→ SPACE FOR LIFE

human spaceflight science newsletter

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NASA

In this issue:

→ UPDATE ON EUROPEAN RESEARCH ON THE ISS:

An overview of research activities during Expeditions 32-34

With ESA astronaut Andre Kuipers concluding a long-duration mission in July 2012 and ESA's next astronaut Luca Parmitano launched at the end of May 2013 the intervening period has been far from quiet on the ISS from a European research perspective with new experiments starting, long-running experiments concluding and established experiments still on-going.

Since the conclusion of the PromISSe mission, European research has still been very busy during ISS Expedition 32, which concluded in September 2012, Expedition 33 which concluded in November 2012 and Expedition 34 which concluded in March 2013. These European research activities were overseen by the control centre teams at the Columbus Control Centre and the various User Support and Operations Centres (USOCs) around Europe and were either controlled solely from ground or had the assistance from the ISS Partner astronauts and cosmonauts on orbit.

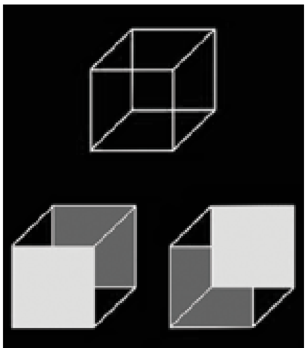
Human Research:

Neuroscience

Gravity plays a fundamental role in our perception of our environment on earth. Adaptation to, and living under weightless conditions, and thereafter re-adaptation to gravity, are challenging for astronauts. Differences in perception have already been highlighted from previous research on the ISS. ESA's neuroscience research on the ISS saw the start of a new experiment as well as the conclusion of the final subject of a well-established ESA neuroscience experiment, both of which are looking into altered perception in space. The Reversible Figures experiment, which started in July 2012 has already been started/completed by four separate astronauts. For ESA's Neurospat experiment which was the first experiment to make full use of the European Physiology Modules facility in June 2009, CSA astronaut Chris Hadfield completed his final session of the experiment as the fifth and final test subject in February 2013. Both of these experiments will be covered by a more detailed article in one of the next issues of the newsletter.

NASA astronaut Sunita Williams undertaking the Reversible Figures experiment in Columbus on 19 July 2012

For Reversible Figures the adaptive nature of the human neuro-vestibular system to weightlessness is being investigated with relation to 3D perception of ambiguous perspective-reversible figures.



The Necker cube (top). Highlighting different perspectives of the Necker cube (Bottom)

This is performed with astronauts recording what they visualise (on a screen) and thereafter every change in perception for the same object. One example of this is the Necker cube shown on the left. Filling in different front (light grey) and back (dark grey) faces of the cube reveals how the Necker cube can be perceived from a higher (above the cube) or lower (underneath the cube) perspective. The experiment is scheduled to take place with six test subjects.

Neurospat has been investigating the ways in which crew members' three-dimensional perception is affected by long-duration stays in weightlessness and also incorporates an experiment (Prespat) from the European Commission within the SURE project[1].

[1] The SURE Announcement of Opportunity is an ESA initiative within the FP6 SURE Project – FP6 Programme "Structuring the Research Area, Research Infrastructures Action" (2006).

Session of the Neurospat experiment on the ISS in February 2012. ESA astronaut André Kuipers looks through light shield at visual stimuli displayed on attached laptop. At the same time brain activity is monitored through an EEG cap

Cardiopulmonary research

Three major long-duration cardiopulmonary experiments were undertaken during Expeditions 32-34. Two of these experiments (Thermolab and EKE) came to a successful conclusion in 2012 and are covered in detail in a separate article in a subsequent newsletter.

The third cardiopulmonary experiment is Vessel Imaging which is studying cardiovascular adaptation of long-duration ISS crewmembers by evaluating changes in wall properties and cross sectional areas of central and peripheral blood vessels. Ultrasound resources in Columbus are used together with ECG

NASA astronaut Dan Burbank setting up Human Research Facility 1 in Columbus for ultrasound scans on André Kuipers for the joint Vessel Imaging and Integrated Cardiovascular experiments in January 2012 and heart rate measurements to determine the flow velocity changes in the aorta and the middle cerebral and femoral arteries and quantify the cardiovascular response to fluid shifts.

To optimise research resources and objectives the Vessel Imaging experiment is carried out in conjunction with NASAs Integrated Cardiovascular (ICV) experiment which is also evaluating cardiovascular adaptation and the mechanisms behind it.

NASA astronaut Joe Acaba finished his final session of Vessel Imaging in September 2012 before conclusion of his mission. NASA astronaut Sunita Williams and JAXA astronaut Akihiko Hoshide finished their final sessions in November, while NASA astronaut Tom Marshburn also completed his first session of the experiment as the 10th and final subject on 31 December. (He subsequently undertook the final session during Expedition 35 on 2 May 2013 before the conclusion of his mission).

With gravity playing such an important role in blood circulation on earth, understanding the cardiovascular adaptation that occurs in space is not only important for planning future exploration missions it can also provide very important indications as to the mechanisms behind conditions such as hypertension and cardiovascular disease (which was estimated to cost around € 200 billion in the European Union in 2010).

With the experiment completed during Expedition 35, the data and results coming from Vessel Imaging will help to optimise the countermeasures used routinely during long-duration space missions.

Immunology
ESA's human research activities within immunology during the Expeditions 32-34 continued with the Immuno experiment. Four cosmonauts completed stress test questionnaires in 2012 and supplied blood and saliva samples to be checked for hormones associated with stress response and carry out white blood cell analysis. These samples (16 in total) were returned to earth with Soyuz 31S in December. The experiment was subsequently started and completed by two Expedition 34 cosmonauts (Oleg Novitskiy and Evgeny Tarelkin) during the first three months of 2013, and had been started by ISS Flight Engineer/cosmonaut Roman Romanenko as the final subject of the experiment in March 2013 (with conclusion of the final session on 8 May during Expedition 35). The results of the Immuno experiment, which is jointly performed under a bilateral cooperation agreement with Roscosmos, will help in developing pharmacological tools to counter unwanted immunological side-effects during long-duration missions in space.

Nutrition, Sleep and Well-Being
ESA's new Circadian Rhythms experiment started in July 2012 during Expedition 32 and continued into Expedition 33 with JAXA astronaut Akihiko Hoshide as the first test subject. The experiment, which will be covered in a separate article in a subsequent newsletter, is aiming to provide a better basic understanding of any alterations in circadian rhythms in humans during long-duration spaceflight. Circadian Rhythms continued through Expeditions 33/34 with NASA astronaut Tom Marshburn and CSA astronaut Chris Hadfield as the second and third test subjects of the experiment.

Hoshide was additionally a test subject (the second) for ESA's Energy experiment which is determining astronaut energy requirements. The experiment, which started with ESA astronaut André Kuipers in 2012 and has a significance to future human exploration missions, will also be covered in a separate article in a subsequent newsletter.

The Space Headaches experiment completed ESA human research activities during Expeditions 32-34 with different astronauts filling in weekly questionnaires related to the incidence and characteristics of headaches that occur on orbit (following daily questionnaires filled in during the first week after launch).

The experiment was completed by NASA astronaut Joe Acaba (as the 2nd test subject) prior to his return in September 2012 and by NASA astronaut Kevin Ford prior to his return in March 2013. By the end of Expedition 34 the experiment was on-going with NASA astronaut Tom Marshburn, and CSA astronaut Chris Hadfield.

Headaches can be a common complaint during space flights. This can negatively affect mental and physical capacities of astronauts/cosmonauts which can influence performance during a space mission.

Data from all the human research activities can help with the development and improvement of countermeasures to help improve the health and efficiency of astronauts in orbit which could also be developed for use within rehabilitation protocols on earth.

