Science in Space Environment (SciSpacE): Research Topics, Platforms and Opportunities

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**ESA’s European Exploration Envelope (E3P) Utilization and Research Programme:**
Enabling future human and robotic exploration of the Solar System while bringing back to Earth knowledge and opportunities.

**The Science in Space Environment (SciSpaceE) Programme**

<table>
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<th>Driven by scientific excellence</th>
<th>Coherent Comprehensive Cross-disciplinary</th>
<th>Impactful Integrated Inspiring</th>
<th>Stable Sustainable</th>
<th>Global cooperation</th>
<th>Economic and societal benefits</th>
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Jason Hatton | 04/06/2018 | Slide 2
Europe’s Space Exploration Vision

- Aspirational role models
- New skills and technology
- Basic & applied science
- New knowledge
- Challenge driven innovation
- Global partners
- Inspiration

The Global Exploration Roadmap

August 2013
Key outcomes for 2020: E3P First Period

- Safe ISS operation & three astronaut missions
- Service modules for first two Orion missions
- World-class science in the space environment
- First Mars life search mission
- First European science & tech for lunar surface
- New human and robotic missions readied for decision at CM19

Technology; commercial partnership; benefit management
• Science and Applications programme uses a variety of ground and space platforms for research, using the unique environment of spaceflight and analogues

• 1500 scientists from across Europe and the World and involved in 200 projects. 60 industrial partners involved in projects

• Support networks and interdisciplinary research

• **Microgravity Applications Programme to foster applied research**

• Research objectives until 2024 defined in **science roadmaps** elaborated with science community relevant to both Exploration and Terrestrial needs, several of which address Health topics
SciSpacE Strategy

Science Road Maps defined by scientific community

Building on strong heritage of excellence & achievements of European scientific community

Socio-Economic: Fundamental Knowledge, UN Sustainable Development Global Goals

Scientific contributions enabling future human exploration

Benchmarking against Objectives
Top level Road Map themes

**Physical Sciences**
- Ultra-precise cold atom sensors, quantum information and high energy particles
  - Boundaries of relativity and quantum physics.
  - Advanced navigation and communication.
- Soft or Complex matter
  - Interactions and self-organisation in foams, emulsions, granular matter, atmospheric dust and colloids.
  - Food and (petro)chemical industry, physics of biological processes.
- Boiling, evaporation and heat transfer
  - Multi-scale modelling of fluid physics including phase change.
  - Efficient cooling of microelectronics, industrial boilers and power plants.
- Advanced material processing
  - Microstructure formation and materials properties.
  - Casting, automotive and aerospace industry.

**Biology**
- Astrobiology
  - Chemical and biological effects of exposure to space radiation and vacuum.
  - Origins, limits and signs of life in the Universe.
- Biology under non-Earth gravity conditions
  - Understanding gravity-dependent processes in cells and organisms.
  - Unravelling the biochemistry of processes in the human immune, skeletal and cardiovascular systems.
- Supporting life in hostile environments
  - Understanding the effects of space factors on microorganisms and plants.
  - Integrated closed-loop life support systems for exploration.

**Human Research**
- The Human body under space conditions: adaptations and countermeasures
  - Understanding human physiological processes.
  - Exploration–related health risks and their prevention.
  - Health and ageing issues on Earth.
- Psychological and neurosensory adaptations to reduced gravity, isolation and confinement
  - Impact of spaceflight on psychological, sensorimotor and neuro-behavioural performance.
  - Selection, training and support methodologies for crew on long-duration missions.

**Selfstanding and multidisciplinary research**
- Energy storage, fire safety, cardiovascular fluid physics, hibernation and torpor

Cosmic radiation risks for Human Exploration of the Solar System
ESA and Sustainable Development Goals

1. **No Poverty**
   - Earth observation (EO)
   - Tele-learning

2. **Zero Hunger**
   - Global monitoring, food security
   - Nutrition
   - Life support

3. **Good Health**
   - Space for Health
   - Human & biology research
   - Telemmedicine, tele-epidemiology

4. **Quality Education**
   - Education and inspiration
   - Tele-education
   - STEM

5. **Gender Equality**
   - Education and inspiration
   - STEM

6. **Clean Water and Sanitation**
   - Life support
   - Water recycling
   - ESA TIGER Project
   - EO Data

7. **Affordable and Clean Energy**
   - Applications research
   - Combustion
   - Heat Management
   - Battery

8. **Reduce Inequalities**
   - Applications and Services for developing countries

