ELIPS-4

human spaceflight

ESA Thematic Information Day

3 July 2012

BELSPO, Brussels, Belgium

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Directorate of Human Spaceflight and Operations
ESA – ESTEC

ELIPS Research Strategy

esa human spaceflight

- Utilize the **outstanding base for unique science** that has been created by substantial investments over the last decades
- Continue with the established science programme in **Life and Physical Sciences (ELIPS)**
- Look for **further research and technology domains**
- **~150 projects** are on-going, in planning or in preparation, but there is room for **new solicitations** in the future
- Support **applied research and industrial R&D**
- Prepare for **Human Exploration**
- Work with our partners to utilize ISS as efficiently as possible and **build strong international science teams**

“Space for Science, Science for Earth”

Role in ESA's Grand Sciences Themes

human spaceflight

#1: Cosmic Climate

- *Earth Observation – the climate of our planet - System Earth*

#2: Understanding Gravity

- *Gravity and the origin of the large-scale structure of the Universe, leading to the testing of General Relativity on the largest accessible scales.*
- *New generation clocks with the objective of accuracy 10^{-18} using atomic clocks and frequency combs.*
- *The mass distribution in the Earth and the planets, potentially by gradiometry using atomic interferometry*
- *Matter under zero gravity - from 'classical' fluid physics and materials sciences to studies of matter at the quantum level.*

Role in ESA's Grand Sciences Themes

human spaceflight

#3: Life in the Universe

- *The formation and evolution of the chemical elements, galaxies, stars and planets*
- *Pre-biotic molecules and the origin and evolution of life in the Universe. Life signatures/condition.*
- *Conditions in the early Earth, life migration.*
- *Role of gravity in the development and functioning of organisms*
- *The study of life and human performance under extreme conditions within our solar system. Extremophiles/adaptation strategies.*
- *Radiation biology, integrated human space physiology, space psychology, human performance under extreme conditions.*
- *Impact of human exploration on individuals and society (including Earth applications of space research)*

#4: Cosmic magnetism and High Energy Particles in Space

- *The physics of cosmic rays up to the very highest energies.*
- *The local space environment and the protection of astronauts, including magnetic shielding.*

ELIPS - European Programme for Life and Physical Sciences in Space

esa human spaceflight

- ELIPS is since 2002 ESA's key space programme to conduct life & physical sciences in space

- To augment efficiency and impact of ISS experiments, also using other mission platforms

- Support Industrial applications and R&D involvement

Sounding Rockets

ESA Research - Main Areas in Space

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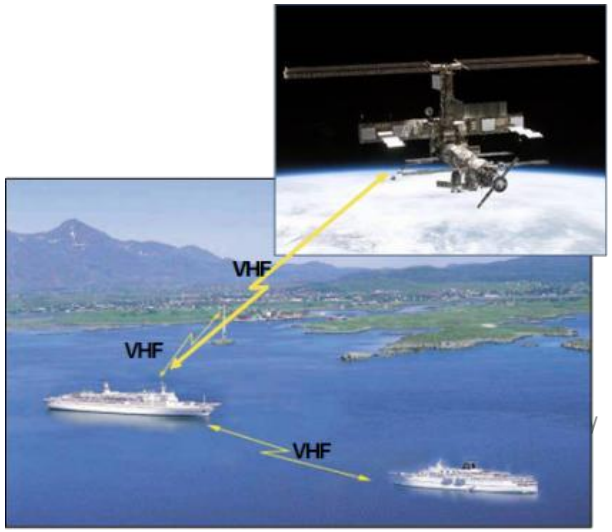
- **Based on consultations with users and recommendations of science advisors**
- **Primarily utilizing the unique condition of long-term weightlessness (microgravity)**
- **Also exploiting unique observation of both Earth and Space**
- **7 "Cornerstones" in Life and Physical Sciences**

elips

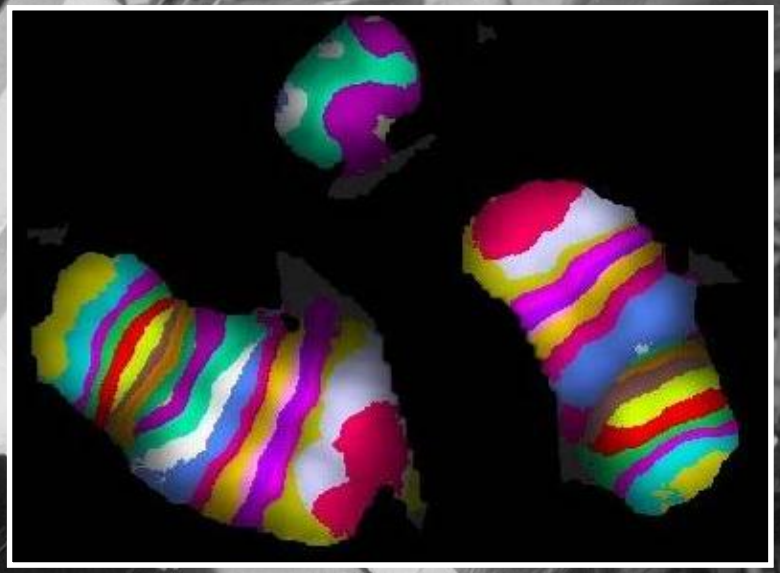
+ Human Exploration Preparation
+ Technological Demonstrations
+ Climate Change Studies
+ Education and Outreach



Key Research Topics

HUMAN PHYSIOLOGY AND PERFORMANCE

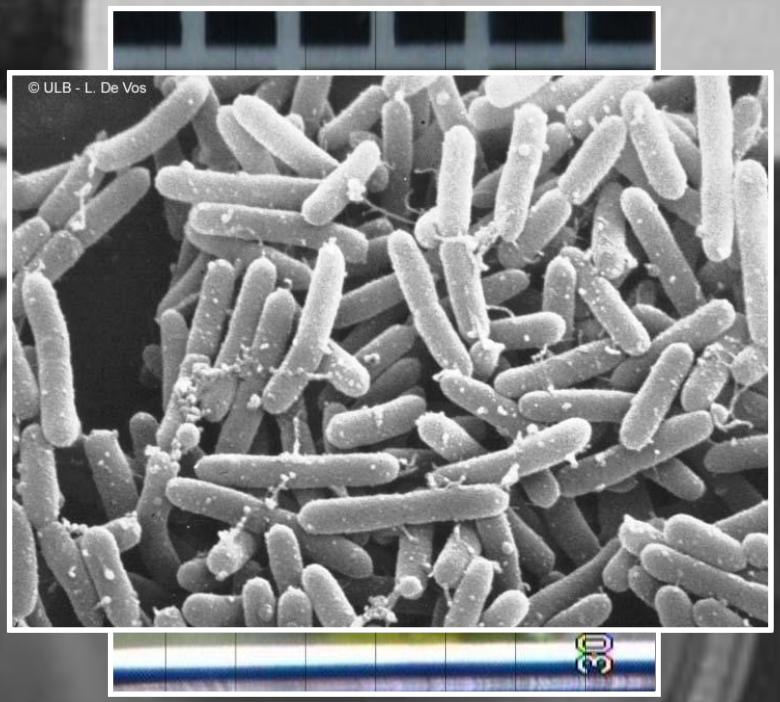
- Mechanisms orchestrating organ systems interaction and recovery under variable gravitational levels (system homeostasis)
- Factors impairing physical and cognitive performance
- Countermeasure strategies
- Radiation