Fluids Research
The return of Soyuz 30S in September 2012 completed the return of scientific results for the SODI-DCMIX1 experiment (which finished in January 2012) with the return of four flash disks containing data. The DCMIX experiment is measuring diffusion in different liquid mixtures using very sensitive optical techniques. Data will compared with current theories, and improve our present understanding of how molecules move in liquid mixtures. The results will be used by the large team of scientists involved in the project to try to understand which of the many existing theories for mass diffusion is correctly predicting the experimental behaviour.

NASA astronaut Shannon Walker working on the SODI series of experiments inside the ISS Microgravity Science Glovebox in September 2010

With respect to the Fluid Science Laboratory, various software upgrades and functional checkouts took place in Expeditions 32-34 in advance of the upcoming FASES experiment. In addition, following approval of additional science requirements from the Geoflow experiment science team, the Geoflow-2 Experiment Container was reinserted into the Fluid Science Laboratory and continued experiment runs (as the Geoflow-2b experiment) from December 2012. Experiment runs continued beyond the end of Expedition 34. Optical fine tuning tests were also undertaken in order to best improve the quality of the science images generated.

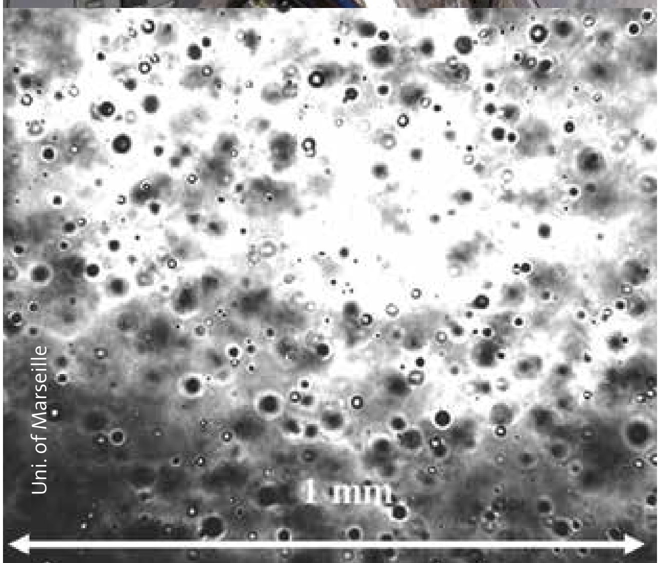
Geoflow-2 (March 11 – May 12) and Geoflow-2b (Dec 12 – Apr 13), which both follow on from the initial Geoflow experiment with new scientific objectives and a different experiment configuration, are investigating the complex flow patterns of an incompressible viscous fluid held between two concentric hemispheres rotating about a common axis as a representation of a planet.

This is of importance for astrophysical and geophysical problems such as global scale flow in the atmosphere, the oceans, and in the liquid nucleus of planets.

For Geoflow-2/Geoflow-2b the incompressible fluid is nonanol which varies in viscosity with temperature (unlike silicon oil as in the first Geoflow experiment) to provide a different aspect of research with more of a simulation to Earth's geophysical conditions.

There have been some issues with the video recording of experiment runs on orbit but, while this has been undergoing resolution planning, science data/images have been directly downlinked to ground during experiment runs. Additional software testing was underway in February, to resolve an issue accessing a Fluid Science Laboratory optical mode needed for the FASES experiment though, if not resolved, this will not prevent FASES from being undertaken as additional work-around procedures could be developed.

The FASES (Fundamental and Applied Studies of Emulsion Stability) experiment is due to take place in the Fluid Science Laboratory following its launch to the ISS on ATV-4 in June 2013. FASES investigates the effect of surface tension on the stability of emulsions which will hold significance for oil extraction processes, and the chemical and food industries.



Top: André Kuipers preparing the Fluid Science Laboratory in May 2012 for optical testing for the FASES experiment
Bottom: Emulsion of hexane in water from ground testing of FASES experiment. The black dots, which are due to light diffusion in the drops, provide the position and the velocity of the drops

Materials Science

ESA's materials science research took a big step forward during Expedition 34 with the recovery of the Materials Science Laboratory (MSL) and the restart of the Batch 2a experiments (CETSOL-2, MICAST-2, SETA-2). Following the primary payload computer crash in the US laboratory in September 2011, the subsequent loss of cooling to the MSL caused some graphite coating to become detached from the external surface of a sample cartridge that was being processed at high temperatures at the time. This led to the development and upload of a dedicated cleaning implement. NASA astronaut Kevin Ford used the implement to successfully clean the inside of the MSL Solidification and Quenching Furnace in November 2012.

This was followed by successful functional checkout and test activities in January which confirmed good functionality of the furnace. Scientific processing was resumed on 23 January with a MICAST-2 sample. This has been followed up so far with processing of a CETSOL-2 sample from 6-7 February, and a SETA-2 sample was installed inside the Materials Science Laboratory by the end of Expedition 34 for subsequent processing.

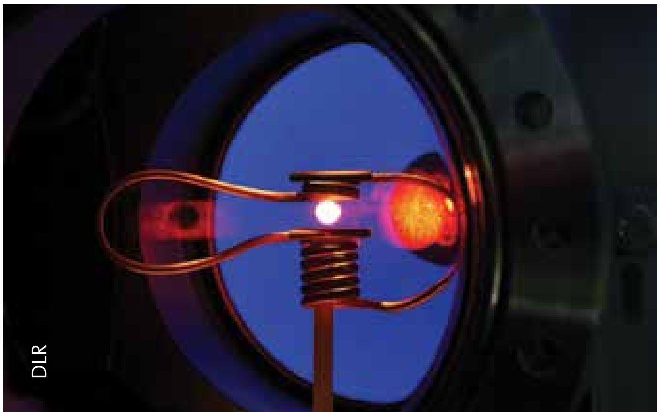
The three Batch 2a experiments are studying solidification processes by generating vitally important benchmark data on orbit that will improve numerical models on Earth. The ultimate goal of this research is to increase our understanding in materials solidification processes in order to help develop new stronger lighter-weight materials which will have a significant impact on industry for solving the most significant issues facing our planet such as fuel efficiency and consumption and recycling of materials.

Canadian Space Agency astronaut Chris Hadfield during exchange of samples for the Batch 2a experiments on 5 February 2013

The SOLAR facility (centre) pictured on the International Space Station in June 2008 during an STS-124 mission spacewalk

Very promising preliminary scientific results have already been presented from the first batch of CETSOL/MICAST experiments from 2009/2010.

Preparations are also picking up momentum for the arrival of the Electro Magnetic Levitator (EML) which will be located inside the European Drawer Rack (EDR) in Columbus and will investigate properties of metal alloys under weightlessness, supporting basic and industrial research. As EML will produce an extensive amount of video data during samples' processing, successful data downlink testing was performed in January 2013 followed in February by a vacuum and a venting system leak check of the European Drawer Rack.



Core element of the ground-based Electro Magnetic Levitator

The Electro Magnetic Levitator will perform container-less materials processing involving melting and solidification of electrically conductive, spherical metal alloy samples, under ultra-high vacuum and/or high gas purity conditions.

Solar Research
ESA's Solar research on the ISS has continued with the Solar payload facility which has been studying the Sun's irradiation with unprecedented accuracy on the external surface of the Columbus laboratory for five years. A detailed overview of this research including unique data acquisition in November/December was covered in a separate article in the previous newsletter. Since the start of 2013 until the end of Expedition 34 (on 16 March), an additional two Sun visibility windows were completed for the SOLAR facility to acquire data (17-29 January and 11-23 February) with the facility celebrating five years since its installation on Columbus on 15 February.

Radiation Research
ESA's radiation research saw the conclusion of one long-duration experiment, the continuation of another and the start of a new experiment. These experiments are improving our knowledge of the radiation environment in low-Earth orbit.

The second part of the ALTEA-Shield experiment which is testing two different shielding materials (Polyethylene and Kevlar) against radiation was concluded in Columbus on 13 November 2012. This second part of ALTEA-Shield included a first session which gathered 54 cumulative days of data for the polyethylene tiles and a further session with Kevlar tiles which gathered 94 cumulative days of data (the minimum requirement was 40 days for each tile set)

André Kuipers setting up the ALTEA Shield hardware in the Shielding configuration on 8 June 2012

This follows the ALTEA-Survey part of the ALTEA-Shield experiment series which finished in December 2011 following an extensive 3-dimensional survey of the radiation environment in the US laboratory.

