more later);



ESA PROGRAMMES

All Member States participate (on a GNP basis) in activities related to space science and a common set of programmes (**Mandatory** programmes).

In addition, Member States choose their level of participation in **Optional** programmes.

Mandatory

- General Budget: Future studies, technological research, education, common investments (facilities, laboratories, basic infrastructure)
- Science: Solar System science, astronomy and fundamental physics

Optional

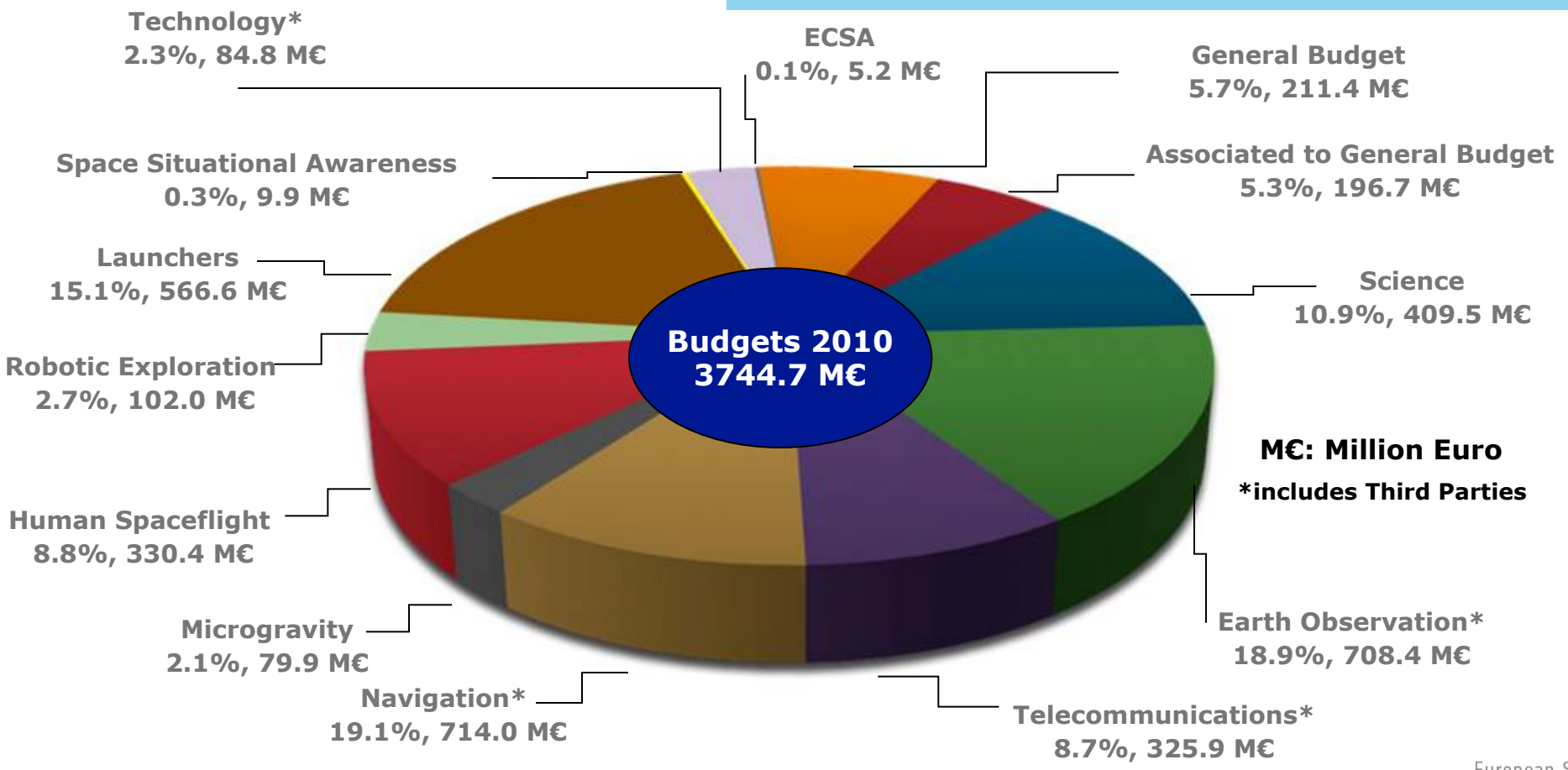
- Human spaceflight
- Telecommunications
- Earth observation
- Launchers
- Robotic exploration
- Space Situational Awareness

"Exploitation"

"Utilisation": The European programme on Life and Physical Science in Space **ELIPS**

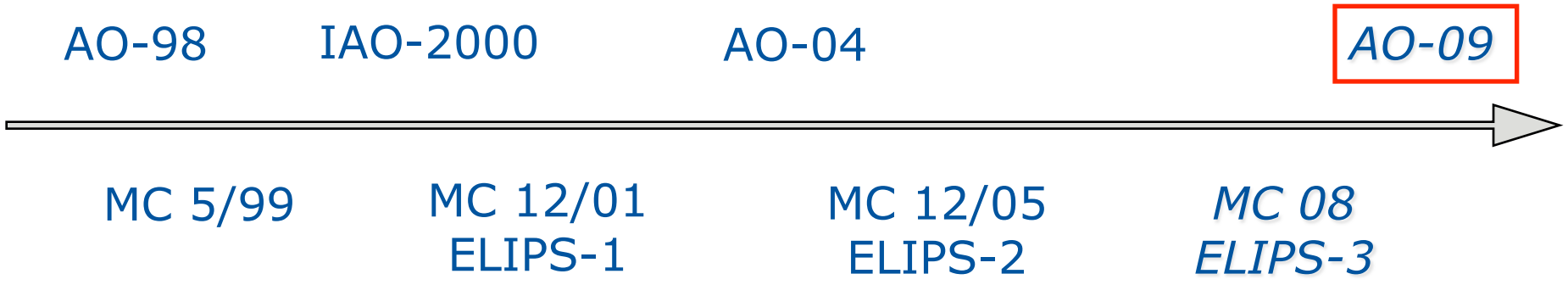
ESA BUDGETS FOR 2010

Programmes and mandatory activities	3739.5 M€
European Cooperating States Agreement (ECSA)	5.2 M€
Total	3744.7 M€

