ESA ELIPS Programme & ISS Utilisation

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ELIPS - European Programme for Life and Physical Sciences in Space

- ELIPS is ESA’s programme for **science and applications** on variety of low gravity and spaceflight analogue platforms.

- Approximately 260 projects involving 1500 scientists in current programme


- ELIPS-4 is a 210MEuro programme

- Support Industrial applications and involvement of industrial partners
20 ESA MEMBER STATES
11 in ISS, 17 in ELIPS

Austria, Belgium*, Czech Republic, Denmark*, Finland, France*, Germany*, Greece, Ireland, Italy*, Luxembourg, Norway*, the Netherlands*, Portugal, Spain*, Sweden*, Switzerland* and the United Kingdom*, Romania, Poland

Canada takes part in some programmes under a Cooperation Agreement.

Hungary, Slovenia, and Estonia are European Cooperating States. Cyprus and Latvia have signed Cooperation Agreements with ESA.

* = ISS Program participants (11)
ELIPS Program participants (15)

Note: Many scientists from countries outside ESA participates in ELIPS projects
ELIPS Research Fields:
Broad Based & Multidisciplinary

**Focused Fundamental Research**
- Fundamental Physics
- Fluid and Interface Physics
- Combustion Physics
- Material Sciences
- Space Biology
- Human Physiology

**Applied Research:**
- diagnostics and novel treatments for age-related diseases
- biotechnological solutions
- lightweight and advanced materials
- energy and waste saving processes
- advanced heat transfer processes
- environment monitoring and control

**Industry-driven R&D and technology demonstrations**
- On-orbit analysis technologies
- Novel materials and on-orbit synthesis processes

**Human Exploration Preparation**
- Enabling Research for Human Exploration (ground-based analogues and ISTAR/Mars500-ISS):
- Human research and space risks mitigation

1500 European scientists involved in approximately 260 investigations in the current ELIPS programme.
The broad interdisciplinary research in ELIPS is supported by access to wide range of platforms, as well as networking opportunities.

- **Investigator Working Groups**
- **Topical Teams**
- **ISS (days, weeks, months)**
- **Sounding Rockets (6-13 min)**
- **Parabolic Flight (20s)**
- **Drop tower (4-9s)**
- **Heavy Ion Radiation Biology (IBER - GSI)**
- **Access to Ground Based Facilities**
- **Short, medium, Long Duration Bed Rest**
- **Isolation Studies**
Drop Tower and Ground Based Facilities

- **Drop Tower Campaigns:** The ZARM Drop Tower Facility (Bremen, Germany) features a 110 meter high drop chamber with a diameter of 3.5 m that can be evacuated. After integration, the capsule is either elevated or catapulted to the top of the tower providing a free-fall duration of 4.7 or 9 seconds respectively with residual accelerations lower than 10^-5 g is achieved. Four drop tower campaigns were completed in 2012, supporting various physical science experiments as well as student “drop your thesis” campaign.

- **Ground Based Facilities:** A variety of ground based facilities at institutions across Europe are accessible to scientific teams via ELIPS, including centrifuges, random positioning machines, clinostats and radiation facilities.

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**Ground Based Facilities**
Head Down Tilt Bed Rest
Simulate unloading and fluid shift occurring during space flight; physiological changes parallel those occurring during spaceflight
- Statistically significant number of subjects
- Healthy subjects supine for 5, 21 or 60 days
- Multiple studies performed, average of 1 study per year
- Interventions to be tested are defined through CFI / Workshop process
- Expert groups define protocol of countermeasures i.e., artificial gravity, nutrition, vibration exercise
- Standardisation:
  a. bedrest conditions
  b. core measurements
- AO (Announcement of Opportunity) every 2-3 yrs
- Recent Bedrests
  MEDES, Toulouse
    2010 Short Duration / Artificial Gravity
    2012 Medium Duration / Exercise & Nutrition
  DLR institute, Cologne
    2010 Short Duration / Exercise
    2010 Medium Duration / Nutrition
    2011/12 Medium Duration / Nutrition
ESA and Concordia: ESA is cooperating with the Antarctic station Concordia since 2001. Concordia is an Analogue Environment for exploration missions, due to its characteristics (hostile environment, extreme isolation of crews, changed day/night cycle, no emergency return possible in winter etc.)

External Medical Monitoring Device: SYSTEM FOR LONG-TERM MEDICAL SURVEY DURING OUTDOOR ACTIVITIES (LTMS-X). Device will be used to monitor crew members when they go outside Concordia.