The Dose Distribution inside the ISS 3D (DOSIS-3D) experiment has been on-going in Columbus (since May 2012) using passive dosimeters located at different locations around the Columbus laboratory and two active DOSTEL detectors located inside the European Physiology Modules (EPM) facility.

An orange-packaged detector located on the front of ESA's European Physiology Modules Facility in the Columbus Laboratory as part of the DOSIS experiment

The passive detectors are used in order to undertake 'area dosimetry' i.e. to measure the spatial radiation gradients inside the Columbus module while the active detectors are used to undertake time-dependent radiation measurements.

The first set of passive detectors (10 Passive Detector Packages and 1 Triple Detector Package) were uninstalled and returned to earth for scientific analysis with Soyuz 30S in September 2012. A second set of passive detectors installed in October were returned to earth for analysis on Soyuz 32S in March 2013.

The aim of the DOSIS-3D experiment is to determine the nature and distribution of the radiation field inside the ISS. The DOSIS-3D experiment builds on the data gathered from the previous DOSIS experiment by combing data gathered in Columbus with ISS International Partner data gathered in other modules of the ISS.

Comparison of the dose rates for the DOSIS-3D and the DOSIS experiments shows a difference in dose level which can be explained due to the different altitude of the Station during the measurements.

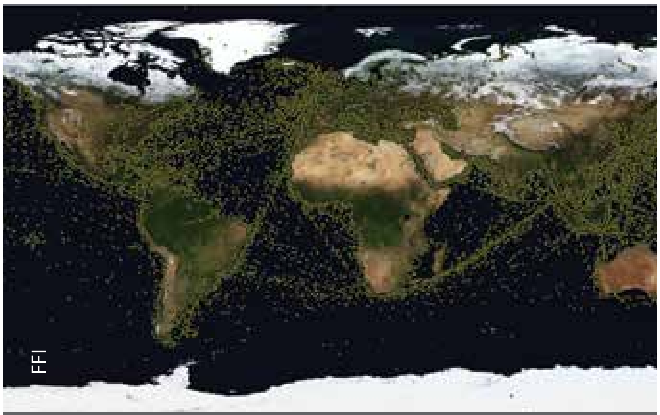
Both ALTEA-Shield and DOSIS-3D were discussed in length in separate articles in the previous newsletter.

The final experiment in the area of radiation research which started during Expeditions 33 was the TriTel (Tri-Axis Telescope) experiment. This experiment is also covered in more detail in a separate article.

Technology Demonstrations

The testing of new technologies on the ISS has proved to be very successful area of research for ESA. The Vessel Identification System continues to monitor global maritime traffic from space.

There has also been downlink of extensive footage from the Erasmus Recording Binocular 2 (ERB-2) which records high definition 3D video images on the ISS, and use of the NightPod tracking device in the European-built Cupola Module which supports a Nikon D3s camera in taking high-definition pictures of the Earth, especially under low light conditions during ISS night orbital passes. This device compensates for the motion of the Space Station by tracking single points on Earth automatically. The footage from these two devices will be used as part of global outreach/education activities.



Plot of global ship positions using AIS data from the Norwegian NORAIS Receiver. NORAIS forms part of ESA's Vessel Identification System for tracking global maritime traffic

The AIS antenna following installation on the outside of the Columbus laboratory

A new technology experiment started during Expedition 34 in 2013, which will have an impact for future spacecraft operations especially on longer-duration human exploration missions. The first two sessions of the Crew User Interface System Enhancement (CRUISE) technology experiment were undertaken in February and March by NASA astronaut Kevin Ford and CSA astronaut Chris Hadfield respectively. The sessions

ESA astronaut and Expedition 26 Flight Engineer Paolo Nespoli, uses the ERB-2 to film the ALTEA-Shield (Survey) experiment on the International Space Station on 8 January 2011

NASA astronauts Kevin Ford (background), and Tom Marshburn, conducting a session of the SPHERES programme in the Japanese laboratory of the International Space Station in January 2013

consisted of the astronauts undertaking a standard cleaning procedure in the Columbus laboratory, supported by (and testing) visual and voice activated procedures/technologies.

The CRUISE experiment is a technology demonstration testing voice guided procedure execution with real-time command and telemetry components included, which aims to significantly improve crew members' operations and performance such as shortening task-to-completion time whilst reducing the occurrence of system-human error.

Education and Additional Activities

Even without an ESA astronaut on mission on the ISS during Expeditions 32-34, education activities continued with the assistance of ISS Partner astronauts. The principal activity that has been undertaken during Expeditions 32-34 was the SPHERES Zero-Robotics Competition which, in Europe, was supported from ESA's ESTEC facility with European high-school teams present for the live link competition event with Kevin Ford and Tom Marshburn on the Space Station.

The algorithms used to control the free-floating satellites during this session were written by competing students from eighteen European teams and twenty-seven US teams. Video filmed on the ISS during the event was downlinked to the ground in January.

→ INFLUENCE OF RADIATION ON FUTURE EXPLORATION MISSIONS:

The Investigations into Biological Effects of Radiation (IBER)

Linear accelerator UNILAC – Inner view of the so-called Alvarez structure

The horizons of human spaceflight are leading us inexorably towards future human exploration missions beyond low-Earth orbit, where a more challenging radiation environment will be faced by our astronauts. In preparation for this one of ESA's key ground-based projects is the Investigations into Biological Effects of Radiation (IBER) which is improving our understanding of what the effects of such a challenging environment would have on our astronauts.

Venturing outside of low-Earth orbit on future human exploration missions provides us with a very challenging environment with respect to radiation. In low-Earth orbit astronauts still have the protection of Earth's magnetic field (and spacecraft shielding materials) to reduce the exposure to a great degree of high energy radiation. Not only is this environment more challenging outside of low-Earth orbit, our knowledge of its effects on humans is also much less. Much more research has been carried out on the ISS and far more astronauts have been exposed to low-Earth orbit for longer durations. The only data we have from outside of low-Earth orbit derives from the Apollo missions. When considering bases on the Moon, or missions to Mars, risks from radiation exposure become one of the major factors of concern. In fact space radiation is one of the major risk factors that may limit human space exploration plans.

Current space radiation risk estimates suffer from huge uncertainties, which are largely due to missing information on the biological effects of the radiation encountered in interplanetary space, especially high-energy heavy ions. The best way to close this knowledge gap is to perform biological experiments using particle accelerators. An advantage in Europe was the existence of facilities containing the necessary infrastructure and know-how, thus avoiding any costly initial investment prior to the start of this research.

Interplanetary radiation

In interplanetary space, the spacecraft, astronauts and everything inside are fully exposed to radiation from Solar Particle Events and Galactic Cosmic Radiation. Solar Particle Events can deliver significant doses within relatively short time periods. Radiation from Solar Particle Events consists mainly of protons. It can effectively be shielded against; however in specific situations e.g. an Extra Vehicular Activity and/or on a planetary surface, where one is shielded only by the thin spacesuit material, a Solar Particle Event presents a lethal threat. Currently the occurrence of Solar Particle Events cannot be predicted, which might impose constraints on mission operations and planning. Also, even if shielded against, Solar Particle Events can still contribute significantly to the overall mission dose and therefore to a higher risk of late effects.

Galactic Cosmic Radiation consists of a variety of particles including heavy ions. Shielding is not very effective because of the high energies of the particles. Due to the low but constant exposure to Galactic Cosmic Radiation, the main danger lies in late effects, like cancer development. However when faced with estimating the risk of late radiation effects, the uncertainties are very high.

For this reason ESA partnered with the Gesellschaft für Schwerionenforschung (GSI) which is operating the best suited facility in Europe for this type of research, in a suburb of Darmstadt in Germany. GSI has been conducting the beam times for the experiments within IBER at its heavy ion accelerator facility following the first Research Announcement which was issued by ESA in 2008.