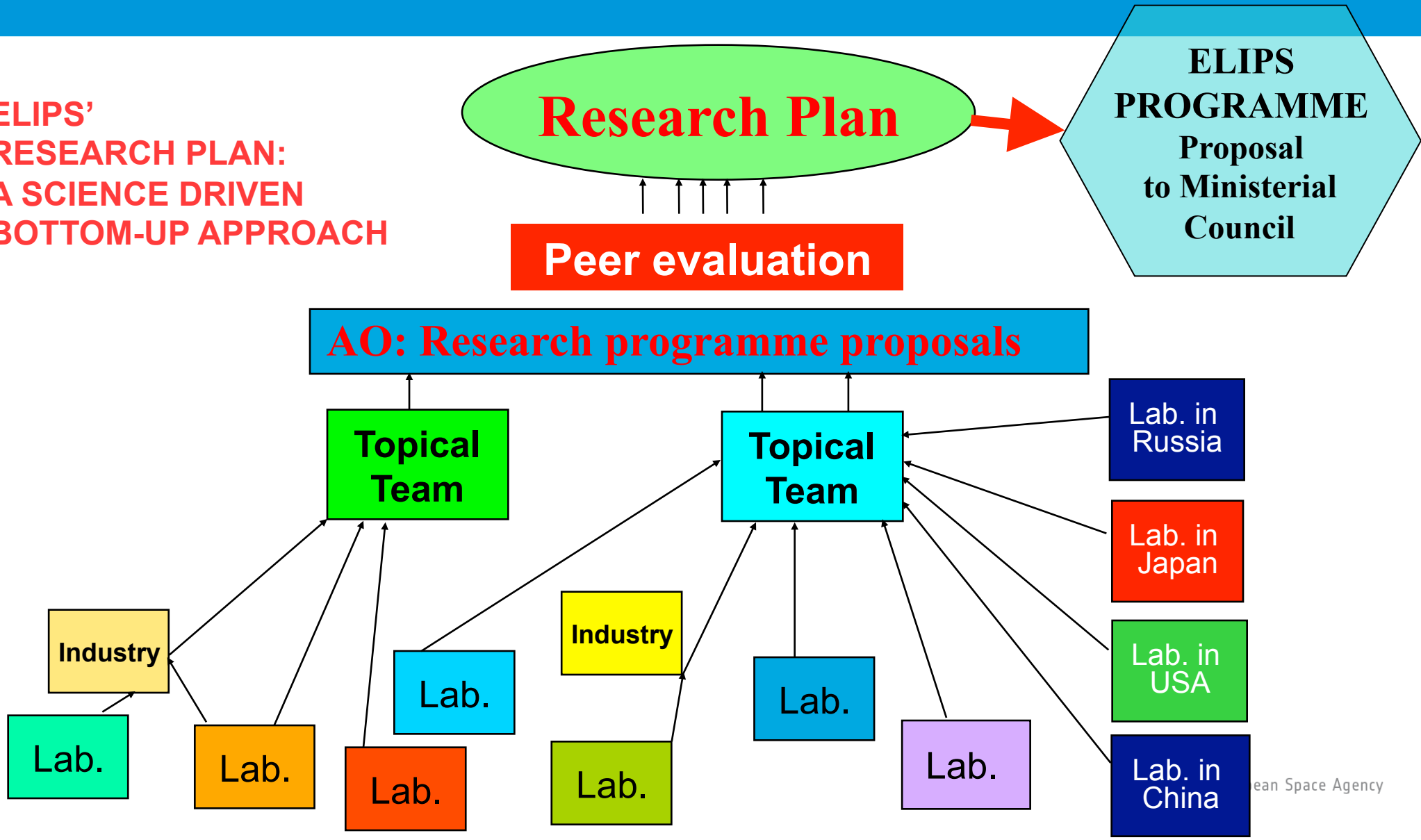


The European programme on Life and Physical Science in Space - ELIPS

- Research programme for experiments on life and physical science in space.
- ELIPS-1 started in 2001, presently in its third phase.
- "Utilisation" budget (285 K€ for 2008-2011) for development and launch of instrumentation, build by European industry. Science teams are funded through national space agencies.



ELIPS' RESEARCH PLAN: A SCIENCE DRIVEN BOTTOM-UP APPROACH



General physics	Materials sciences	Physics of fluids and combustion	Exobiology	Biology	Human adaptation and performance
Test of fundamental physics theories and measurement of fundamental constants to unprecedented levels of precision.	What are the thermophysical properties of high temperature melts?	What are the dynamics and the properties of interfaces?	Organic compounds and mineral interactions under space conditions	How does gravity alter development and performance of organ systems?	What are the mechanisms orchestrating organ systems interaction and recovery under variable gravitational levels (system homeostasis)?
Universal time scales, time transfer, and clock comparison at world scale	What is the influence of convection on the formation of different microstructures in alloys?	What are the key mechanisms of phase separation when coupled to evaporation and heat transfer in particular?	Polymerisation, stability and replication studies under space conditions	What are the molecular mechanisms for sensing and adaptation to variable g-levels by cells (microbial, fungi, plants and animals)?	What factors impair physical and cognitive performance?
Dynamics and properties of degenerate quantum gases in microgravity conditions	What is the influence of the processing conditions on the features of crystalline and amorphous phases of biological, organic and inorganic materials?	What is driving the stability of complex fluids? How does coarsening happen?	Response of pre-biotic building blocks to extraterrestrial conditions.	How do different gravitational levels interfere with the formation of multi-cellular structures (cell-cell, cell-extracellular matrix/ cellwall interactions)?	How can we assess and monitor health, psychological well-being and interpersonal relationships in conditions of isolation?
Matter wave interferometry from atoms to large molecules	Understand the fundamental link between materials processing, structure and properties of new light-weight structural metallic or intermetallic materials	Measure the chemical physics of bulk homogeneous samples of supercritical fluids	Mechanisms of survival and adaptation of extremophiles to extraterrestrial conditions	How does gravity modify the lifecycle from embryonic development to senescence?	What are the factors governing the inter-individual variability in the response to spaceflight conditions?
Higher performance atomic clocks in space, from the microwave to the optical domain		Understand the combustion process of dispersed systems		What are the biological responses to multiple stressors?	What are the human responses to multiple stressors?
Test of entanglement over long distances and quantum communication in space		Understand fundamentals of convection with model fluids systems. Study convective instabilities under conditions not realisable on Earth.		How do evolution and cross-interactions between organisms occur under space conditions?	Can one identify and validate optimal countermeasure strategies based on physical, pharmacological, nutritional and psychological interventions

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ELIPS Mission Platforms

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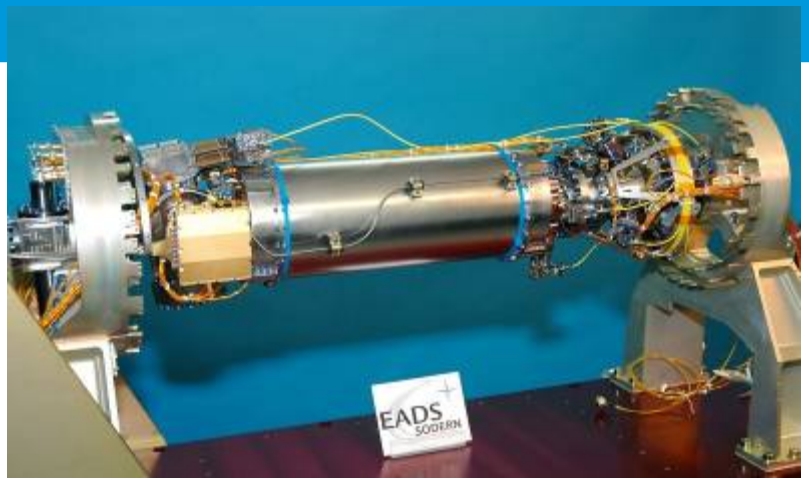
- **Fundamental Physics**
  - Physics of Plasmas and solid/liquid dust particles
  - Cold Atom Clocks, Matter Wave Interferometers and Bose-Einstein Condensates
- **Fluid Physics**
  - Fluid and Interface Physics
  - Combustion
- **Material sciences**
  - Thermophysical properties of Fluids for Advanced Processes
  - New Materials, Products and Processes