Key Research Topics

BIOLOGY

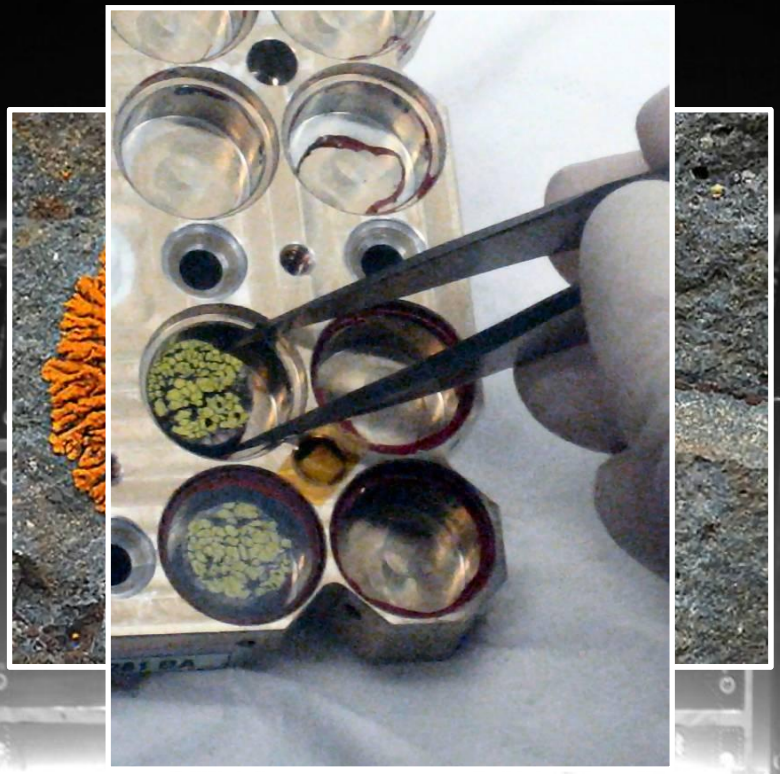
- **Sensitivity to Gravity of cells, plants and animals**
  - Molecular mechanisms for sensing and adaptation
  - Multicellular structure formation
  - Development and performance of organ systems
  - Lifecycle from embryonic development to senescence
- **Biological responses to multiple stressors**



Key Research Topics

ASTROBIOLOGY

- Organic compounds and mineral interactions
- Polymerisation, stability and replication studies
- Response of pre-biotic building blocks to extra-terrestrial conditions
- Mechanisms of survival and adaptation of extremophiles



Key Research Topics

ATMOSPHERIC AND ENVIRONMENTAL RESEARCH

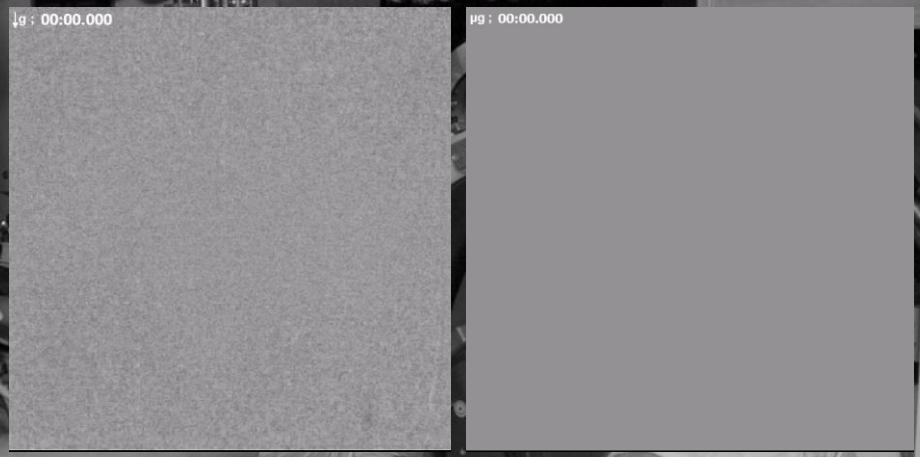
- Novel data understanding global climate change
- Global animal migrations
- Space-atmosphere interactions
- Solar spectral irradiance

Key Research Topics

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.

In-situ Solidification

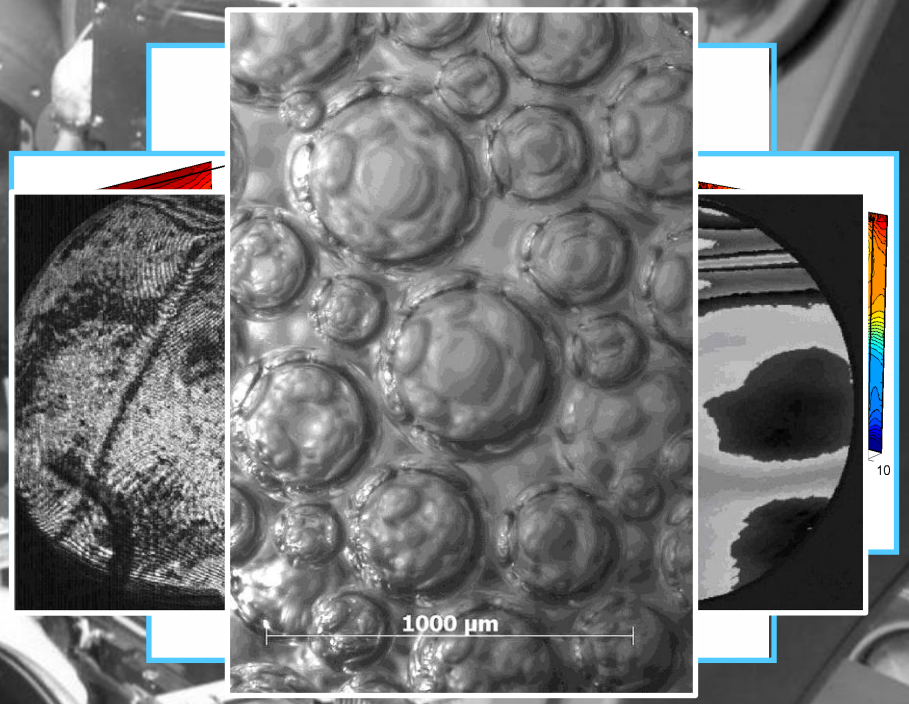


Ground *Space*

Key Research Topics

PHYSICS OF FLUIDS AND COMBUSTION

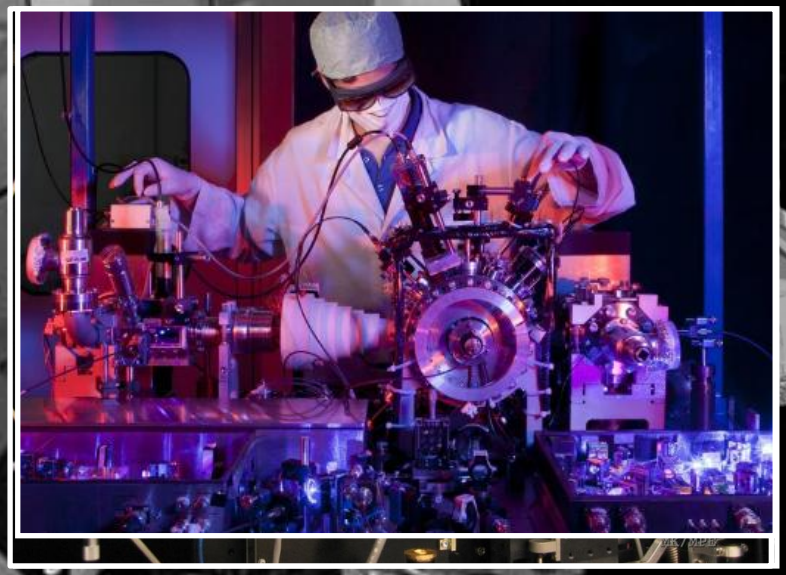
- Dynamics and properties of interfaces
- Convective instabilities under conditions not realisable on Earth
- Phase separation, evaporation and heat transfer
- Complex fluids: coarsening and stability
- Combustion processes of dispersed systems



Key Research Topics

FUNDAMENTAL PHYSICS

- Fundamental Constants of Nature
- Universal time scales and clock comparison at global scale
- Dynamics of degenerate quantum gases
- Test Einstein's Weak Equivalence Principle
- Mimic molecular interactions