IBER Research

From this first announcement 33 proposals were received of which 10 were selected and implemented over a two-year timescale. The beam times for this first set of experiments was concluded in September 2010.

The successful implementation of this first campaign led to the release of a second "Announcement of Opportunity in October 2010. Of the 28 proposals received by the January 2011 deadline, 8 were rated "Excellent" and 7 were rated "Very Good" for scientific merit and therefore underwent a general feasibility evaluation. As was the case with the 2008 Announcement of Opportunity, the feasibility evaluation was conducted with support by experts from GSI. Based on the outcome of both reviews all 15 projects were recommended to be selected for definition. Six of the recommended proposals are continuation projects from the Announcement of Opportunity 2008 IBER experiments, which also explains the relatively high success rate.

The implementation started in May 2012, for a duration of two years, during which multiple irradiation periods will take place. Many of the research projects within IBER are looking at the effect of different radiation particles on different cells and tissues of the body. From the 2010 Announcement of Opportunity the research is covering a variety of areas:

In neuroscience this covers the effect of radiation on visual receptors and networks, and ion channels that underlie nerve impulses and nerve cell function in the hippocampus (which plays important roles in the consolidation of information from short-term memory to long-term memory and spatial navigation).

In cardiovascular research IBER experiments are covering the effect of radiation on cardiovascular disease and tissue degeneration (including platelet production and thrombus formation).

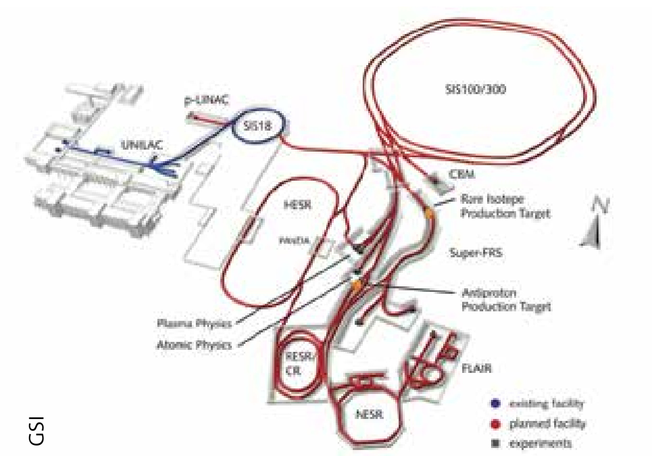
In immunology research is covering measures to counter immune system depression using the hormone leptin.

In genetics there are various experiments covering the effect of radiation on DNA/chromosomal damage/repair and cancer risk, and identifying biomarkers that can be used for tracing radiation exposure and predicting individual radio-sensitivity to heavy ions.

In musculoskeletal research one IBER experiment is studying the effect of radiation on bone cell (osteoblast) generation.

View inside Matroshka Phantom's head on the International Space Station in 2006 revealing location of radiation sensors

Additional research is making an assessment of radiation transport through the body using a simulated human head (derived from ESA's previous Matroshka experiments on the ISS) and testing of novel Habitat Protection Structures to shield the crews.



GSI

The planned facility FAIR (red), which will be connected to the existing GSI accelerators (blue)

Future Perspectives

The GSI facilities provide an extremely valuable resource for enabling this type of research. This will hold even greater potential with the expansion of the GSI site to include the Facility for Antiproton and Ion Research (FAIR). Though this may put a slight delay on beam times during its construction, it will also expand facilities and offer the opportunity of a wider spectrum of research.

The research that has been undertaken coming from the 2008 Announcement of Opportunity, and is on-going from the 2010 Announcement of Opportunity, will help ESA and Europe contribute to overcoming the challenges posed by space radiation, and help prepare humankind's exploration into the solar system.

Already an interesting aspect coming from this type of research is the finding of synergies between hadron therapy and space radiation research. While particles and application characteristics may differ, some issues, like (secondary) cancer development, individual radio-sensitivity, radio-protecting drugs etc. are very relevant for both.

→ IMPROVEMENTS IN RADIATION RESEARCH IN LOW-EARTH ORBIT:

The TriTel Experiment

ESA's radiation research on the International Space Station (ISS) has been on-going for many years and has built on decades of previous radiation research. This research has been extended with the TriTel (Tri-Axis Telescope) experiment which has been undertaking a three dimensional survey of the radiation environment inside the Columbus laboratory of the ISS and reached a successful conclusion on 10 May 2013.

The TriTel experiment is providing us with an extensive amount of data helping us to better understand Earth's radiation 'weather' surrounding our planet which in turn helps in assessing whether this has an impact on climatology and helping to safeguard our astronauts now and for future missions.

The TriTel experiment consists of three elements: the Detector Unit (the black box on the left in the right-hand picture) which provides continuous time-dependent measurements, a data processor (the flat box on the right, also known as the Interface Unit) and a set of passive detectors (wrapped in an orange-


NASA/Hungarian Academy of Sciences

TriTel hardware in the Columbus laboratory on the ISS coloured pouch) which provides the accumulated total dose when the recording period is over

The Detector Unit contains three active radiation detectors ('telescopes') aligned perpendicular to each other to provide a full 3-dimensional mapping of radiation entering Columbus. It was installed and activated in ESA's Columbus laboratory on 6 November 2012 following transport to the ISS on Soyuz 49P, with a successful checkout a few days later.

An accompanying set of passive radiation detectors was launched on Soyuz 33S which arrived at the ISS on 21 December 2012. The passive detectors consist of several layers of plastic track detectors and a layer of thermoluminescent detectors. As is the case for the active detectors in the Detector Unit, the passive detectors are positioned in three orthogonal directions to provide together a full 3D scan of the radiation environment.

On 15 March 2013 a downlink of all accumulated data was undertaken which revealed good functionality of the Detector Unit following analysis by the science team. Up until 10 May (the final day of science acquisition) a cumulative total of 139 days of data had been gathered by TriTel. ISS Expedition 35 Commander Chris Hadfield carried out the close out activities, with data downlinked and a USB of data and the passive radiation detectors packed for return on Soyuz 33S.

ESA has already been undertaking 3D radiation dosimetry activities on Columbus with the DOSIS and DOSIS-3D experiments (covered in the previous newsletter) though the 3-dimensional element was through the use of passive dosimeters spread around Columbus to undertake area dosimetry i.e. to measure the spatial radiation gradients inside the Columbus module.

With TriTel however the 3D measurements are provided with the active sensors providing time dependent measurements so that we can not only see the directions (and type) of radiation particles passing through Columbus, but when and how they pass through during the ISS orbit and with what frequency.

This could be extremely important for future long-duration 'deep space' missions with directional variation of radiation due to the fact that the shielding properties of any spacecraft are not the same in every direction.

TriTel can be equipped with a display that tells the crew immediately what is going on. This panel though this is not used in the current experiment in Columbus. During solar flares on a manned mission to Mars for example, the spacecraft could be rotated in such a way that there is a maximum amount of shielding mass between the crew and the Sun. During that rotation, TriTel could help the crew to put the spacecraft in the best position with optimal shielding.

The same procedure could also be used on unmanned spacecraft to protect sensitive electronics, with the TriTel data delivered in the telemetry.

Top: Detector unit Bottom: Interface unit

With the TriTel experiment in Columbus now completed we look forward to seeing how the data can build upon our current knowledge and help to update models of the radiation environment in low-Earth orbit.

This will not be the end of experiments using TriTel on the ISS. A prolongation of recording is foreseen on the ISS with TriTel no longer in Columbus, after the transfer of hardware to come under Russian responsibility in a bilateral agreement with the Hungarian science team. This will provide a straightforward opportunity to compare the radiation conditions in the Columbus module with other segments of the ISS.