Internal Medical Monitoring Device: The prototypes of the SYSTEM FOR LONG-TERM MEDICAL SURVEY (LTMS) were tested in the 2008 and 2011 season. The LTMS is an easy-to-use integrated medical monitoring device developed by ESA for monitoring crew members when they are inside Concordia.
Short Duration Microgravity or sub 1.g (lunar, martian gravity), up to 20s

2-3 Campaigns per year with multiple flights

- Permits short duration physiology experiments to be performed, as well as Biology and physical sciences experimentation
- Investigator team participates inflight, permitting real time adjustment & operation of experiment
### Payload weight
- **Rexus**
  - total: 160 kg
  - scientific: 110 kg
- **Maser/Texus**
  - total: 370 kg
  - scientific: 285/260 kg
- **Maxus**
  - total: 800 kg
  - scientific: 485 kg

### Sci. Payload diam./length
- **Rexus**: 0.43/1.5 m
- **Maser/Texus**: 0.43/3.3 m
- **Maxus**: 0.64/3.5 m

### Apogee
- **Rexus**: 140 km
- **Maser/Texus**: 250 km
- **Maxus**: 750 km

### Microgravity level
- **Rexus**: $\leq 10^{-4}$ g
- **Maser/Texus**: $\leq 10^{-4}$ g
- **Maxus**: $\leq 10^{-4}$ g

### Microgravity time
- **Rexus**: 3 min
- **Maser/Texus**: 6-7 min
- **Maxus**: 12-13 min
Maxus and Texus Sounding Rockets
Before ISS –

ESA Multi-User Facilities for Spacelab / Space Shuttle

- BIORACK Biology Facility
- Spacelab D-1, IML-1, IML-2, IML-3, IML-4, IML-5
- SpaceHAB S/MM-03, S/MM-05, S/MM-06
  - 80+ Experiments flown
  - 380+ publications & reports
- BIOPACK (STS-107) small biology facility and portable glovebox
ESA Spacelab module
(used on 25 mission 1985-1998)

- European contribution to Shuttle programme
- Modular system of pressurised labs, pallets, external instrument platforms and interfaces
- Multi-user rack in pressurised modules, supporting research in life and physical sciences
BIORACK (Shuttle – Spacelab/SpaceHab)

- Incubator
- Standard container interface
- Type-I
- Type-II
- Glovebox
International Space Station (ISS)

- Large permanently inhabited space station in low Earth orbit with a crew of 6
- Fully assembled with several laboratory modules and elements provided by International Partners (United States, Russia, Europe, Japan and Canada)
- ESA Columbus laboratory module with several multi-user life and physical science facilities
- ESA Automated Transfer Vehicle for resupply
- Facilities and resources shared between partners
  - Laboratory modules and facilities (incl. cold stowage)
  - Transportation, to and from ISS on a variety of visiting vehicles
  - Crew time, data and operations
- ESA has rights to use 8.3% of USOS ISS resources
- Continuous operation provides flexibility for replanning, multiple experiment runs
**ISS Transportation Logistics**

- **Launch Site:** Baikonur
  - **Late Access:** L-14h

- **Launch Site:** KSC
  - **Late Access:** L-12h

- **Launch Site:** Kourou
  - **Late Access:** L-weeks

- **Launch Site:** Tanegashima
  - **Late Access:** L-weeks

- **Launch Site:** Wallops
  - **Late Access:** L-weeks

**Passive temperature control available**

- **Launch – hatch opening time**
  - L+60 to L+90h

- **Launch – hatch opening time**
  - L+3d?

- **Launch – hatch opening time**
  - >L+6d

- **Launch – hatch opening time**
  - >L+8d

- **Launch – hatch opening time**
  - >L+3d?

**Experiment Transfer to vehicle to landing:**

- ~36h
- 2d?

**Experiment Handover**

- Landing to handover in Moscow ~12h
- Landing to handover in JSC ~40h

**Experiment return to scientists**

- Download
- Upload
Flight Program Working Group (FPWG)

Crew Rotation and Port Utilization Graphic – For Reference Only

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ESA ISS Research laboratory

- **Internal Accomodation**
  - Research **Facilities** accommodated in racks
  - Direct crew interaction possible with experiments

- **External Accomodation**
  - Columbus External Payloads Facility (CEPF)

- **Commanding and data**
  - Communication integrated into USOS communication architecture
  - Video, data and commanding
  - Each Facility operated by a User Support Center (USOC)
ESA’s ISS Facilities

External Payloads:
- ASIM
- ACES
- EXPOSE

Climate Change

European Drawer Rack

European Physiology Module

Fluid Science Lab

BIOLAB

European Transport Carrier

ER-3 EMCS

MSG

HRF - 1/-2 PFS

HRF - MARES

PCDF

KUBIK

SOLAR

ASIM, ACES, EXPOSE

KUBIK

MEEMM + CardioLab

PCDF

3x MELFI

MATERIAL SCIENCE LAB
ISS as a space-based observation platform

300-460 km, 51.6° inclination orbit
- Covers ~85% of earth surface & ~95% population
- Distance to earth limb ~ 2300km
- 16 orbits / day – non sun synchronous