Research Implementation Strategies

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- **Science driven bottom-up approach**
  - Build strong science teams by supporting Topical Teams in dedicated scientific areas of interest
- **Announcement of Opportunities (AO) have been "open", but some focus might be needed in future**
  - Current pool of ELIPS experiments completed around 2017
  - Likely new AOs in 2013/2014 timeframe
  - Coordinate internationally as far as possible
- **ESA provides research hardware development and flight resources; Scientists funded by national sources.**

Working Internationally and engaging R&D Industry

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- Involve international teams of theorists, modellers, experimentalists and communicators
- Optimise ISS resources by cooperation with other ISS partners through joint experiments
- Associate non-space R&D industry wherever possible in space research
- Embed space projects into larger ground-based, application-oriented projects often funded by the EC

Belgian Science Community
B-USOC

esa human spaceflight

- Strong involvement of numerous and very active Belgian Scientists in 54 different ELIPS projects
  - ✓ 34 in 22 projects in Physical Sciences
  - ✓ 20 in 10 projects in Biology
  - ✓ 25 in 10 projects in Human Research
  - ✓ 49 in 12 projects in Ground-based Research

- B-USOC with excellent track record in ISS utilisation
  - ✓ SOLAR
  - ✓ MSG experiments
  - ✓ EDR experiments
  - ✓ Standalone experiments

Belgian Space Industry

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- Capacity and competitiveness of Belgian Space Industry has increased significantly
  - ✓ Participation in many payload projects (fluid physics, biology, human physiology)
  - ✓ Continuous development of advanced instrument technologies

- Major industrial involvement areas:
  - ✓ FSL Experiment Container
  - ✓ EDR Subrack Payloads
  - ✓ Biolab Experiment Container
  - ✓ Human Physiology Instruments
  - ✓ Sounding Rocket Modules

Transfer of Knowledge

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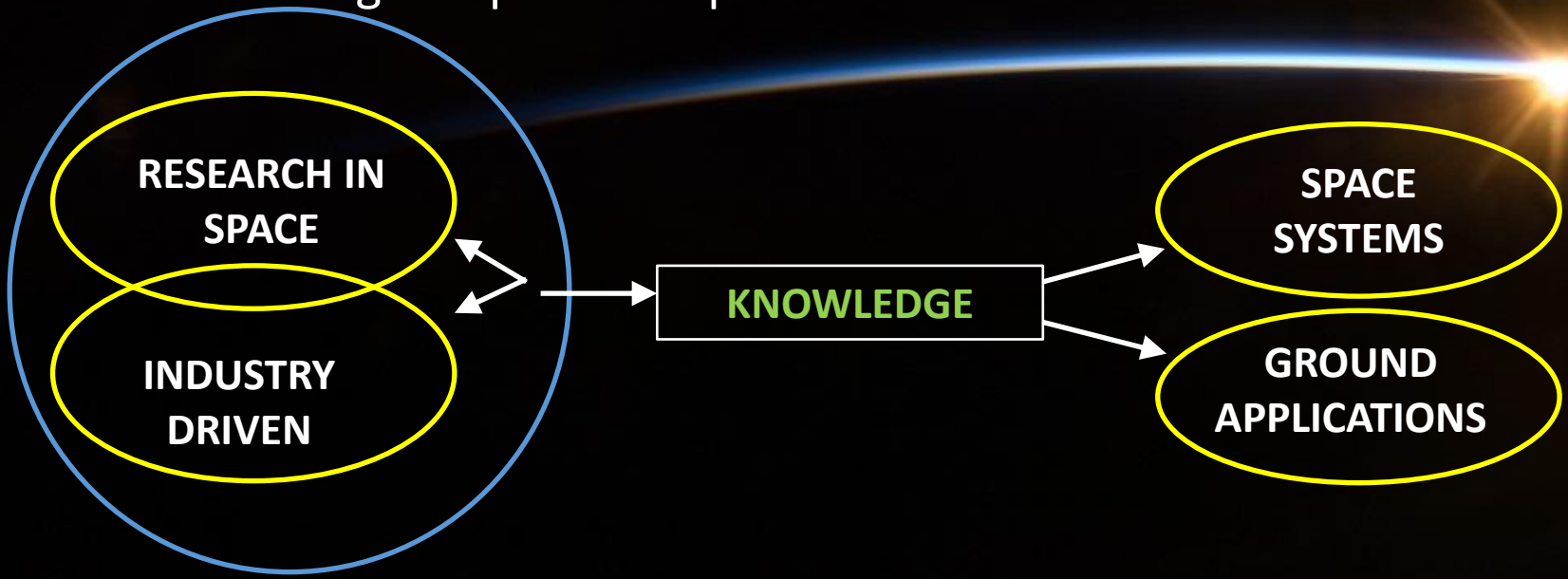
Support and accelerate the transfer of knowledge generated by research in space into industrial processes and/or products

- 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



Budget Proposal ELIPS-4 Science Core

1 General Activities		**26**
Experts, Advisory Groups, User Information	3	
Topical Teams	1	
Ground-based Facilities	2	
Support to Applied Research Projects and Industry driven R&D	13	
EC projects initiation/coordination	3	
Education and Outreach	2	
General Studies	2	

Budget Proposal ELIPS-4 Science Core

2 ISS Utilisation Hardware Development		**208**
Pre-Phase A: Feasibility Studies		***2***
Phase A/B: Development Studies		***12***
Phase C/D:		***194***
FSL Experiment Containers	19	
LIFT (FASTER-2)	8	
MSG (DirSol samples, Vip-Gran)	8	
MSL Cartridges	15	
EML Samples + Fac. upgrades	25	
Critical/supercritical Fluids	9	
ICAPS	16	
COLIS	8	
Human Physiology Equipments	8	
On-orbit Sample Analysis Instrumentation	12	
Biology Experiments	22	
Rodent Research	6	
KUBIK-II	8	
ASIM Completion	6	
ACES Completion	10	
Ongoing P/L Development Reserve	10	
Complementary ISS Resources	4	

Human Exploration Technology

human spaceflight

3 Autonomous Payloads/Missions/Campaigns		69
Bedrest	8	
Isolation Studies	3	
IBER Studies	2	
Baseline Data Collection	3	
Drop Towers & Parabolic Flights	13	
Sounding Rockets (Maser/Texus/Maxus)	40	

Subtotal External Procurements	303
Programme Integration Cost (22%)	85
TOTAL PROGRAMME Cost	388

ELIPS Elements for Human Exploration Technologies

Separate envelopes in the ELIPS-4 Programme Proposal

1 Analysing Interferometer for Ambient Air (ANITA-2)
2 Microbial Detection in Air System for Space (MiDASS)
3 Micro-Ecological Life Support System Alternative (MELiSSA)

Part 4: HE Technology Programme Elements (separate envelopes)

ELIPS Slices Elements	Proposal (M€)
A) ANITA-2	20
B) MiDASS	24
C) MELiSSA Technologies	22

MELiSSA Technologies
Micro-Ecological Life Support System Alternative

- MELISSA activities aim at gaining knowledge for the development of regenerative life-support system for Space through a biological and chemical/physical approach, up to the ultimate 100% degree of closure.
- The concept was initiated in 1986 by long term vision people (C.Chipaux / MATRA) before manned space at ESA had any thought regarding manned Mars trip.
- Melissa consortium was created in 1989 and taken on-board by ESA, and seriously started around 2001
- Budget: 22 M€ (incl. Integration costs)

MELiSSA Ph.	Activity Title	Budget
1	Waste Processing	1.40
1	Photo-autotrophic bioreactor	0.60
1	HPC PCU	3.00
2	Nitrification Bioreactor	1.50
2	BIORAT 2	0.50
2	BIORAT B+	1.50
3	C2 Procurement	1.00
3	Nitrification Control	0.50
3	Pilot plant	4.00
3	System tools	1.00
3	Belissima	1.00
3	Concordia	2.00
	Total [MEuro]	**18.0**

Outreach and Education

“Space for Science, Science for Earth"

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THANK YOU!