➜ ESA UTILISATION ACTIVITIES DURING THE THE VOLARE MISSION WITH LUCA PARMITANO

A brief look at research during the current long-duration ISS mission

The end of May has seen ESA's 6th astronaut launched to the ISS as an Expedition crew member. As always the central part of this mission is an extensive research programme. We take a look at what research will be undertaken during the Volare mission with ESA astronaut Luca Parmitano.

ESA astronaut and ISS Expedition 36/37 Flight Engineer Luca Parmitano during training

Italian ESA astronaut Luca Parmitano launched to the ISS on 28 May 2013. Not only was he the 6th ESA astronaut Expedition crew member on the ISS, he was also the first ESA long-duration astronaut from the most recent group of astronauts selected in May 2009.

Utilisation Overview

Within the crew time allocation of about 75 hours ESA has composed a package comprising a variety of different utilisation activities in the following thematic groups.

Parmitano will remain as a member of the Expedition 36 Crew (pictured) until September when, following a crew reconfiguration he will become a member of the Expedition 37 Crew until his return in November

Life Sciences

Research into the effects that weightlessness and the conditions of space have on the human body take a significant share of the experiment programme with Luca Parmitano being the subject of 6 ESA and 10 ISS Partner experiments in human research. For ESA this includes the Energy and Circadian Rhythms experiments discussed in detail in separate articles in a subsequent newsletter as well as the Space Headaches experiment discussed in brief in the first article (on research during Expeditions 32-34).

Outside of these Parmitano will be a subject of the new Sarcolab and the ongoing Cartilage experiments which are looking into the effects of spaceflight on muscle deterioration (Sarcolab) and articular cartilage deterioration (Cartilage) due to long-duration stays in weightlessness. These two experiments only involve pre- and post-flight procedures and will help in the development of methods to prevent/counteract such effects on astronauts for example using different methods of exercise, new technologies or dietary supplements and hence improve/maintain the health and performance of our astronauts in orbit. This could also provide insights into the mechanisms behind similar medical conditions on Earth and in turn assist with prevention/rehabilitation procedures.

A new experiment series which Parmitano will begin as the first test subject is the Skin-B experiment which is a study into skin physiology namely in terms of aging in weightlessness. With the skin being the largest organ of the human body and having multiple functions including thermal regulation, protection against pathogens and damage, helping to maintain fluid balance in the body, and providing the means of tactile sensation to name a few, the skin is vital in maintaining the body's homeostasis.

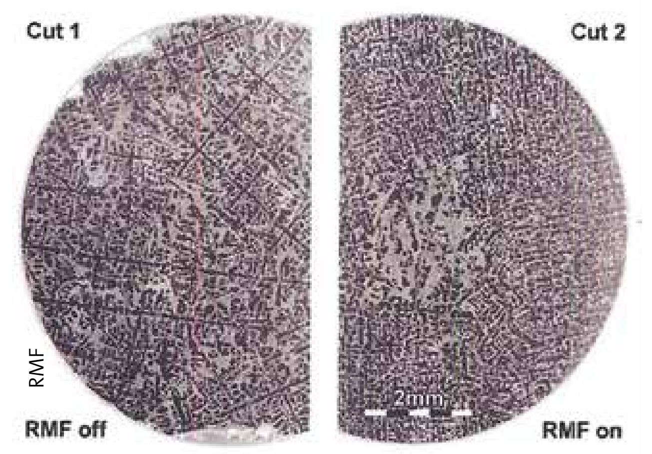
Skin aging is slow on Earth but very much accelerated in space with astronauts commonly suffering from cracking skin and rashes or itchiness. The Skin-B experiment will collect data on astronaut's skin such as its structure, oxygenation, hydration and elasticity. The goal is to develop a computer model of how skin ages. This will help in developing a mathematical model of aging skin. This will not only provide insights into skin physiology and skin aging processes in space (and on Earth), it will also provide insights into the aging process in other (similar) bodily tissues. This could help in determining the impact on astronauts on future long-duration missions to the Moon and Mars for example where environmental conditions are more challenging.

Using a Tewameter® to measure water loss from the skin

In biology Parmitano will also undertake a biology experiment for NASA as part of their National Laboratory Pathfinder series of experiments.

Materials, Fluids and Combustion Sciences

In materials science Parmitano will be a key astronaut in undertaking activities for a selection of the Batch 2a alloy experiments (CETSOL-2, MICAST-2, SETA-2 projects) which are looking into materials solidification processes in metal alloys. These experiments which are undertaken in ESA's Materials Science Laboratory (MSL) in the US laboratory are also covered in brief in the first newsletter article (and in a detailed article in one of the next issues of the newsletter). Parmitano will have the task of swapping out the Sample Cartridge Assembliies (SCA) for the Batch 2a experiments. The MSL facility is jointly operated and scientifically utilised by ESA and NASA.



Metallographic sections of a processed MICAST sample. Left: under diffusive conditions. Right: under forced convection induced by rotating magnetic field

Turning to fluid science the ATV-4 will bring a new experiment unit to the ISS which is studying emulsion stability. The FASES (Fundamental and Applied Studies of Emulsion Stability) experiment is due to take place in the Fluid Science Laboratory and investigates the effect of surface tension on the stability of emulsions. Emulsions are very common on Earth, in nature such as milk and also in man-made products. FASES is investigating the physical principles which determine the stability of different emulsions and which compounds can influence this. This knowledge is very helpful to industry in using/designing the best compounds to stabilise or destabilise different emulsions depending on their use and optimising their utilisation towards greener products. The research holds significance for oil extraction processes, and the chemical and food industries.

The measurements will be carried out in 44 sample cells positioned in a carousel with 28 transparent emulsions and 16 opaque emulsions. These thin emulsions of different compositions will be optically and thermally characterised with on-orbit operations for the Fluid Science Laboratory controlled from the Microgravity Advanced Research and Support Centre (MARS) in Naples, Italy (the Facility Responsible Centre for the Fluid Science Laboratory).
A detailed article on FASES will be appearing in a subsequent issue of this newsletter.

NASA astronaut and ISS Expedition 35/36 Flight Engineer Chris Cassidy is currently scheduled to carry out the initial installation procedures in FSL of the FASES experiment module containing a total of 44 samples inside.

ATV-3 during rendezvous and docking procedures with the ISS in March 2012

ESA astronaut and Expedition 26/27 flight engineer Paolo Nespoli with Robonaut 2 hardware on the ISS in March 2011

Parmitano will be involved in International Partner experiments covering colloidal physics (as part of the Binary Colloidal Alloy Test series of experiments) and combustion science (Flame Extinguishment Experiment-2 or FLEX-2)

Within solar/radiation research Luca will not be directly involved with on-orbit activities but ESA research in this area will be on-going during the Volare mission with the Dose Distribution inside the ISS 3D (DOSIS-3D) experiment, undertaking 3D monitoring of the radiation environment inside the ISS, and the Solar facility on the external surface of Columbus which will continue its monitoring of the solar irradiation of the Sun with unprecedented accuracy with its two active instruments.

Technology, Earth Observation and Education.
In Technology the Vessel ID System continues to monitor maritime traffic from the ISS since June 2010. Parmitano could also make use of ESA's NightPod tracking device for taking images of Earth (especially at night). The mechanism supports a Nikon D3s camera in taking high-definition pictures of a particular point on Earth. Parmitano is additionally involved in a NASA Earth Observation activity.

With relation to International Partner experiments Parmitano will undertake activities with NASA's Robonaut technology demonstrator which has been undergoing extensive test activities involving a variety of different astronauts on the ISS. This has either involved astronauts setting up the hardware for tests controlling the equipment from ground, or more recently astronauts on the ISS controlling the equipment themselves using telerobotics gear to have the robot mimic their movements. Robonaut was designed with the intention of eventually supporting future operations in the EVA environment as well as certain Intravehicular Activity situations.