- **Biology**
  - Molecular and Cell biology
  - Plant Biology
  - Developmental Biology
- **Exobiology**
  - Origin, Evolution and Distribution of life
- **Physiology**
  - Integrative gravitational physiology
  - Non-gravitational physiology of spaceflight
  - Countermeasures

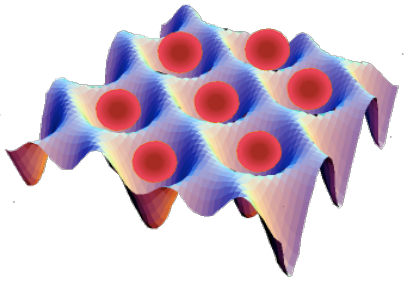
- **Planetary Exploration**
  - Preparation of Human Planetary Exploration

Fundamental physics

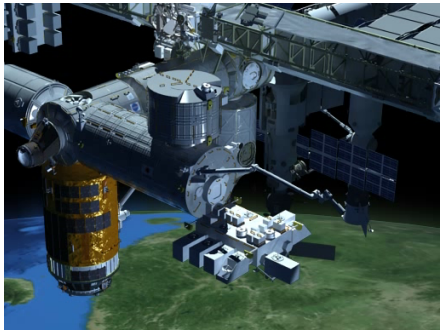


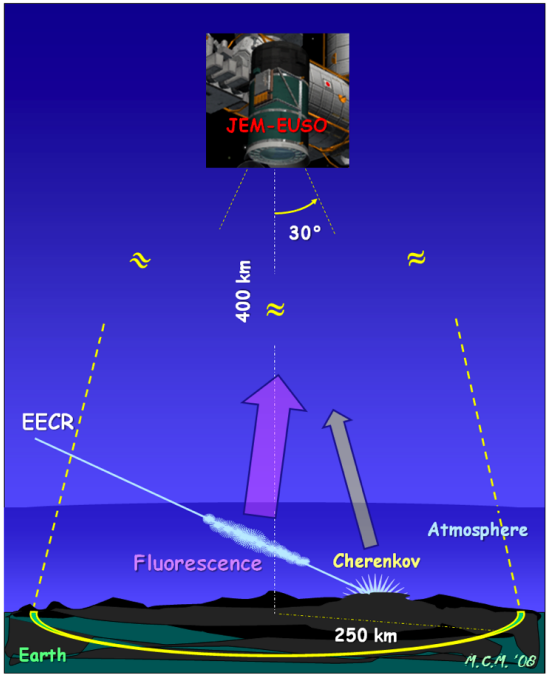
–The Atomic Clock Ensemble in Space (ACES) mission: launch on HTV in 2014-2015

–Second generation of cold-atom sensors for space: Strontium, Ytterbium

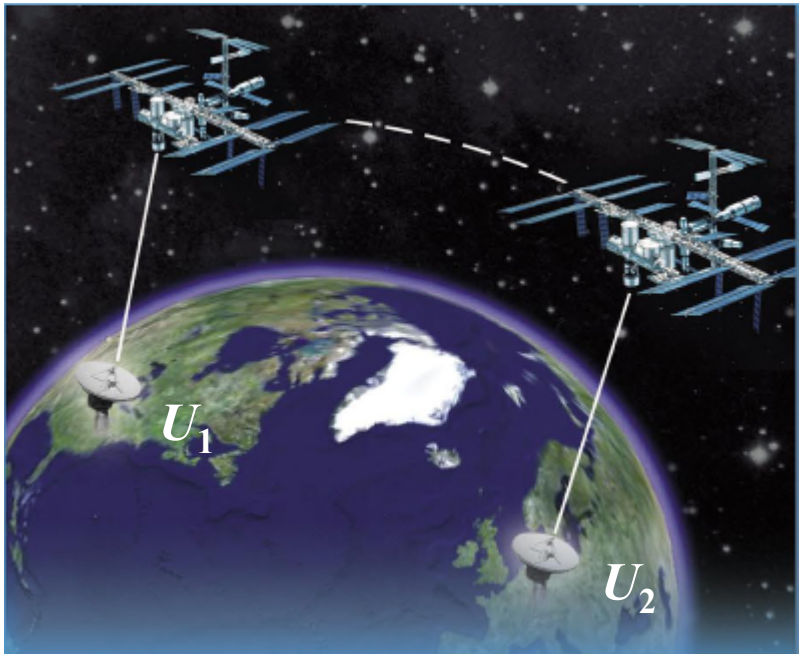


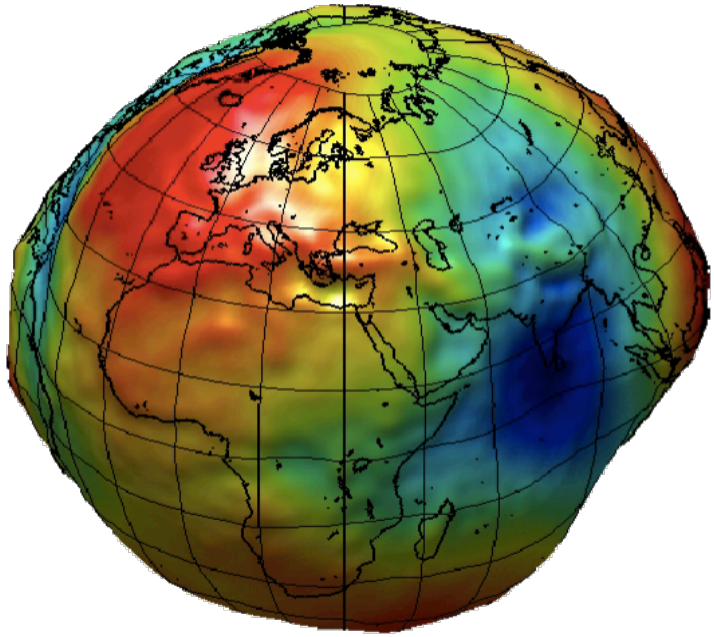
–Extreme Universe Space Observatory: JEM-EUSO (2.5 m near UV telescope, external)





ACES Mission Objectives	ACES performances	Scientific background and recent results
	Fundamental physics tests	
Measurement of the gravitational red shift	Absolute measurement of the gravitational red-shift at an uncertainty level < $50 \cdot 10^{-6}$ after 300 s and < $2 \cdot 10^{-6}$ after 10 days of integration time.	Space-to-ground clock comparison at the 10^{-16} level, will yield a factor 35 improvement on previous measurements (GPA experiment).
Search for time drifts of fundamental constants	Time variations of the fine structure constant α at a precision level of $\alpha^{-1} \cdot d\alpha / dt < 1 \cdot 10^{-17}$ year $^{-1}$ down to $3 \cdot 10^{-18}$ year $^{-1}$ in case of a mission duration of 3 years	Optical clocks progress will allow clock-to-clock comparisons below the 10^{-17} level. Crossed comparisons of clocks based on different atomic elements will impose strong constraints on the time drifts of α, m_e / Λ_{QCD}, and m_p / Λ_{QCD}.
Search for violations of special relativity	Search for anisotropies of the speed of light at the level $\delta c / c < 10^{-10}$.	ACES results will improve present limits on the RMS parameter α based on fast ions spectroscopy and GPS satellites by one and two orders of magnitudes respectively.