Europe's ISS Assets

esa
human spaceflight

- **Columbus On-orbit Laboratory**, attached to ISS since Feb 2008
- **ATV transport vehicle** for logistic support of ISS
- **ISS science facilities** for dedicated research disciplines
- **Columbus Control Center** and 9 dedicated User Support Operation Centers

Internal Payload Facilities

Programme Elements of ELIPS-4

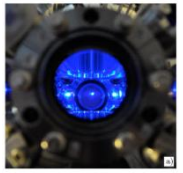
Science Core

Human Exploration Technology

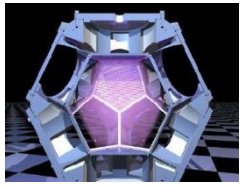
ELIPS-4: Programme Elements

Phase A/B developments

FUNDAMENTAL PHYSICS

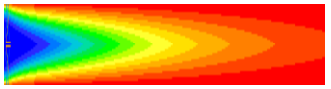


SOC and QWEP (AO-2004-100, AO-2004-133)



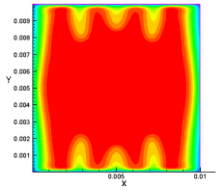
Plasmalab project (PK-5, AO-2009-1000) to enable studies of the dynamics of simulated molecular interactions

Space-QUEST for quantum physics correlation and communication (AO-2004-054)



FLUID PHYSICS

SCWO: DECLIC or FSL insert for investigations of the physico-chemistry of supercritical water (AO-2004-127)



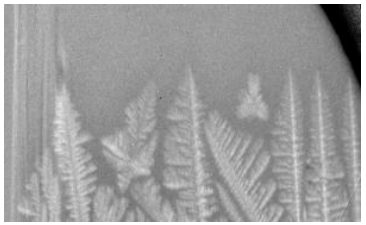
VIPIL-CRIT: SODI experiment insert to investigate vibrational physics in critical fluids (AO-2009-1061)

ELIPS-4: Programme Elements

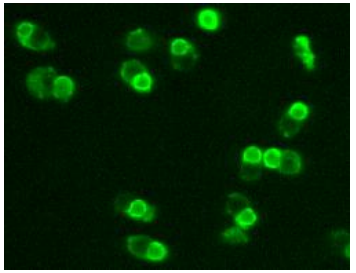
Phase A/B developments

MATERIALS SCIENCES

XRMON: if feasibility study concludes positively, initiate a phase A/B study to enable solidification experiments with in-situ diagnostic on ISS (AO-2004-046 associated with AO-1999-117, AO-1999-114, AO-1999-046, AO-2009-1094)



COLIS: advanced light scattering capability for colloid physics and nucleation in solutions studies (AO-2004-049, AO-2004-070)

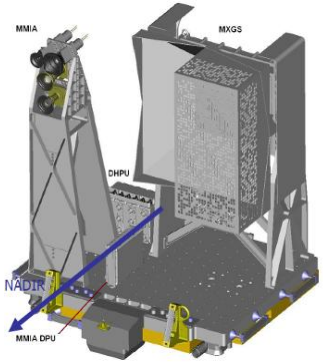


ELIPS-4: Programme Elements

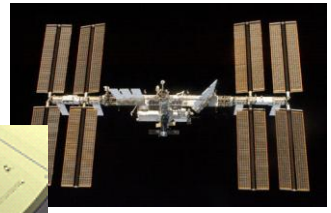
Phase C/D developments in Physical Sciences

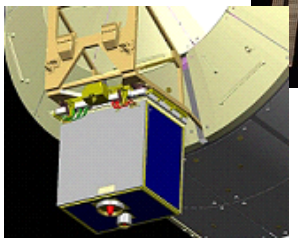
FUNDAMENTAL PHYSICS

ACES: Completion of payload development and preparation for the mission including the deployment of the international network of Microwave Link Ground Terminals



ASIM: Completion of payload development (incl. adaptation to SpaceX launch carrier) and preparation for the mission



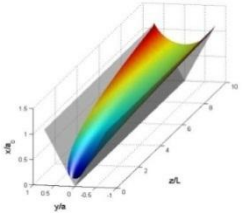


ELIPS-4: Programme Elements

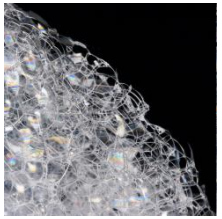
Phase C/D developments in Physical Sciences

FLUID PHYSICS

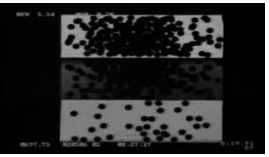
RUBI: FSL-EC for research on boiling (AO-2004-111)



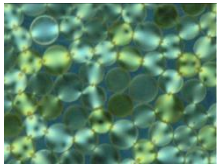
Thermal Platform I: FSL-EC and related inserts for dedicated heat transfer studies (AO-2009-014, AO-1999-110, AO-2009-1153, AO-2004-111, AO-2004-096)



FOAM-C: FSL-EC supporting research on foam and emulsion coarsening, (AO-1999-108, AO-2009-0813) as well as on granular materials and colloid physics (AO-2009-0943, AO-2004-049)



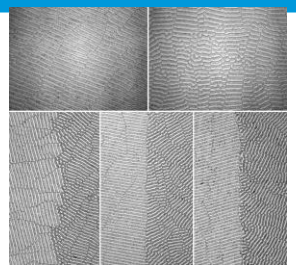
VIP-GRAN: self-standing instrument to investigate granular gases and granular compacts (AO-2004-121, AO-2009-0943)



LIFT: follow-on research to FASTER on liquid films stability

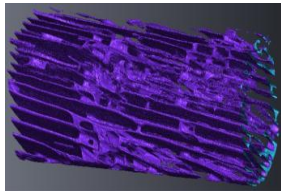
ELIPS-4: Programme Elements

Phase C/D developments in Physical Sciences

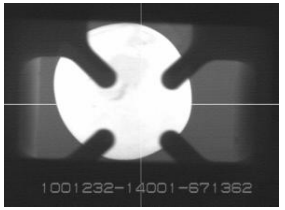


MATERIALS SCIENCES

TRANSPARENT ALLOYS: completion and production of project specific samples (AO-1999-117, AO-1999-046, AO-1999-114)

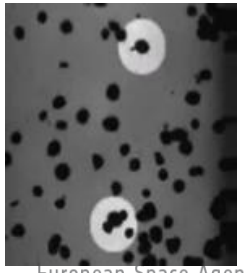


MSL: Development/production of project specific cartridges (candidates: AO-1999-031, AO-1999-117, AO-1999-114, AO-1999-046, AO-2009-1051, AO-2009-1094, AO-2000-075, AO-2009-1055)



EML: Preparation/implementation of batch 2/3/4 experiments (AO-1999, AO-2000, AO-2004, AO-2009)

ICAPS: Completion of the instrument to elucidate dust aggregation kinetics and related albedo