A student talks to a crewmember onboard the International Space Station during an ARISS contact

As with all ESA human spaceflight missions education activities will be an important element of Luca's mission aiming, amongst other things, to increase the interest in science based topics and space in general. Luca's education package includes a Space Robotics competition where students (11-19 years old) have to build a robot capable of certain space-simulated tasks; "Mission-X: Train Like an Astronaut" where schoolchildren aged 8–12 tackle physical and mental activities in a six-week programme in order to promote fitness and wellness in the young; and the Amateur Radio on the International Space Station (ARISS) project which uses standard amateur radio equipment on the ISS to contact ground stations for answering questions from assembled students etc. Parmitano is also involved in a number of education activities for NASA.

The research activities form just one part of Luca's mission on the ISS, within which he will be involved in facility maintenance activities. In addition Luca will also undertake two spacewalks during his mission on the ISS and be a key astronaut for robotics activities. He will participate in docking ESA's ATV Albert Einstein in June, Japan's fourth HTV as well as the Dragon and Cygnus cargo ships that are part of NASA's commercial resupply programme.

→ PARABOLIC FLIGHTS FOR FUTURE EXPLORATION:
The second Joint European Partial-gravity Parabolic Flight Campaign (JEPPF)

Airbus A300 Zero-G at the Bordeaux airport

ESA's parabolic flight campaigns have been on-going for almost 30 years, testing experiment hardware as well as new technologies, equipment and procedures destined to fly on weightless research platforms such as the International Space Station. One of ESA's latest campaigns has been looking beyond the ISS to future planetary exploration missions beyond low-Earth orbit and also to provide additional gravity parameter ranges for experiments in Physical Sciences.

With the interest in human exploration missions outside of low-Earth orbit gathering momentum, the necessity to prepare equivalent hardware and procedures for partial gravity environments such as on the Moon and Mars is also gathering momentum and ESA successfully took part in the second Joint European Partial-gravity Parabolic Flight campaign (JEPPF) in December 2012. This joint ESA, CNES and DLR organised campaign was a reflight of 11 of the initial set of 13 experiments from the first partial-g campaign in June 2011 with a new set of experimental parameters and two new experiments.

As usual the campaign flew out from the Mérignac-Bordeaux airport in France using a modified A300 Airbus owned by Novespace. The flight campaign took place in special airspace in an area over the Atlantic ocean where no other traffic is allowed (with an alternative dedicated area near Corsica over the Mediterranean sea).

The pilots followed special flight paths to create Moon and Mars gravity conditions for respectively 25 and 30 seconds each time, with each flight providing a total of up to 12 minutes of partial gravity conditions inside the aircraft. Flights were carried out over the course of three days with 40 passengers on board each day.

The success of the first joint flight campaign not only led to the planning of the second campaign but also the reflight of many of the initial experiments with new parameters to enhance the impact of research.

Each day's flights is helpful, not only in gathering important data, but also in highlighting where tweaks in instrumentation need to take place and possible issues that could occur to avoid an occurrence of such an issue during a human exploration mission where reconfiguration or replacement of hardware might be difficult or impossible.

Research Overview

Obviously with the nature of prospective human exploration missions in the future, human research is a key issue that takes a central focus of research activities.

Human Research (5 experiments)

All the human research experiments on the 2nd Joint European Partial-gravity Parabolic Flight campaign were reflights (or follow-up experiments) from the first campaign. Two studies ('Alterations in autonomic cardiovascular control induced at partial g forces' from Prof. S. Van Huffel, Dr S. Vandeput, Prof. A, Aubert (Univ. Leuven, B) sponsored by ESA, and 'Orthostasis

Test subjects during the experiment "Alterations in autonomic cardiovascular control induced at partial g forces" as part of 1st Joint European Partial-gravity Parabolic Flight campaign in June 2011

beyond Earth' from Prof. F. Wappler, Drs. U. Limper, P. Beck (Univ. Witten/Herdecke, D), Dr U. Mittag, P. Gauger (DLR, Köln, D) supported by DLR) are looking into cardiovascular function which is known to be altered in weightlessness (and reduced gravity) in a similar way to prolonged bed rest such as in the elderly or injured. Numerous experiments have been undertaken to study the reaction of the cardiovascular system in weightlessness but in reduced gravity these are the first steps. This will obviously have an influence on determination of relevant countermeasures and the length of time astronauts can remain healthy on such missions; help in validating mathematical models of cardiovascular function; and attempt to model characteristics/parameters of cardiovascular function based on levels of gravity.

Conducting the 'Orthostasis beyond Earth' experiment during 1st Joint European Partial-gravity Parabolic Flight campaign in June 2011

With a prospective Mars mission estimated to take 1.5 years, an estimation of cardiovascular impairment is vital when considering key mission elements such as initial post-landing activities and extravehicular activities under the influence of Mars gravity (which is about 1/3 of Earth's gravity).

The findings will help to improve the medical support of future astronauts during their stay on the surface of Mars and Moon, but also to better understand why people faint or suffer blood pressure control problems on Earth.

Dexterous manipulation in microgravity experiment during 1st Joint European Partial-gravity Parabolic Flight campaign

Two additional experiments ("Dexterous manipulation in microgravity" from Profs. P.Lefèvre, J.L. Thonnard, (U. Louvain, B), Dr J. McIntyre (U. Paris Descartes, F) supported by ESA and "Role of the gravitational component of the efference copy in the control of upper limb movements" from Drs J. McIntyre, M. Tagliabue, P. Senot (Univ. Paris Descartes, F) sponsored by CNES) are studying motor control and coordination of the upper limbs in astronauts on exploration missions. During weightless missions such as on the ISS, the arms and hands are the primary means of locomotion, and it is obvious that in the lower gravity conditions on the Moon (0.16g) and Mars (0.37g) that the upper limbs will play a more significant role than on earth but in a different way.

"Role of the gravitational component of the efference copy in the control of upper limb movements" experiment during 1st Joint European Partial gravity parabolic flight campaign

This knowledge will additionally play a determinant role in the future design of prostheses, where the question of which sensory signal is necessary for successful control of movements is crucial.

With known alterations in perception in weightlessness and even certain visual 'errors' that occur on Earth but not in weightlessness, understanding the neural processes that occur at gravity levels between 1g and 0g will provide us with a great deal of fundamental information in how the Central Nervous System adapts under the influence of gravity.

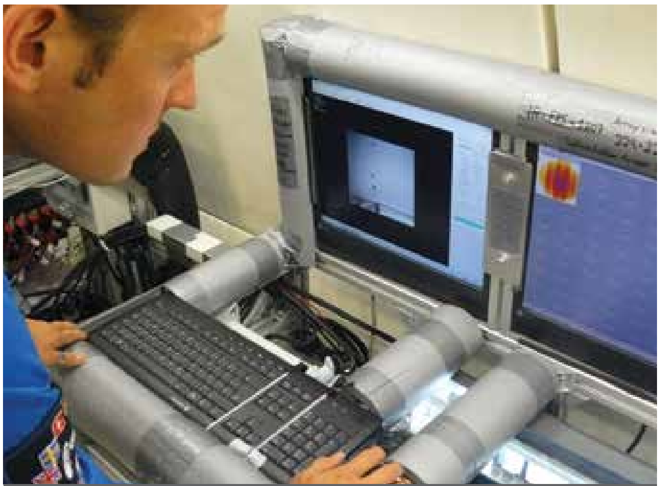
A third experiment "The effect of altered gravity condition on postural control" from Prof. A. Gollhofer (Univ. Freiburg, D), supported by DLR is also looking into neuromuscular adaptions in partial gravity environments, using different balance tasks to assess postural control.
The aim is to assess the benefit of balance training as a countermeasure against the depletion of postural control in microgravity.

Biology (2 experiments)
Turning to biology two experiments undertook exploration-relevant research during the parabolic flight campaign. One experiment ("Partial gravity and vestibular decompensation in rats") from Profs. P. Denise, S. Besnard, H. Normand (Univ. Caen, F), Prof. G. Clement (ISU, Strasbourg, F), Dr S. Wood (USRA, Houston, USA) and sponsored by CNES is expanding the research on adaptation in the vestibular system (which controls balance) and influences conditions such as space motion sickness. Rats are studied in this research (eye movements, neck muscle activity and motor behaviour). With data available from ISS research this experiment will provide important insights into the adaptation of the vestibular system.