9. **Industry 4.0**
   - Materials technology transfer
   - Patents

10. **Education and Inspiration**
    - Tele-education
    - STEM

11. **Sustainable Cities and Communities**
    - ISS and Concordia
    - Integrated applications
    - EO: Mapping, Air quality
    - ESA EO Programmes
    - Copernicus
    - Polar region monitoring

12. **Responsible Consumption and Production**
    - Life support
    - Compact, low power systems
    - ISS, Concordia
    - ESA EO Programmes
    - Copernicus
    - Marine projects

13. **Climate Action**
    - ESA EO Programmes
    - Copernicus
    - Polar region monitoring

14. **Life Below Water**
    - ESA EO Programmes
    - Copernicus

15. **Life on Land**
    - ESA EO Programmes
    - Copernicus

16. **Peace and Justice**
    - Integrated Applications
    - Copernicus Inspiration

17. **Partnerships for the Goals**
    - Broad partnerships across programmes with other agencies, industry and institutions

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European Space Agency

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## SciSpacE Roadmaps

### Exploration Relevance

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### Socio-Economic Benefits/ Global Goals

- Essential contribution
- Important contribution
- Relevant contribution
SciSpace Roadmaps: Health Topics

**Physical Sciences**
- Ultra-precise cold atom sensors, quantum information and high energy particles
  - Boundaries of relativity and quantum physics.
  - Advanced navigation and communication.
- Soft or Complex matter
  - Interactions and self-organisation in foams, emulsions, granular matter, atmospheric dust and colloids.
  - Food and (petro)chemical industry, physics of biological processes.
- Boiling, evaporation and heat transfer
  - Multi-scale modelling of fluid physics.

**Health Issues**
- **Terrestrial and Space Exploration:**
  - Cardiovascular, Bone Muscle, Immune system
  - Countermeasures
  - Diagnostic techniques / technology
- Casting, automotive and aerospace industry.

**Biology**
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  - Selection, training and support methodologies for crew on long-duration missions.

**Cosmic radiation risks for Human Exploration of the Solar System**

**Self-standing and multidisciplinary research**
SciSpacE Activities relevant to Health

Human Physiology Research
• Physiological and Psychological Research on ISS Crew members
• Bedrest Studies
• Isolation Studies
• Countermeasures

Biology Research
• Flight and Ground studies on medically relevant cell, tissue cultures and animal models
• Technology for tissue / organ culture and transport
• Radiation Research

Applied Life Science Research
Eg.
• Wound Healing, Ageing,
• Personalised medicine, Nutrition
Scispace Roadmaps: Life support and clean water

Regenerative Life Support Systems

Terrestrial:
- Food production in confined environment
- Water Purification / treatment techniques

Space Exploration:
- Life Support Elements for Deep Space Habitat

Biology

- Biology under non-Earth gravity conditions
  Understanding gravity-dependent processes in cells and organisms.
  Biochemistry and health-related phenomena.

Supporting life in hostile environments
Understanding the effects of space factors on microorganisms and plants.
Integrated closed-loop life support systems for exploration.

Human Research

The Human body under space conditions:
adaptations and countermeasures
Understanding human physiological processes.
Exploration – related health risks and their prevention.
Health and ageing issues on Earth.

Psychological and neurosensory adaptations to reduced gravity, isolation and confinement
Impact of spaceflight on psychological, sensorimotor and neuro-behavioural performance.
Selection, training and support methodologies for crew on long-duration missions.

Cosmic radiation risks for Human Exploration of the Solar System

Self-standing and multidisciplinary research
Energy storage, fire safety, cardiovascular fluid physics, hibernation and torpor
SciSpace Activities relevant to Water and Agriculture

Regenerative Life Support Systems
- SciSpacE, Expert and MELISSA (TEC)

Space Exploration:
- Life Support Elements for Deep Space Habitat

Terrestrial:
- Food production in confined environment
- Water Purification / treatment techniques
ESA Ground Based Facilities

Access to range of ground based facilities (GBF) at European Institutions, including centrifuges, random positioning machines, clinostats and radiation facilities

Drop Tower at Zarm in Bremen provides 4.5s to 9s high quality microgravity

Continuously Open Access Research Announcement for GBF & Drop Tower

Periodic IBER Announcement of Opportunity for Radiation Research at GSI facility
Bedrest Studies

Head Down Tilt Bed Rest, for 5 to 60 days. Average of 1 study per year
Simulate unloading and fluid shift occurring during space flight; physiological changes parallel those occurring during spaceflight
Interventions to be tested are defined through CFI / Workshop process
Expert groups define protocol of countermeasures i.e., artificial gravity, nutrition, vibration exercise

Periodic AO (Announcement of Opportunity) every 2-3 yrs
BEDREST STUDIES AND ARTIFICIAL GRAVITY
ESA’S MULTI-YEAR BEDREST PROGRAMME PLAN
Isolation Studies

ESA is cooperating with the Antarctic station Concordia since 2001

Concordia is an excellent Analogue Environment for exploration missions, as crew completely isolated for several months during overwinter.