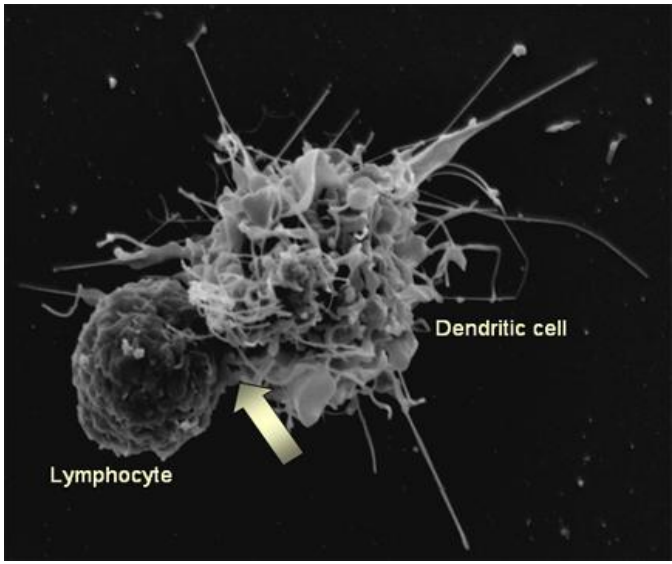


ELIPS-4: Programme Elements

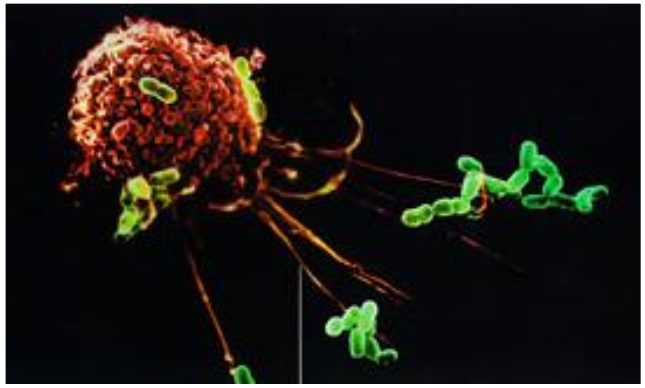
Phase C/D developments for Human Research

IMMUNOLOGY RESEARCH

Concious (ILSRA-2009-1121): new filter for blood collection required, as well as containers for sampling of exhaled air



MoCISS (ILSRA-2009- 1149): stimulation of immunological cells from crew to be incubated on-orbit. KUBIK experiment containers to be developed



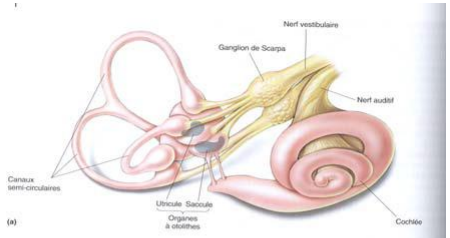
ELIPS-4: Programme Elements

Phase C/D developments for Human Research

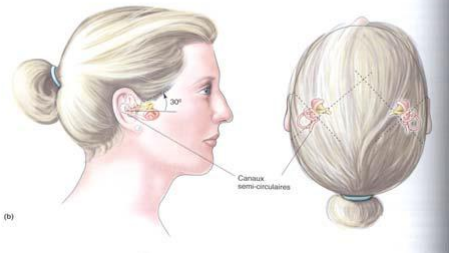
NEUROVESTIBULAR & COUNTERMEASURES RESEARCH

Straight Ahead (ILSRA-2009-1093): Tactile vest needed, with accelerometers. Current plan is to use JAXA head-mounted display.

GRASP (ILSRA-2009-989): Head mounted display with LED markers required, in addition Dextrous Manipulation (GRIP) H/W needs to be used.



Patterns (ILSRA-2009-1048): Accelerometers required on head and torso, with data collection system. RFID system for tracking crew movements on ISS.



mRSS (ILSRA-2009-873): Miniaturized respiratory sensor system, allowing measurement during regular training activities (wearable system)

ELIPS-4: Programme Elements

Phase C/D developments for Biology Research

ISS KUBIK BIOLOGY & Small Internal Standalone Experiments

ARIES – Stem Cell Differentiation in Microgravity (ISLRA-2009-1078)

SFEF – Endothelial Cell Function in Microgravity (ISLRA-2009-1026)

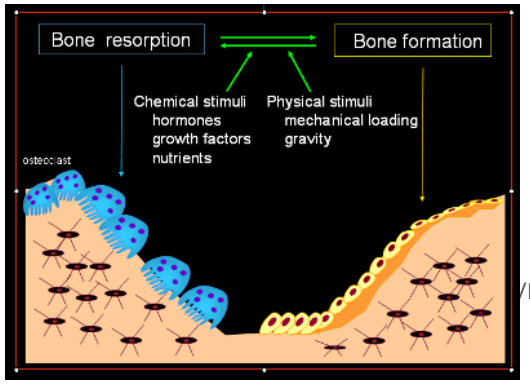
GROC – Osteogenic Cell Function in Microgravity (ISLRA-2009-1017)

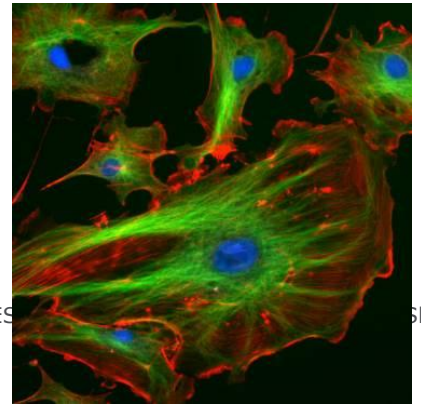
JUNCTION – Endothelial Cell-Cell Interaction (ISLRA-2009-1067)

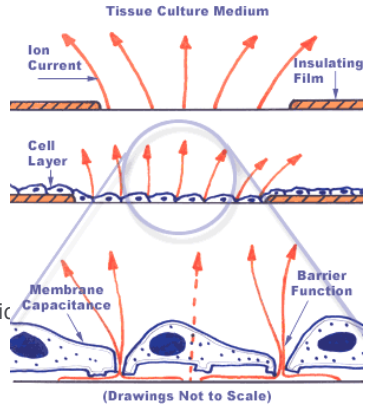
Zebra and Medaka Fish Microgenomics (ISLRA-2009-0860)

BIOROCK (E-GEM) – Microbial processing of minerals in microgravity, lunar and martian gravity (ISLRA-2009-0952)

ARBEX – Archea Bacteria sampling inside ISS (ISLRA-2009-1053)







ELIPS-4: Programme Elements

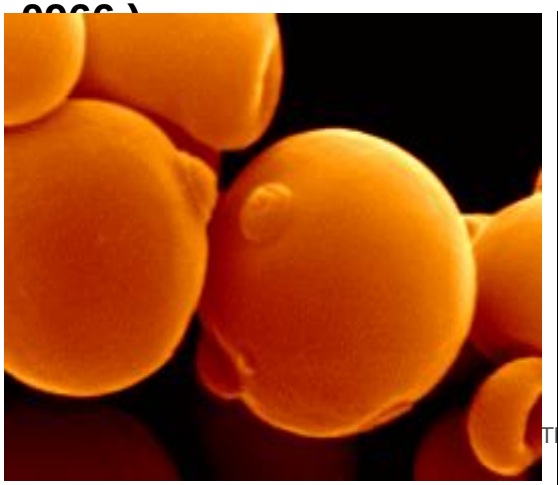
Phase C/D developments for Biology Research

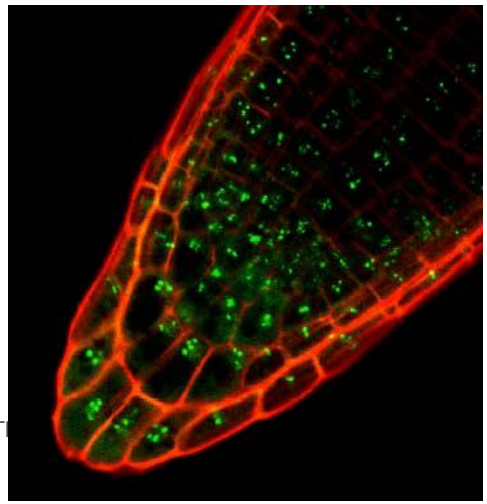
ISS BIOLOGY EXPERIMENTS FOR EMCS

BIOREACTOR – Combination of SACESTRE (ISLRA-2004-222) and AO2004-069 (YING-C). Core development anticipated under PRODEX, some ELIPS support for systems engineering aspect

GENERA-B/MULTIGEN-2/CELL ROOT PROLIF Combined Experiment studying Arabidopsis seedling growth and differentiation (ISLRA-2001-001, ISLRA-2004-028, ISLRA-2001-050)