The second biology experiment (from Prof. R. Hampp (Univ. Tübingen, D), sponsored by DLR and a reflight from the first campaign) is looking into gravity dependant plant processes in Arabidopsis plants focussing on calcium and reactive oxygen signalling within the model plant species. Many weightless experiments have been undertaken with Arabidopsis species. This research will help to improve our knowledge in partial gravity environments which will have even more significance as crews on exploration missions will have to be more self-sufficient, having to generate a certain degree of food themselves to optimise launch mass and hence costs.

Fluid Science (2 experiments)
Following up from research on the 1st partial-g campaign, fluids were covered with an experiment ("Influence of pressure on single bubble cycles under low gravity conditions") from Prof. P. Stephan and Dr S. Fischer (Techn. Univ. Darmstadt, D) and supported by ESA covering boiling phenomenon which have an important application in such devices as heat exchangers and cooling systems for dispersal of excess heat from equipment. This is extremely important in spacecraft for optimal thermal control in the challenging and widely varying thermal conditions in space, especially as gravity-driven convection cannot be used in the design of such heat exchangers.

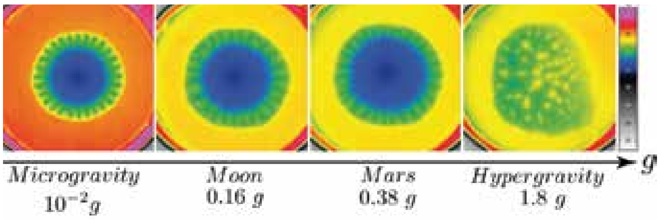
The absence of gravity-driven convection In weightlessness causes bubbles to collect on heater surfaces which can lead to gas layers forming in pipes as bubbles coalesce causing inefficiency in a heat exchanger system (as gas is an inefficient medium through which to transfer heat). However in low



Data recording for experiment during 1st Joint European Partial-gravity Parabolic Flight campaign which preceded "Influence of pressure on single bubble cycles under low gravity conditions" experiment during 2nd campaign.

gravity environments buoyancy is still the overriding force, the question is how this process works. The data from this experiment will serve to highlight the fluid processes involved with boiling phenomenon in partial gravity environments and help to improve/update numerical models of fluids behaviour in such environments. In addition to the scientific objectives the experiment serves as a preparation platform which allows the test of several technical approaches for the RUBI (Reference mUltiscale Boiling Investigation) experiment, which is still under development and will fly on the ISS.

Typical applications can be found on many scales, from large (e.g. in nuclear or conventional power plants) over medium sized (e.g. in the process industry) to small everyday applications (e.g. refrigerator cooling cycles). Understanding the fundamental physical phenomena of the boiling process is mandatory to develop reliable design guidelines and numerical tools to further enhance evaporator design for better performance or reduced size.



Methanol droplets evaporating onto a substrate at Ts = 45°C, mean diameter = 8 mm at different gravity levels
(Image: D. Brutin, F. Carle, Aix Marseille Université. F)

Also the prediction of undesired boiling, for example within rocket fuel tanks facing the sun, are of interest, as the thermal insulation of an arising vapour layer can lead to thermal failure of the wall material.

A new experiment on this campaign (though following up previous microgravity research) was the experiment 'Evaporation dynamics and thermo capillary instabilities in alcohol (ethanol, propanol and methanol) droplets' from Drs D. Brutin, F. Carle (Aix Marseille Université. F) and supported by CNES. Evaporation is extensively used within various applications: cooling, combustion, deposition of thin films in electronics, paints, fire protection (sprinklers) etc.

Evaporation study in microgravity improves our understanding of evaporation on the Earth as removing gravity effects, we can better observe the phenomenon of diffusion, which is the limiting phenomenon of evaporation at any level of gravity in most cases for a low overheated substrate. This will not only improve fundamental knowledge on this subject but also assist in making better use of evaporation in relevant areas such as for fluid systems of satellites, spacecraft and space stations.

The evaporation rate in microgravity was compared to the evaporation rate in normal gravity to validate theoretical models of evaporation limited by diffusion in vapour phase and to establish the convective component of evaporation on Earth.

Modelling Moon and Mars Conditions (4)

The research discussed so far has covered or been directly related to the spacecraft and astronauts undertaking such an exploration mission. Another branch of the research has covered the conditions that would be found on the Moon and Mars which would also assist in optimal planning for the conditions that we expect to experience in-situ on these celestial bodies. Some of the research could also provide information on planetary formation.

Image of a global dust storm on Mars from the Hubble Space Telescope

One experiment from Dr J. Teiser, Pr. G. Wurm, T. Kelling, T. Meisner (Univ. Duisburg-Essen, D) supported by DLR simulated light and pressure conditions on Mars (with simulated soil samples) to study dust erosion on Mars and explain how dust gets into Mars atmosphere where dust devils and global dust storms are common. This process is poorly understood as the gas pressure is too low to allow a regular lift by wind though is thought to be induced by the light irradiation coming from our Sun.

The small particles are also a vital ingredient in disks around young stars where they provide the seeds for planet formation. This experiment is not only important for increasing our fundamental knowledge of Martian conditions and planetary formation, it is also important for the design of future spacecraft. This follows on from an experiment during the first campaign.

The results will be applied to models of dust motion on Mars and to model the recycling of dust in protoplanetary disks.

Another experiment in this area ("Magnetically Excited Granular Matter" from Prof. E. Clement (ESPCI, Paris, F), Dr. M. Sperl, (IMPS, Köln, D) and sponsored by ESA) is studying granular materials which are interesting both for their scientific importance, and for industrial applications. Granular gases (such as dust storms on Mars) are being studied especially with respect to the cooling processes that occur within them. It is a fundamental research experiment to understand e.g. sandstorms and wind-driven sand movement better.

Two additional new experiments are related to the sustainable human presence in the Solar System. One experiment ("FLOREIA - Flowability of lunar regolith in reduced gravity") from Prof. A. Höhn (Techn. Univ. Munchen, D) and supported by ESA is looking into lunar in-situ resource utilisation though the sample handling research proposed for parabolic flight is equally applicable to Mars and Near Earth Object (NEO) sample handling procedures. The experiment is examining possibilities for the extraction of solar wind implanted particles and volatile elements from lunar regolith, which may provide several gaseous components valuable to a human presence on the Moon. In this context the transport and processing of lunar regolith and its consequences for the stability of solar wind implanted particles and volatile elements was investigated.

Unlike sand, the surface of regolith particles is fresh and sharp, so that it can easily get stuck when guiding it through funnels and tubes. During the experiment different types of simulated lunar regolith material which sufficiently represent the physical properties of real lunar regolith were filled into variable funnel shapes to investigate the influence of geometry and surface properties on the flow characteristics.

The results of the parabolic flight experiments will be important for the design of planetary rovers regarding the excavation, transport and processing of regolith, and the design of analysis devices.

A CNES project ("PROGRA2-Regolith" from Dr J.B. Renard (CNRS, Orléans, F)) which is based on extensive research flown on previous parabolic flights is investigating the ability to reproduce the planetary bodies' regolith during parabolic flights. This will have an important influence on determination of the optical properties of regolith grains with a specific focus on optimal design of instrumentation for in-situ analysis during exploration missions in order to better determine some physical properties of such grains.

This experiment used a preliminary instrument to determine the height of the deposited layer of different natures of grains during various gravity conditions (1.8 g, 1 g, 0.4 g and 0.1 g). The samples used were Martian and Lunar analogues (produced in a laboratory).

The quality and duration of microgravity obtained, the flexibility and variety of possibilities for experiments and tests and the ease in flight preparation make aircraft parabolic flights a unique and versatile tool for European scientists and engineers to perform experiments and tests in microgravity and at different g levels.

The JEPPF campaigns are the first parabolic flight campaigns organized jointly by ESA, CNES and DLR and the first European parabolic flight campaigns entirely dedicated to experiments in reduced gravity at 0.16 g and 0.38 g (Moon and Mars g levels). They were marked by an excellent cooperation between the three agencies during the campaign preparation and performance phases.