Relativistic geodesy: mapping of the Earth gravitational potential based on the precision measurement of the red-shift experienced by two clocks at two different locations

- ACES will perform intercontinental comparisons of optical clocks at the 10^{-17} level after 1 week of integration time, measuring the local height of the geoids at the 10 cm level.
- The global coverage offered by ACES will complement the results of the CHAMP, GRACE, and GOCE missions.

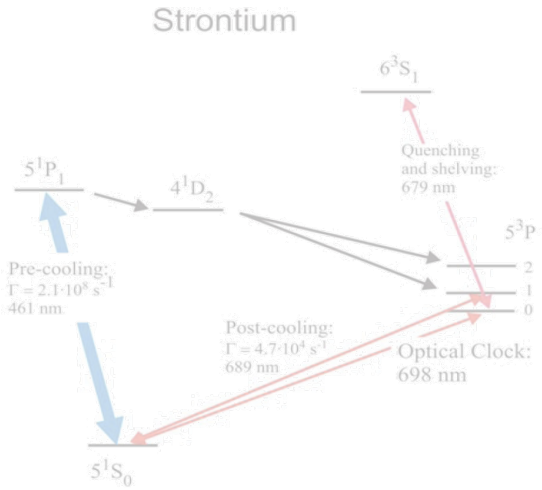
Space Optical Clocks: Clock ensemble in space based on the optical transitions of strontium and ytterbium atoms for fundamental physics tests in space.

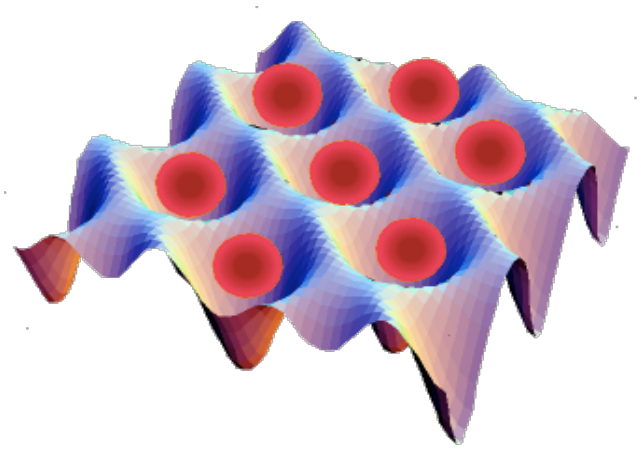
Team: Düsseldorf Univ. (D), SYRTE (F), ENS (F), PTB (D), Firenze Univ. (I)

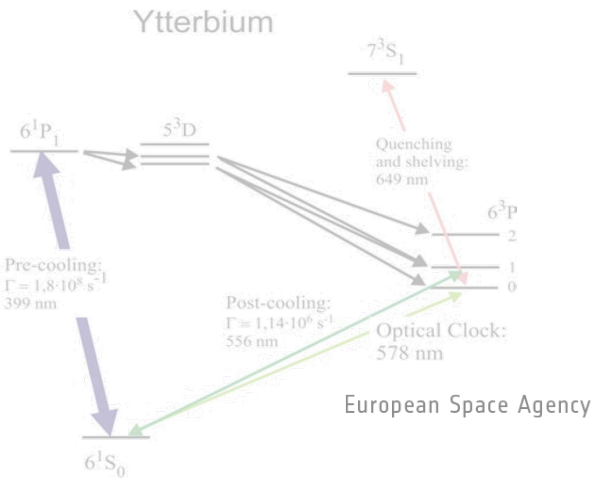
Status: Pre-phase A study to realize ground-based prototypes of atomic clocks based on Sr and Yb optical transitions as first step towards space qualification. SOC-2 project selected from a Space Call of the EC

Objective: Optical clock reaching 10^{-17} stability and accuracy for a mission opportunity on the ISS in 2018-2020.