EPRS – Planarian (Flat Worm) regeneration in microgravity (ISLRA-2009-





ELIPS-4: Programme Elements

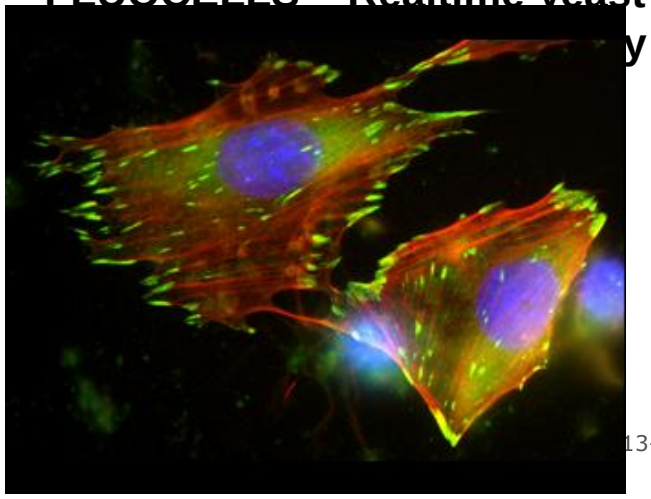
Phase C/D developments for Biology Research

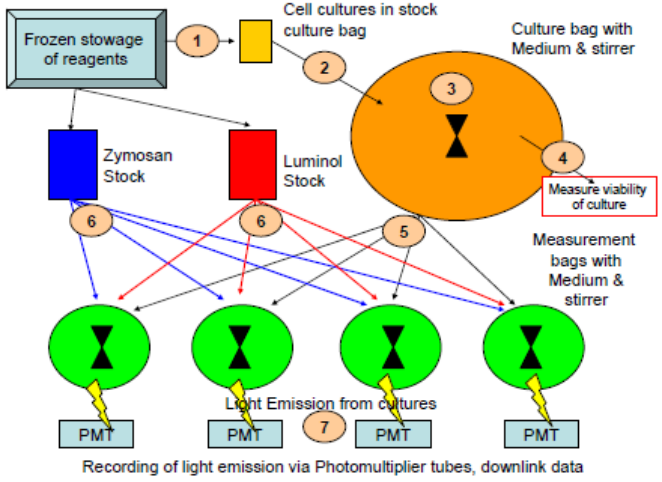
ISS BIOLOGY EXPERIMENTS for BIOLAB

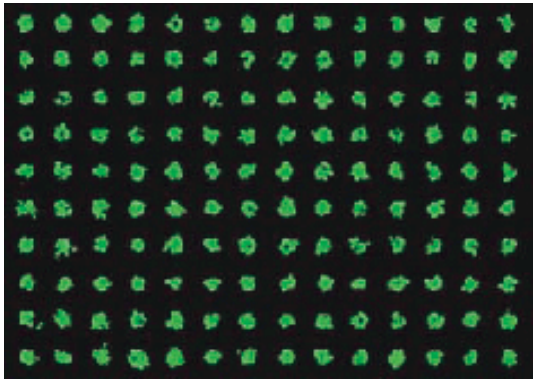
FLUOLIVE – Live cell imaging of cytoskeleton dynamics using fluorescence microscope under microgravity and variable g-levels (ILSRA-2009-0398)

FARGIS – Immune response to microgravity measured by inflight assay of GFP reporter gene, cytokine release using TRIPLELUX system (ISLRA-2009-1045)

FLUOCELLS – Realtime yeast cell gene expression using GFP reporter







ELIPS-4: Programme Elements

Phase C/D developments for Exobiology Research

ISS EXOBIOLOGY EXPERIMENTS

OREOCUBE – Evolution of organic compounds under solar UV. OREO/S Nanosatellite heritage & significant US participation in project, therefore NASA contribution to experiment anticipated (ISLRA-2009-1102)

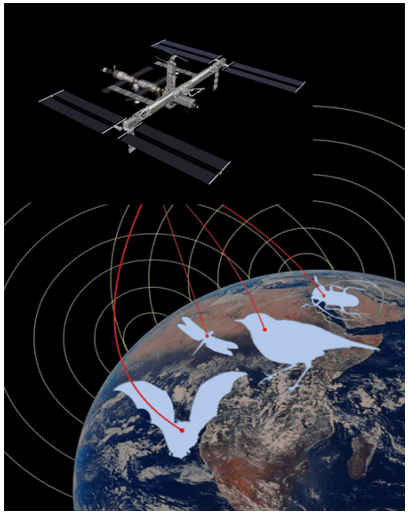
EXPOSE-R2 – Consortium of exo/astrobiology and organic chemistry experiments (ISLRA-2009-834, -836, -890)

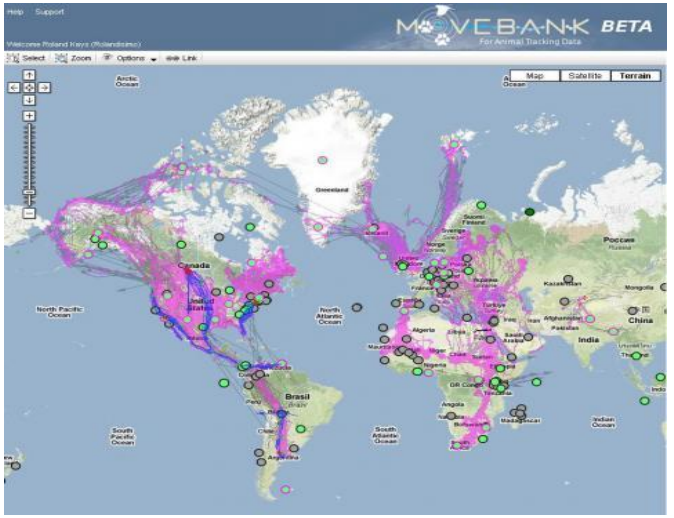
ELIPS-4: Programme Elements

Phase C/D development in Animal Migration Tracking

ISS ANIMAL MIGRATION TRACKING

ICARUS – Multinational project for tracking small animals on a global scale using minaturised tags communicating with ISS receiver/transmitter. Goal is to identify unknown migrations, impact of climate change on animal migration and biodiversity as well as spread of animal borne diseases (ISLRA-2009-0870)



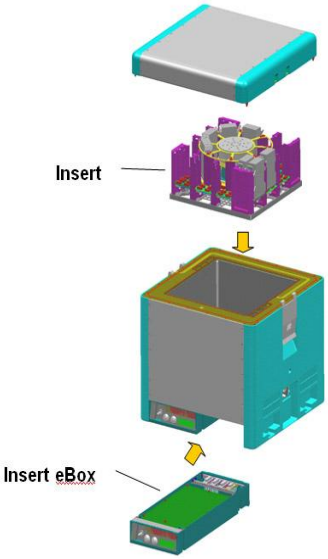


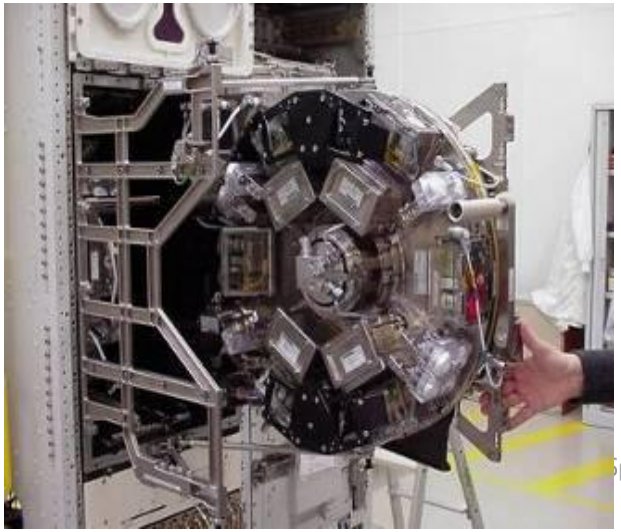
ELIPS-4: Programme Elements

Phase C/D of ISS Life Science Capabilities Evolution

BIOLOGY FACILITY EVOLUTION

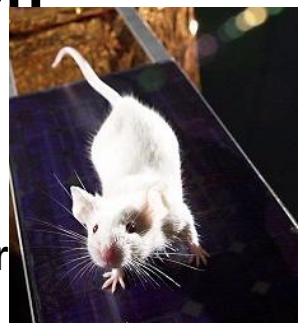
Enhanced capability for biology experimentation, either by upgrade of an existing incubator or new incubator based on KUBIK type concept but with data/commanding and flexible experiment interface