Infrastructure for instrument operation
- JAXA: SMILES – Trace gase measurement in stratosphere; Apollo – Troposphere pollution
- NASA: SAGE-3; Ozone measurement; HICO – Hyperspectral Imager for Coastal Ocean
- ESA: SOLAR – Solar Irradiance measurements;
- ASIM – Transient Luminous Events above Thunderstorms
- GEROS – GNSS Reflectometry, Scatterometry
- ACES – Atomic clock; applications to Geodesy
ESA Facilities for Bio/Exobiology

- European Modular Cultivation System (BIOLAB)
- ISS
- EXPOSE-E & EXPOSE-R
- KUBIK
- European Modular Cultivation System

Non-ISS Facilities:
- Sounding Rockets
- Parabolic Flight
ISS KUBIK Facility

Small Incubator / refrigerator
- +6°C to +38°C
- Mechanical & electrical interfaces for experiments
- Standardised experiment inserts
- 1g centrifuge available
- KIP interface plate for more complex experiments
- Can operate in Soyuz (powered upload)

Utilisation 2006–present
- 21 Experiments performed
- 3 Experiments in definition or preparation

Status
- Two KUBIKS currently on orbit
- 12-18 month new experiment development time depending on complexity
- Short (<9 month) leadtime in case of reuse of existing experiment units
- Several cell, microbiology, plant and aquatic animal experiment cassettes available
KUBIK: Modular inserts & operation

Example: XENOPE HW (Kayser Italia)
ISS Capabilities in development / International Partner capabilities

**Rodent Research (NASA & International Partners)**
- Basic Mice / Rodent habit available from 2013 (AEM-X)
- International facility with artificial gravity under study

**Aquatic Habit (JAXA)**
- Aquarium for Zebrafish / Medaka

**In Orbit Analysis instruments developments (International Partners)**
- Gene Expression; RT-PCR & Gene Array
- Cytokine / ELISA Analysis
- Microfluidic Flow cytometer (CSA)
- Realtime bioluminescence / fluorescence assay (ESA Tripleux H/W development)

**Fluorescence Microscopy (JAXA)**
- Fluorescence Microscope with remote control and sample thermal control
Human Physiology Research Onboard ISS: Ongoing Experiments

**Immune system:**
- IMMUNO – Immune function (Russian joint experiment)

**Cardiovascular, Pulmonary, Vascular & Exercise:**
- CARD – Cardiovascular (soon Completed)
- EKE – Exercise Capacity (joint protocol with NASA VO2MAX expt)
- EDOS – Bone loss (trabecular structure) (Russian joint experiment)

**Bone, Muscle, Nutrition:**
- SOLO – Nutrition/Bone Loss (soon Completed)
- Thermolab – Thermoregulation (joint protocol with NASA VO2MAX expt)

**Neurovestibular:**
- NeuroSpat - NeuroCognitive
- 3D SPACE – Neurovestibular/Cognitive (Completed)
- PASSAGES – Neurovestibular/Cognitive
- Vessel Imaging – Vascular function
- ZAG – Neurovestibular (Completed)
- OTOLITH – Neurovestibular (Completed)
- SPIN–GAZE – Neurovestibular/Cardiovascular (Russian joint experiment)

18 new Physiology experiment selected in the ISLRA-2009 International Life Science Research Announcement.
- Circadian Rhythm
- Cardiovascular Physiology
- Bone Loss
- Neurovestibular research
- Countermeasure research/exercise physiology
- Psychology
- Pulmonary physiology
Three Biology Facilities onboard ISS – KUBIK, EMCS and BIOLAB

- Provide controlled temperature, artificial gravity (1.g control, sub 1.g levels), electric power, commanding, data, video & imagery

EXPOSE External Astrobiology facility

26 Biology Experiments performed since 2006 covering a range of disciplines

- 11 Cell Biology
- 7 Plant Biology
- 2 Developmental Biology
- 6 Microbiology

Several Radiation dosimetry experiments

13 Astrobiology, Organic Chemistry & Dosimetry Experiments performed in EXPOSE and EXPOSE-R

21 New Biology and Astrobiology Experiments selected in ISLRA-2009

- Broad range of disciplines represented
- Development and Implementation ongoing

Fast Track AO’s utilising KUBIK considered for the future
1) Experiment uploaded via soft pouches: KUBIKs already on orbit