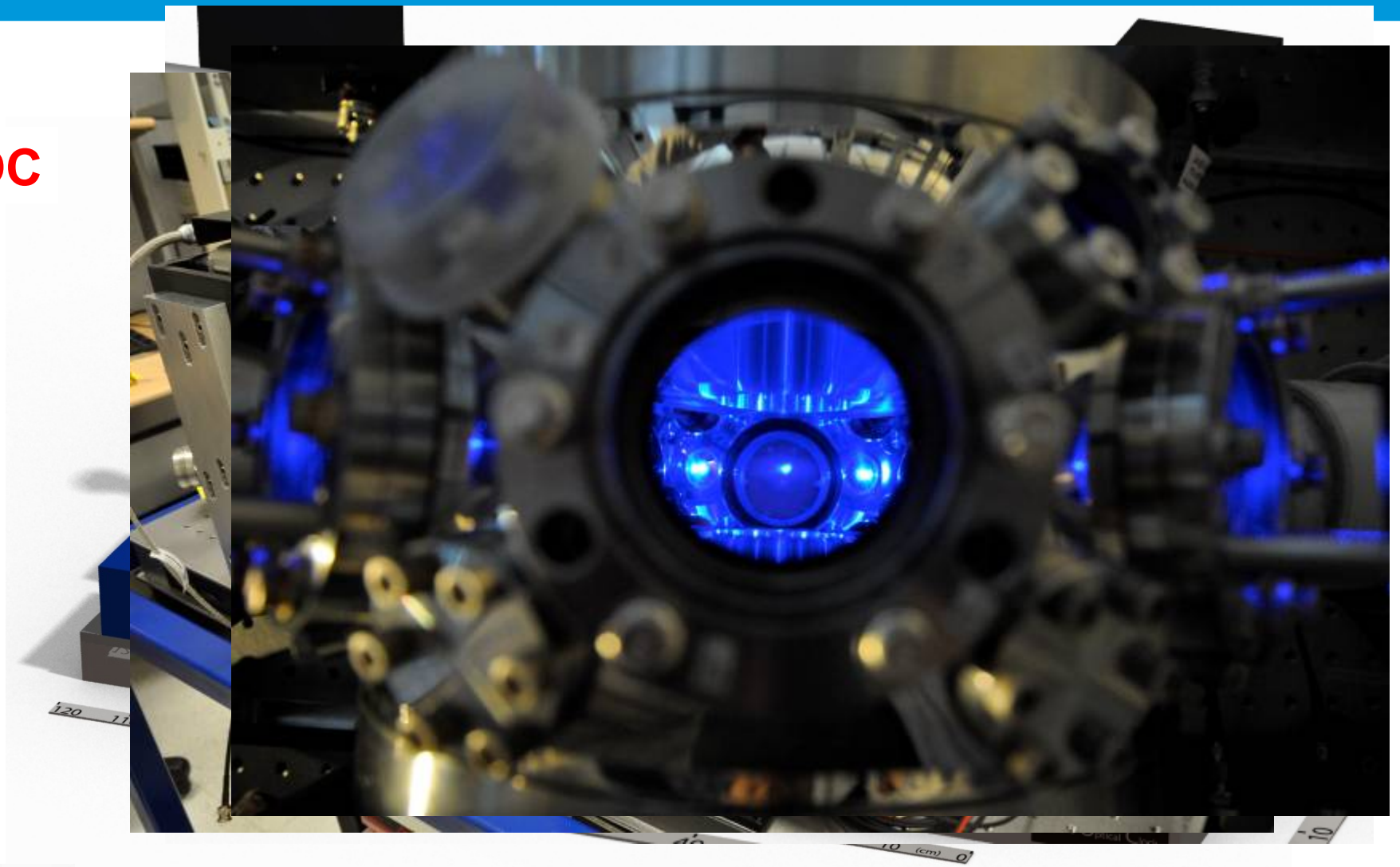
Cooperation of US teams is welcome







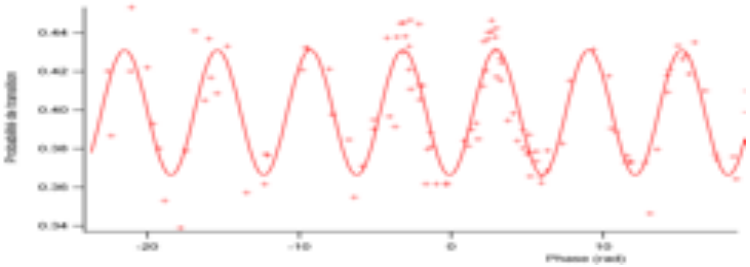
SOC



ICE Supported by CNES

Q-WEP

2010 - 2012 : Airborne test of the Universality of free-fall.

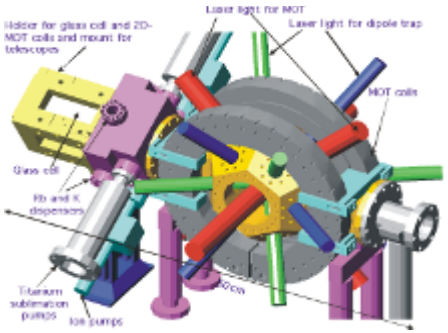


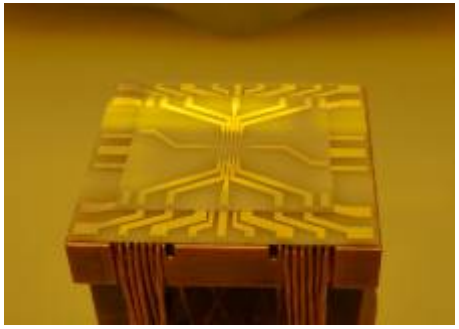
The I.C.E. team performing interferometry during parabolic flights

Quantus supported by DLR

Q-WEP

- Test of chip-based and all-optical atom lasers for precision inertial sensing
- Study of evolution & control of ultra-cold potassium and rubidium ensembles
- Test of free fall of isotopes of potassium and rubidium





SAI supported by ESA

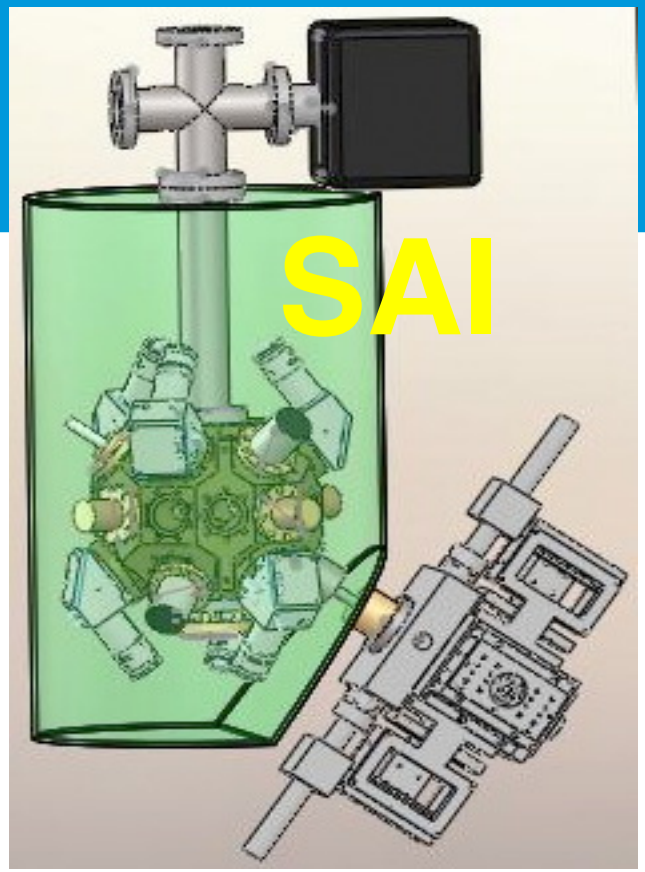
Q-WEP

2011-13 Tests with current prototype

2011-14 Extension to dual-species differential measurement using ^{87}Rb and ^{85}Rb, at the level of $5*10^{-15}$ m/s2.

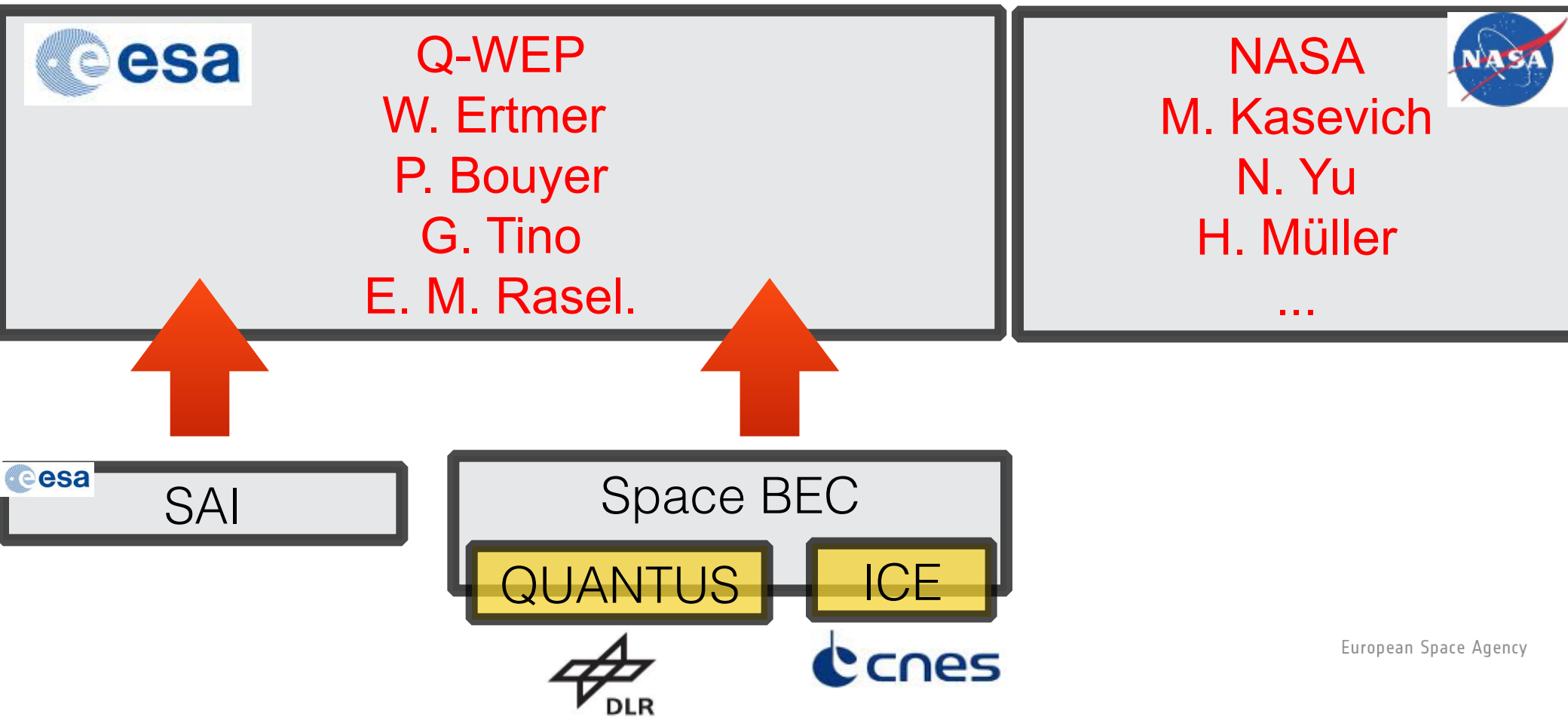
2012-16 Development, Tests and validation of breadboards and component EMs on the ground and in the air