ELIPS-4: Programme Elements

Phase C/D of ISS Life Science Capabilities Evolution



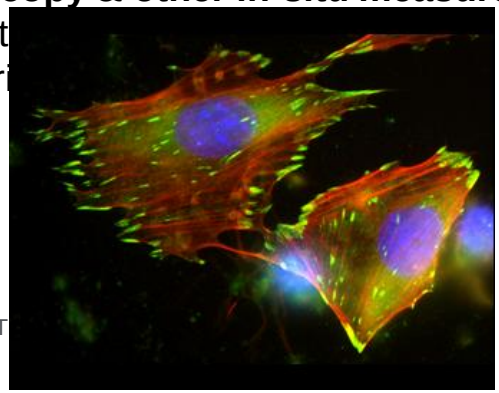
RODENT RESEARCH

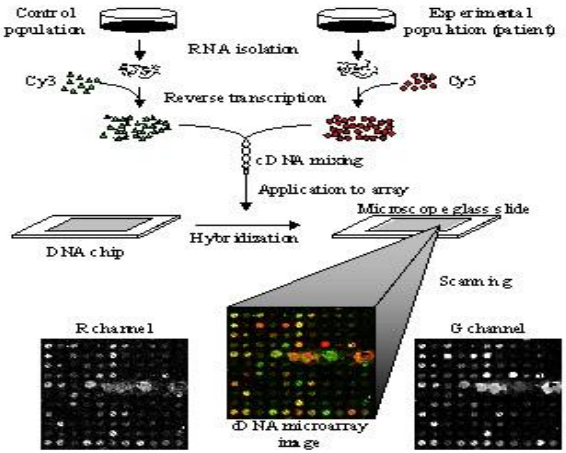
Provide regular access to flight opportunities in this important field for European scientists by contributing hardware to co-operative projects with ISS Partner

ON-ORBIT ANALYSIS AND IN VITRO MEASUREMENT CAPABILITIES

Develop capabilities for on-orbit analysis of human physiology and biological samples

- **IBICA** – Immunoassay of blood and urine samples (currently in phase A development)
- **Bioanalyser** – Gene Expression analysis of Biology and physiology samples
- **Fluorescence Microscopy & other in-situ measurements.** The 3 experiments incorporat cell measurer reused for future experi

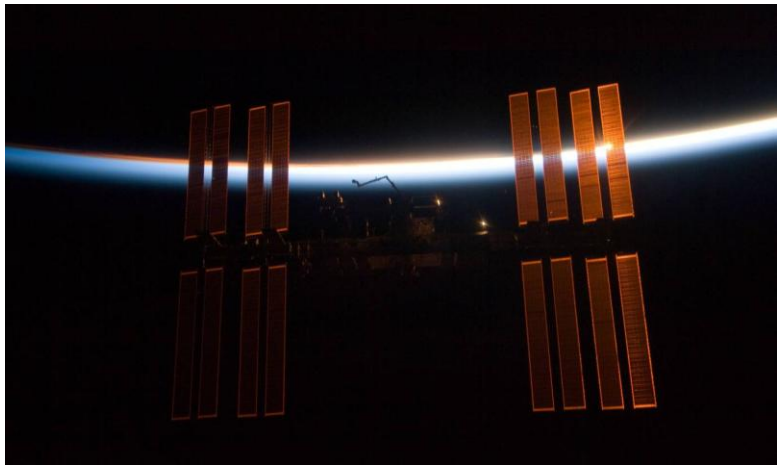




Climate Change Studies from ISS

- **1-2 proposals have been recommended by ESAC for selection from AO**
- **Phase A funded through GSP studies (tbc)**
- **Phase B/C/D funding tbd (but <u>not</u> within ELIPS)**

- **Note: The SOLAR, ASIM and ICARUS experiments are also relevant for Climate Change studies.**

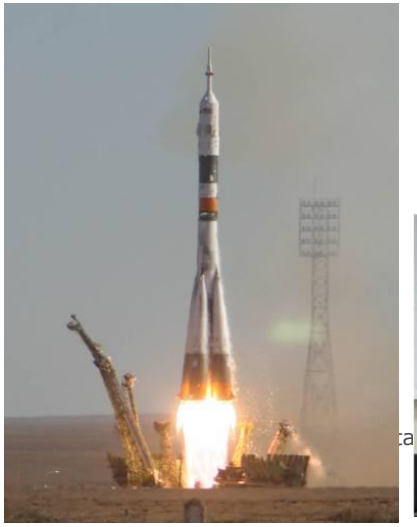


ELIPS-4: Programme Elements

Phase E: Integration/Operations

Access to Russian ISS Transport capabilities and resources. The Russian ISS transport vehicles have proven and unmatched late access/transport to ISS/Early retreval times. In addition in human physiology access to Russian crew members provides additional subjects to enhance statistics. Therefore, it is important to maintain access to these logistic capabilities and resources

ESA/Russian Joint Experiments Implementation of some experiments jointly with Russian,s where there is complementary Russian and ESA experiments may offset some of the total ISS resource requirements for ESA. Several ELIPS-4 projects are candidates for joint ISS experiments



ELIPS-4: Programme Elements

Part 3: Non-ISS Payloads and Missions/Campaigns (1/3)

BEDREST

The intention is to continue the successful bedrest activities, consultation with the user community will define interventions to be tested as well as duration of bedrest required.

ISOLATION STUDIES

Continuation of research and technological demonstrations on Concordia. After the successful Mars500 study, further isolation studies are planned, but preferably in a European facility this time (e.g. Envihab of DLR).

Human Exploration Preparation

INVESTIGATIONS INTO BIOLOGICAL EFFECTS OF RADIATION (IBER)

The IBER studies at GSI, Darmstadt have been very productive and further opportunities on this ground-based platform is planned.

ISS BASELINE DATA COLLECTION

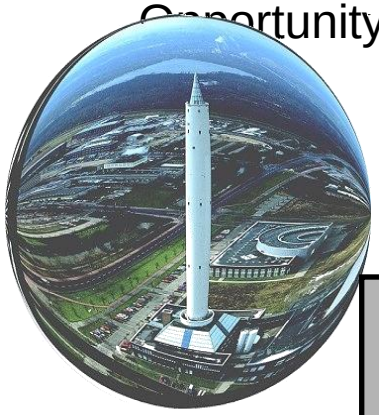
Collection of baseline reference data is mandatory for Human research on ISS. In order to maximise utilisation possibilities it is important to be able to perform these activities both in USA and Europe for regular ESA implemented experiments, but also in Russia in order to allow for cooperative experiments with this ISS partner by access to Russian ISS crew members.

ELIPS-4: Programme Elements

Part 3: Non-ISS Payloads and Missions/Campaigns (2/3)

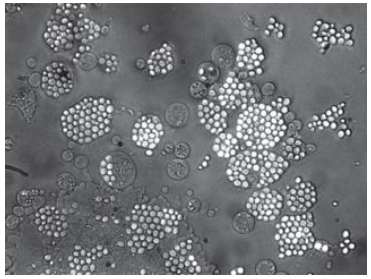
DROP-TOWER AND PARABOLIC FLIGHTS

Provide access to the drop-tower and parabolic flights in preparation for longer-duration flights or for self-standing projects selected through the Continuously Open Announcement of Opportunity (CORA).