**Typical Mission Scenario**

- **Samples' preparation**
- **HW integration**
- **KUBIK**
- **Centrifuge**
- **Static insert**
- **Tmin °C – Tmax °C**
ScienceTeam/ESA/Industry meetings
- Define / Baseline Requirements
- Progress Meetings
Experiment Sequence Test (EST)
AT-1/AT-2 Acceptance meetings
Launch Campaign at Baikonur
Launch Campaign at Baikonur
Inflight Operations and Ground Support
Landing Operations
ELIPS Research Opportunities: Relevance to a health issues of a sedentary and ageing population

- Physiological changes occurring in astronauts during spaceflight parallel some of the changes that occur during ageing and inactivity
  - Cardiovascular and pulmonary deconditioning
  - Significant bone and muscle loss
  - Metabolic changes

- In contrast to ageing, physiological changes occurring in spaceflight are rapid, but largely reversible

- Head Down Tilt Bedrest used as an analogue of spaceflight for human physiology studies, this allows the physiological changes to be studied in a carefully controlled environment with healthy subjects

- Cell culture and rodent studies can be conducted in microgravity as well as ground based analogues to better understand the underlying mechanisms
Selected Research Achievements: Cardiovascular

- Astronauts exposed to microgravity experience a fluid shift towards the head, which is compensated by an overall drop in vascular blood pressure. On return to normal gravity orthostatic intolerance is often observed. Similarly, orthostatic intolerance occurs in sedentary or elderly patients when standing up.

- The arterial baroreflex gain is increased in some astronauts following spaceflight

- Arterial stiffness also altered in astronauts during spaceflight, although results not consistent

- Increased arterial stiffness can occur during ageing, this can increase the resistance of blood flow into the brain
  - Robertson, Tessmer and Hughson, J Human Hypertension, 24, 190-196 (2010)

- 5-days HDT Bed Rest elevated hormones of the renin-angiotensin-aldosterone system. This could promote vascular stiffness.
Changes in vascular smooth muscle cell contraction regulating calcium channels – relevance to orthostatic intolerance

Selected Research Achievements: Immunology

Significantly suppressed immune response observed in astronauts returning from spaceflight since time of Apollo missions

- Decreased response to mitogenic stimulation (monocytes, T-cells), Decreased T-cell & NK numbers, increased Epstein-Barr virus reactivation observed in ISS Astronauts

- Weakened cell mediated immunity observed in medium duration bedrest, paralleling changes observed in spaceflight
  - Kelson et al., Cytokine (In press)

Con-A Activation of Lymphocytes in Microgravity

![Graph showing Con-A Activation of Lymphocytes in Microgravity](image)
Selected Research Achievements: Immunology

- Severe and significant reduction in cytokine / chemokine induction in spaceflown mice
  (STS-131 Mouse Immunology Experiment preliminary results)
- Isolated Immune Cells show a significantly reduced responsiveness to mitogenic and physiological immune challenges in microgravity.
  - Changes in gene expression patterns have been characterised permitting putative to identification of gravity sensitive intracellular signalling pathways
    - Link between cytoskeleton organisation and impaired cell movement/contact
    - Enhanced 5-LOX dependant apoptosis activity observed in microgravity cultured T-cells (5-LOX is implicated in some neurodegenerative diseases)
PHYSICS OF FLUIDS AND COMBUSTION

• Dynamics and properties of interfaces
• Convective instabilities under conditions not realisable on Earth
• Phase separation, evaporation and heat transfer
• Complex fluids: coarsening and stability
• Combustion processes of dispersed systems
**MATERIAL SCIENCES**

- Thermophysical properties
- Microstructures in alloys – convection influence
- Influence of the processing conditions on features of crystalline and amorphous phases and of biological, organic and inorganic materials.
- Links: materials processing - structure - properties of new light-weight structural metallic or intermetallic materials.
Transfer of Knowledge

Support and accelerate the transfer of knowledge generated by research in space into industrial processes or products

- Research in space - production of benchmark data - most useful if supported by a large body of ground-based research
- Performing space experiments as part of industrial R&D projects is an effective way of providing industry with knowledge acquired in space
41 M€ ESA/EC IMPRESS Project on “Intermetallic Materials”

- New lightweight TiAl turbine blades for jet engines and gas turbines (50% lighter than conventional nickel superalloys)
- New NiAl catalytic powders for hydrogen fuel cells and other chemical processes (better than conventional platinum and many hundreds of times cheaper)
- The above research was enabled by experiments on EML, sounding rockets and regular parabolic flights
- MAP projects: ThermoProp, Nequisol, Cetsol/Micast, Vapour Synthesis
- Supported by sophisticated modelling
“Space for Science, Science for Earth"