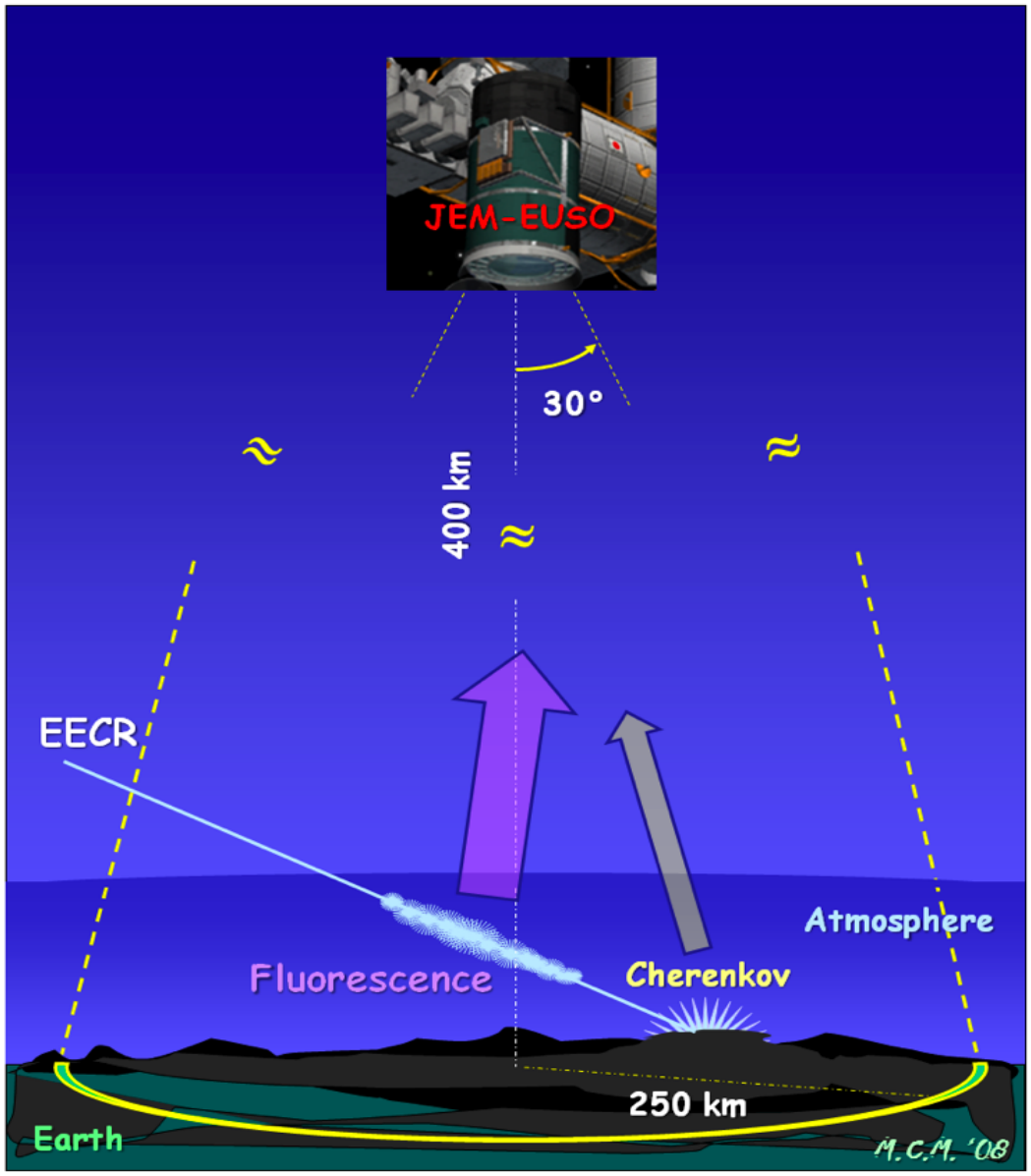
2016-18 Development of a flight model and ground facilities verification campaigns



Q-WEP

ESA project on a joint initiative to test of the weak equivalence principle with quantum matter to parts in $10^{14/15}$