Studies on psychology, physiology as well as station environment (eg. Microbial community)

Isolation roadmap established for future isolation studies, possibly using other platforms
Parabolic Flight

2-3 campaigns per year
20s of microgravity, or intermediate g-levels depending on campaign
Investigator can fly with experiment, research in all disciplines including Human Research

Continuously Open Access Research Announcement
Sounding Rockets

6 – 13 minutes of high quality microgravity during flight, with short late access (<3 hours) and early retrieval (1-2 hours)

Realtime telescience capability

Typically 1-2 missions per E3P period.

Proposals can be submitted to Continuously Open Access Research Announcement
International Space Station

Principle long duration microgravity and space environment platform used in SciSpacE

Shared utilisation with ISS partners, including possibility to use International Partner facilities

Multi-user facilities for main research disciplines, with experiment specific inserts where applicable

Periodic Focus Research
Announcements on specific science priority topics and/or...
SciSpacE Research Platforms on the ISS
SciSpacE Research Platforms on the ISS: Human Physiology

European Physiology Modules
Human Research Facility 1
Human Research Facility 2 + Pulmonary Function System
SciSpacE Research Platforms on the ISS: Biology and Exobiology

- Biolab
- KUBIK
- eOsteo
- Exobiology Facility
SciSpacE Research Platforms on the ISS: Physical Sciences

Fluid Science Laboratory

Electro-Magnetic Levitator

Material Science Laboratory (in the US Lab)

Microgravity Science Glovebox (in the US Lab)
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)
Lunar Orbit Gateway

Human tended Cis-Lunar Space Station to enable sustained Human Exploration beyond LEO (cis lunar and deep space), with periodic crew visits Possibility to perform experiments during crewed and uncrewed phases.

Capabilities are significantly constrained compared to ISS so only research which requires the unique environment and cannot be accomplished in Low Earth Orbit should be performed on Gateway

Possible Research Focus areas include Exobiology and Radiobiology

Formal decision for ESA participation in Gateway expected at C/Min 2019
Investigating Thermoregulation in Space

- Normal core body temperature ~37 °C
- Severe deviations can be life-threatening
- Heat transfer processes challenged in weightlessness: Impaired convection
- Thermolab experiment: investigated effects of spaceflight on CBT
- New thermal sensor technology
Thermolab Results

- CBT rises higher/faster in space during exercise
- Sustained increase in resting CBT
- Increase in anti-inflammatory proteins.
- Impairments still prevalent after return
- Other potential factors
- Implications for astronaut well-being
- Sensor technology:
  - Useful diagnostic tool future missions
  - Earth applications
RESULTS: ISS SCIENCE

TripleLux-A Experiment

Understanding the effect of spaceflight on immune function

- Immune dysfunction observed in astronauts and cell experiments since time of Apollo
- Decreased T-lymphocyte function observed in long and short duration ISS flights
- Weakened cell mediate immunity observed in bedrest and Concordia
- In vitro immune cell culture experiments show significant decreased T-cell and monocyte activation, cytoskeleton disruption and impaired locomotion. Signalling pathways sensitive to altered gravity tentatively identified
RESULTS: ISS SCIENCE

TripleLux-A Experiment

Understanding the effect of spaceflight on immune function

**Triplelux- A Experiment**

- Reactive oxygen burst (ROS) used by macrophages to destroy pathogenic microorganisms, one of the first lines of immune defence
- Measured in ROS burst from macrophages using chemiluminescent assay
- Parabolic flight experiments had shown ROS burst was altered on timescale of seconds
- ISS Experiment showed rapid change with altered gravity level, but reversible within ~42 seconds
- Assay could be used as a rapid assessment of immune function in astronauts
SciSpacE Summary of Research Opportunities

Research Announcements on ESA Portal

http://www.esa.int/Our_Activities/Human_Spaceflight/Research/Research_Announcements

Continuously Open Research Announcement

Topical Teams – coordination amongst science teams, incubation of ideas
Ground based facilities – up to 50kEuro support for access to facility
Parabolic flight, Sounding Rockets – flight opportunity

Microgravity Applications Programme

Applications oriented research, ESA / Industry co-funding

Periodic Ground Based Announcements of Opportunity

IBER radiation, Bedrest, Concordia

Focussed Research Announcements

Specific research thematic

Flight and Ground Platforms
we explore. you benefit.
Human Spaceflight and Robotic Exploration