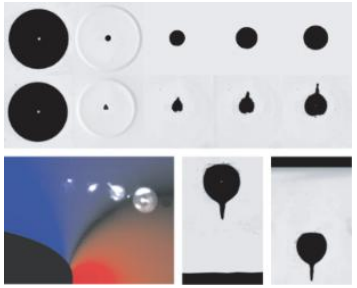


Brownian motion of a particle during free-fall in the drop-tower (Univ Braunschweig)

Cardiovascular investigations on parabolic flights



Freshly collected hemocytes at the surface of a Neubauer chamber



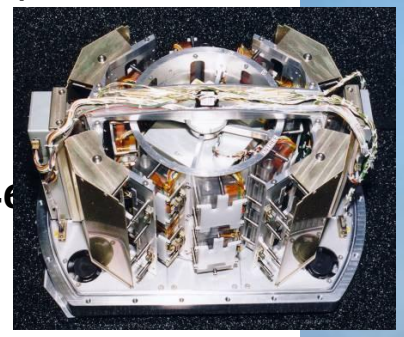
Cavitated bubble collapse on parabolic flights (EPFL)

ELIPS-4: Programme Elements

Part 3: Non-ISS Payloads and Missions/Campaigns (3/3)

SOUNDING ROCKETS

Tentatively ~ 1 launch per year, optimized among MAXUS, MASER, TEXUS



Physical Science Experiment candidates

(new or re-flight, not exhaustive)

- **CDIC-3 (AO-2009-1082), SiSSI (AO-2009-1051), XRMON (AO-2004-046**
- **PERWAVES (AO-2009-0918),**
- **QWEP (AO-2004-133),**
- **DOLFIN (AO-2009-1153), SOURCE (AO-2004-111), BIOMICS (AO-2004-113), CIMEX (AO-1999-110)**

Biological Science Payload candidates

- **MAXUS 9 Payloads: EUGRAPHO (AO2009-0910/-912)**
- **BIM-2 Payloads (Facility reflight): GRAMAT/SPARC Plant biology Experiments (AO2004-031/-041)**
- **Dedicated TEXUS/MASER Modules: ENDOFIL (AO2004-039), EMIT (AO2009-1057)**

ANITA-2
Analysing Interferometer for Ambient Air

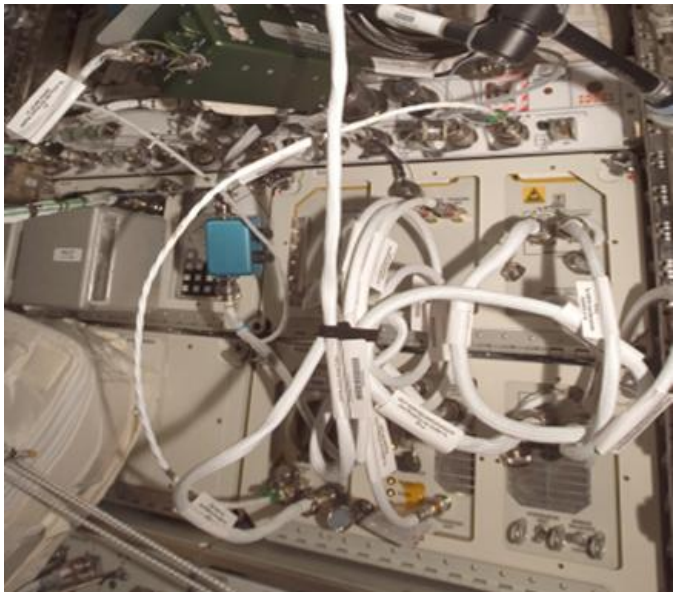
Background:
Lessons learnt from ANITA mission have been drawn and preliminary breadboard of complete ANITA-2 instrument currently being studied.

Objectives:
Development of ANITA-2 Flight and ground models to be operated on ISS (min. 3 years continuous operation)

Output:
ANITA-2 flight, ground and training models

Budget:
20 MEuro

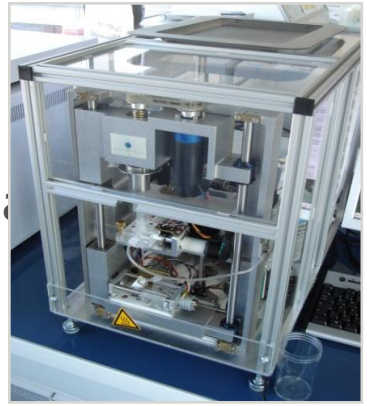
Countries/Companies:
D (KT), N (SINTEF), B (Qinetiq)



MIDASS
Microbial Detection in Air/Surfaces System for Space

Background:

- Development of a "real time", miniaturized, automated system for sampling and monitoring the microbiological quality of air, surfaces and water, for ISS.
- A real-time Microbial Detection System for space applications is recognised extremely important at MMOP level, and no equivalent exist within our international partners.



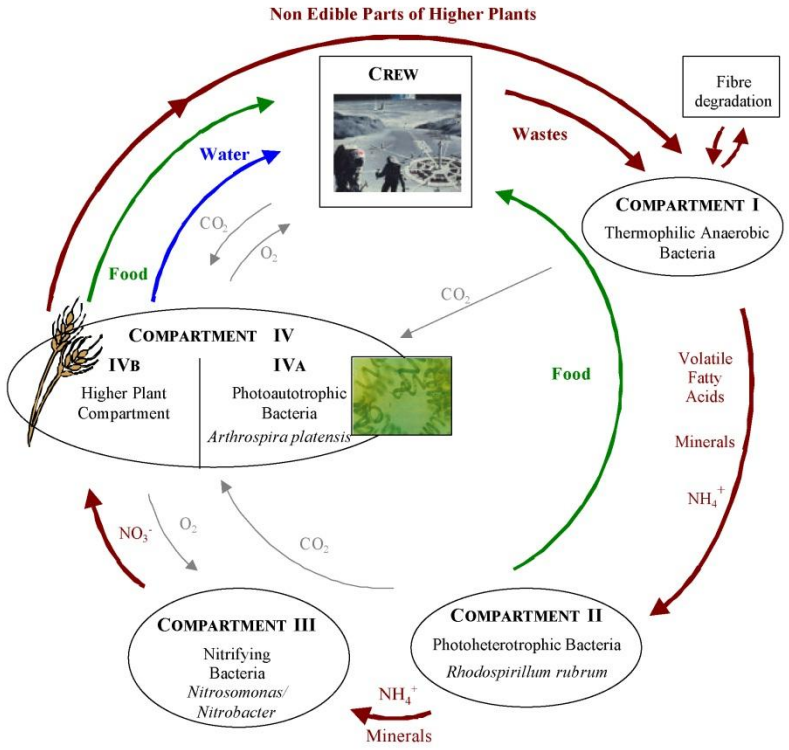
Objectives:

The proposed activities will cover the design, development a qualification of flight equipment suitable for ISS.

Budget: 24 M€

Countries: B, D, E, F, I (ITT for the selection of the space company, NTE/SENER and Kayser Italia have participated to ph. B development)

The MELiSSA Concept



Budget Proposal ELIPS-4 HE Technology

Part 4: HE Technology Programme Elements (separate envelope)

ELIPS Slices Elements	Proposal (M€)
A) ANITA-2	20
B) MiDASS	24
C) MELiSSA Technologies	22

MELiSSA Ph.	Activity Title	Budget
1	Waste Processing	1.40
1	Photo-autotrophic bioreactor	0.60
1	HPC PCU	3.00
2	Nitrification Bioreactor	1.50
2	BIORAT 2	0.50
2	BIORAT B+	1.50
3	C2 Procurement	1.00
3	Nitrification Control	0.50
3	Pilot plant	4.00
3	System tools	1.00
3	Belissima	1.00
3	Concordia	2.00
	Total [MEuro]	**18.0**