JEM-EUSO

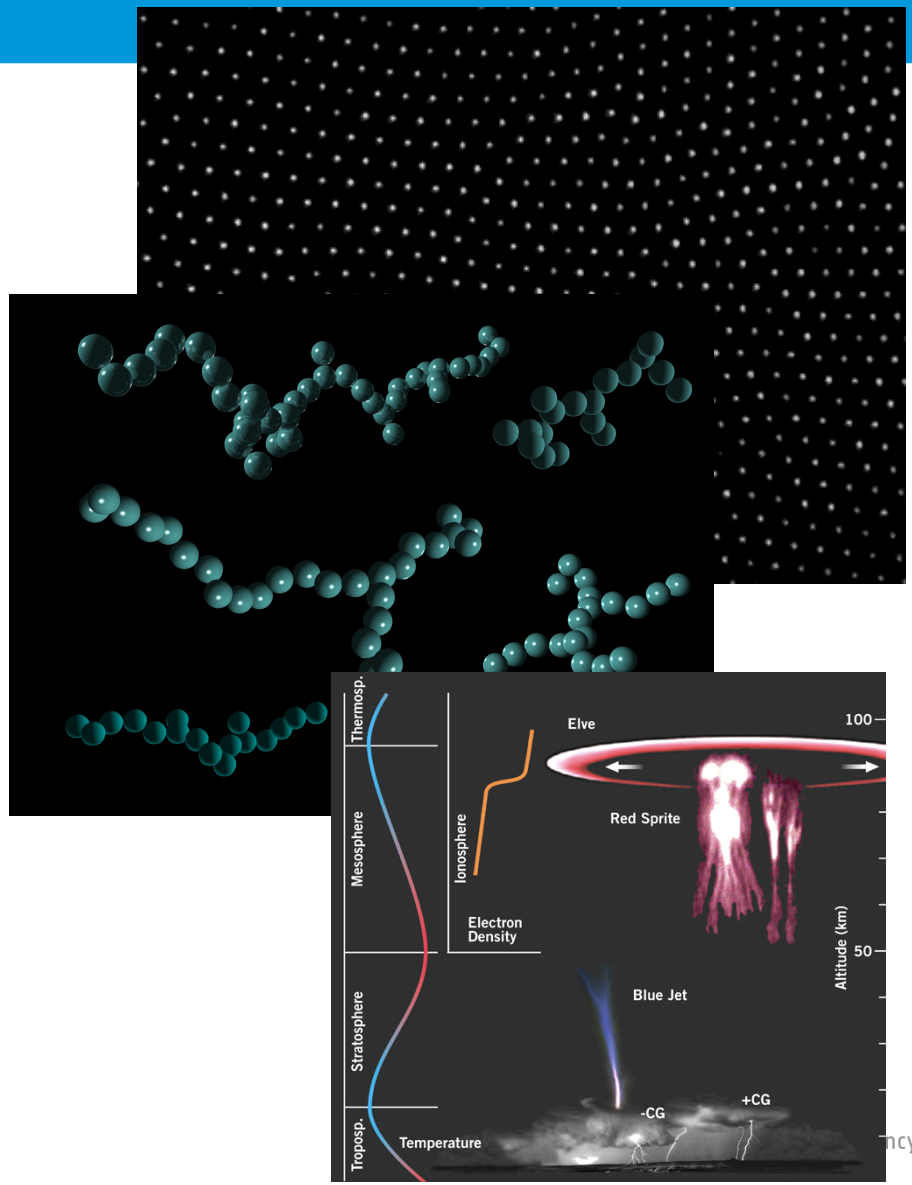
THE IMPLEMENTATION OF THE JEM-EUSO PROJECT CAN ONLY BE BASED ON AN INTERNATIONAL COOPERATION AGREEMENT BETWEEN JAXA, NASA, ESA AND ROSCOSMOS

Fundamental physics

–Complex plasmas: dynamics of particles in plasmas (PK-4);

–Simulation of dust agglomeration in molecular clouds and star-forming regions (ICAPS)

–Studies high altitude optical emission on upper atmosphere and near-Earth space and transient luminous events (external payload) (ASIM)

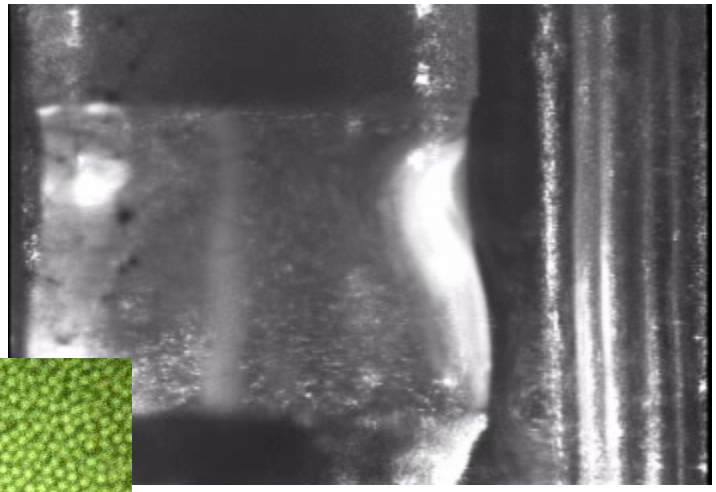


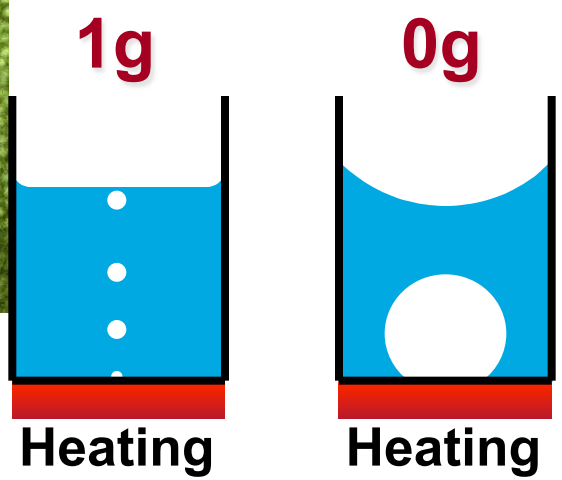
Fluid physics

–(Chemo)-Hydrodynamic instabilities: “thermal” convection, thermocapillary convection, biomimetic fluid flows

–Soft matter: foams, emulsion, colloids. Fundamental problems of solidification and stability.

–Boiling and evaporation, heat transfer, heat pipes



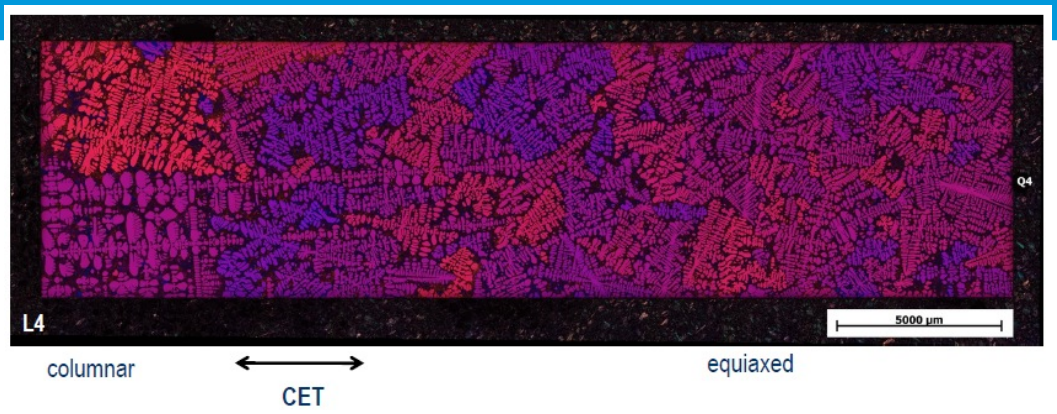


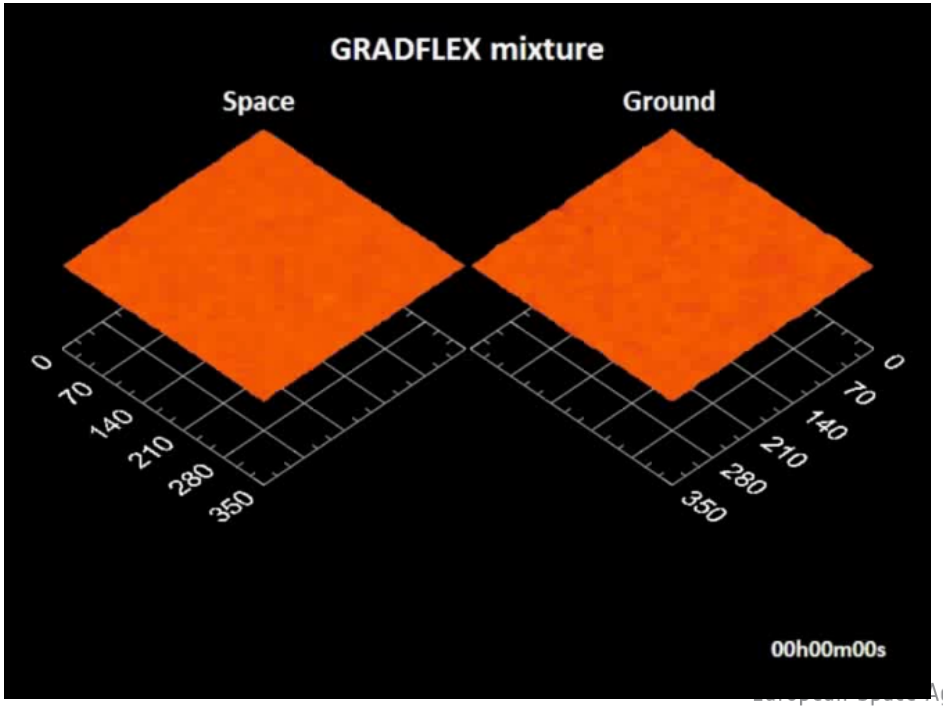
Material science

–Thermophysical properties of fluids: metallic and non-metallic; formation of microstructure in solidification of metallic alloys

–Measurement of diffusion and thermodiffusion coefficients in hydrocarbon mixtures

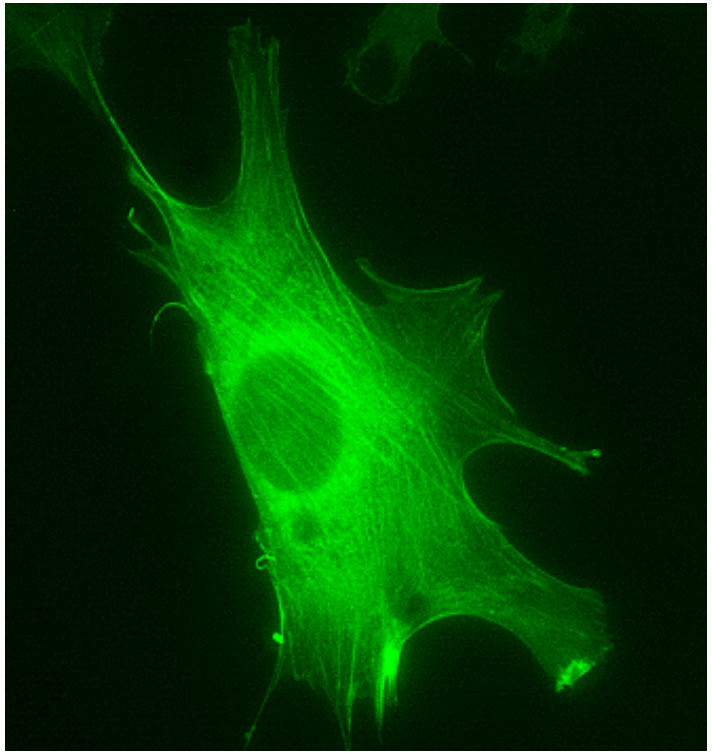
–Diffusion in absence of gravity





Biology

- **Fundamental Research**
  - What role does gravity play in biological processes?
- **Support space exploration**
  - Understand the mechanism by which spaceflight affects processes relevant to human physiology
    - Osteoporosis,
    - immune system
  - Effects of cosmic radiation / dosimetry



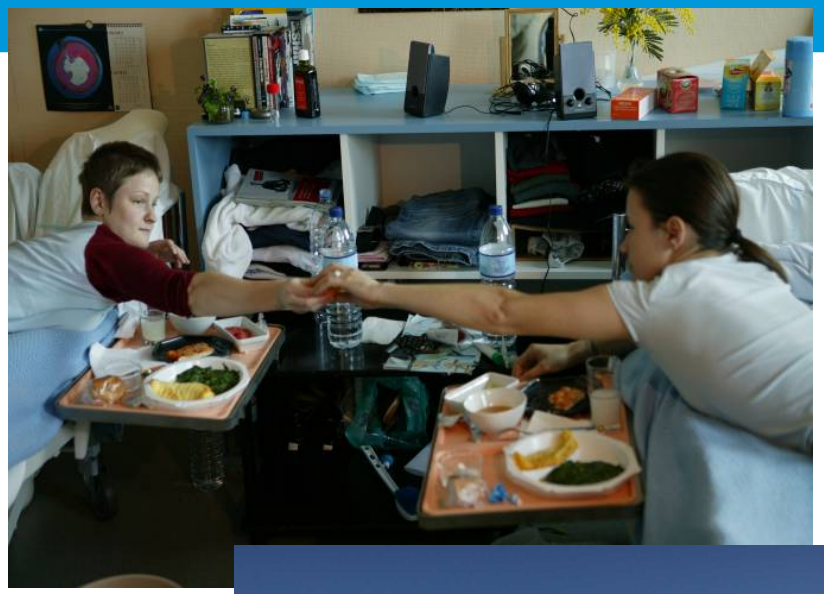
Human Physiology

- What are the mechanisms orchestrating organ systems interaction and recovery under variable gravitational levels (system homeostasis)?
- What factors impair physical and cognitive performance?
- How can we assess and monitor health, psychological well-being and interpersonal relationships in conditions of isolation?
- What are the factors governing the inter-individual variability in the response to spaceflight conditions?
- What are the human responses to multiple stressors?
- Can one identify and validate optimal countermeasure strategies based on physical, pharmacological, nutritional and psychological interventions

Ground studies

–Bed rest (Induces Physiological changes similar to those induced by exposure to weightlessnes)

–Isolation studies: Mars500 (simulation of full Mars mission), Concordia (antarctic base).



ELIPS at a glance

PROJECTS

ISS, Sounding Rockets, Free Flyers		
Physics (All)	**68**	
Fundamental physics: quantum and cold atoms	6	
complex plasmas, dust particles and atmospheric physics	6	
Fluids	23	
Thermophysical properties	9	
Crystallisation and soldification	24	
Life Sciences (All)	**95**	
Hyman Physiology	48	
Biology (all)	47	
ISS Biology		26
Sounding Rockets		11
Rodents		7
Miscellanous / Free flyer		3
TOTAL ISS and SR	**163**	
IBER	15	
Bed Rest	46	
Mars500	15	
Concordia	8	
GBF	11	
TOTAL ALL	**258**	

INVESTIGATORS

(approximate numbers, but individual – no double counting)

ISS	900
SR and FF (additional to ISS)	150
IBER	80
Bed Rest	180
Mars500	110
Concordia	40
GBF	40
TOTAL	**1500**

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Thank you