In all discussions, scientists clearly outlined the need to perform additional partial-g parabolic flight campaigns to acquire additional data. Based on this, ESA, CNES and DLR may decide in the future to co-organise again similar campaigns.

→ THE KEY ELEMENTS OF THE ELIPS-4 PROGRAMME

Conclusions of the ESA Council at Ministerial level and what it means for research in Life and Physical Sciences

All walks of European life have been affected by the financial instabilities that have been a common feature in European society for the past few years. There was in general a very positive outcome for the Agency from the Ministerial Council in November 2012 for most programme proposals from the various ESA Programme Direcotates. We take a look at how the Life and Physical Sciences research in conjunction with human spaceflight activities will be funded until 2016 through ELIPS Period 4 as a result of the Ministerial Council.


ESA – S. Corvaja

ESA Council at Ministerial Level in Naples on 20 November 2012

The research activities for ESA's Directorate of Human Spaceflight and Operations is funded almost entirely through the European Programme for LIfe and Physical Sciences in Space (ELIPS) with the activities for the period until 2016 covered under ELIPS Period 4. This covers all the areas of science and technology (and some education activities) and research in all stages of development from initial science opportunities solicitation and selection, planning phases through to development stages to being carried out on the chosen research platforms. ELIPS also covers funding on all available research platforms linked to non-ISS human spaceflight activities: sounding rockets, parabolic flight campaigns, drop towers and an extensive amount of ground-based studies and simulations. The mission resources for the International Space Station are provided by the ISS Exploitation Programme.

Following a very intensive but productive Ministerial Council in November 2012 the 15 countries participating in the ELIPS-4 Programme decided an overall funding level of 210 MEuro for the Science Core Activities until 2016. Even though this is still a significant level of funding, due to the extensive number of ELIPS projects proposed to be implemented within ELIPS-4, this only represented about 54% of the funding required to undertake all activities. As such major replanning and reconfiguration has been undertaken following the Ministerial Council in order to prioritise and optimise the ELIPS-4 research activities and goals and maximise the return on investment whilst endearing to secure stability and continuity within the different projects. This had to factor in many different components including: requirements of the European science communities; scientific and technological preparation for Human Exploration; promotion of the development of applications on Earth and to capitalise on past investments and utilisation initiatives; ensuring advanced instrument technology development by industry; supporting international collaboration for the benefit of European utilisation by optimisation of mission resources and flight opportunities; and maintaining the overall ELIPS utilisation flexibility and programme robustness.

The prioritisation of the research activities was undertaken with both Life and Physical Sciences Working Groups namely concerning the new payload developments for ISS utilisation concerning fluids research, materials science, human research and biology in order to maximise the science potential for European users by optimum use of the available budgetary resources in ELIPS-4. Subsequently the Programme Board approved the proposal of ESA for the prioritisation of imminent research activities but also had to take into account the deferral of projects until ELIPS-5 (from 2016).

ISS Hardware Development

Hardware development for ISS utilisation covers the largest financial proportion, accounting for just under two thirds of all ELIPS-4 funding but bearing about 50% of reduction. These activities are essential for a continuous ESA utilisation programme on the ISS which is securing the best possible exploitation of the ISS and return on ESA investments and operations costs.

Within the fluid science domain full funding has been allocated for the development/implementation of the CIMEX-1, RUBI and FOAM-C experiments in the Fluid Science Laboratory. This is related to the high scientific importance and related implementation priority of these projects which allow a broad spectrum of heat and mass transfer and complex fluid experiments and offer a promising potential for applied research projects. These three projects will also be essential for the following generation of science and applications objectives in this domain. The full development of the LIFT experiment (which will follow up the FASTER experiment which is due to take place on the ISS in 2014) and the COLIS experiments have been deferred until ELIPS-5 whilst experiments in critical/supercritical fluids have been fully descoped within ELIPS-4.

Within materials research the extensive research activities and collaborations with NASA allow for the streamlining of ESA funding for the Materials Science Laboratory (MSL) and Electro-Magnetic Levitator (EML) activities on the ISS whilst at the same time securing continuous scientific utilisation of these payloads until 2017. The DirSol (Transparent Alloys) experiment (the experiment unit of which is fully funded under ELIPS-3) due to take place in the Microgravity Science Glovebox has also received funding for the development of the first batch of sample cartridges in ELIPS-4. With the Materials Science Laboratory already on the Station since 2009, the Electro-Magnetic Levitator is the next major ESA materials research facility due for launch to the ISS.

In other areas of the Physical Sciences ELIPS-4 funding will complete the development work of the Atomic Clock Ensemble in Space (ACES) and Atmospheric Space Interactions Monitoring Instrument (ASIM) external payloads and the ICAPS Cosmic Dust experiment. ACES will be used to probe our knowledge of the fundamental laws of physics ruling the Universe, testing Einstein's general relativity and alternative theories of gravitation, and ASIM will study giant electrical discharges (lightning) in the high-altitude atmosphere above thunderstorms and their role in the Earth's climate. Both have seen a shift of launch carrier (HTV to SpaceX) though completion of development work should see the ACES and ASIM payloads launch presumably together in spring 2016). For research which is currently in its planning/definition phase there will be related reductions with a focus put on phase A and/or B studies deemed necessary to secure a mature state of the next generation of ISS experiment/payload developments in ELIPS-5.

Within human physiology activities it has been possible to allocate full funding to the development of biomedical instrument hardware for numerous human research experiments selected within the last ILSRA-09 research announcement. Unfortunately it was unavoidable to descope the development of On-orbit Sample Analysis Instrumentation as, amongst other reasons, the establishment of the SpaceX spacecraft again offers the possibility for (conditioned) download of life sciences samples for detailed analysis in Earth laboratories.

Continuing in the area of biology/astrobiology, there has been a modest reduction in experiment funding, though without any significant impact for experiments already under development for the internal Biolab, EMCS, and KUBIK facilities and the Expose-R2 exposure facility. In addition the implementation of the highly ranked ICARUS experiment from ILSRA-09 for global bird tracking over long distances from the ISS will be taken over by national funding from DLR both for the flight segment and ground segments. A further cost reduction had to be accommodated within additional biology hardware development (Life Science Glovebox and KUBIK-II incubator development) through project reconfiguration.

Launch of Maxus 8 sounding rocket

Research taking place inside aircraft during 44th parabolic flight campaign

Non-ISS Research Activities

The non-ISS research activities, have seen funding levels that are around 70 % of the originally proposed level, which allows to secure a full spectrum of activities on the different autonomous research platforms. The two Sounding Rocket missions MAXUS-9 and MASER-13 (which are scheduled for launch in 2015) will see their full implementation, though no further TEXUS missions could be accommodated.

Parabolic Flight Campaigns which undertake the full spectrum of research in life and physical sciences and technology will continue at a rate of about two campaigns a year.

Drop Tower research has seen a minor cost reduction though the inherent costs in this area are themselves relatively small though at the same time providing high quality weightlessness for very short-duration experiments.

For the ground-based research areas, Bed Rest Studies and ISS Baseline Data Collection will only see modest reductions due to scientific significance of these areas and Isolation Studies and space radiation studies will have a reduced funding level but will still be able to secure the execution of essential scientific activities in the time frame until 2016.

Within the area of general activities which includes such elements as Support to Applied Research Projects and Industry-Driven R&D as well as EC Projects Initiation/Coordination, advisory bodies etc, there has been a cost reduction of 50%

Internal view of the ZARM drop tower in Bremen, Germany. The drop tower capsule being prepared

across all areas to bring it in line with reduced subscriptions to ELIPS 4 though the funding for Topical Teams which are essential for the elaboration of dedicated science topics by expert groups of scientists prior to or after AO solicitations remains at a full funding level.

Human Exploration Technologies

Within the area of Human Exploration Technologies, the ANITA-2 and MiDASS projects have been withdrawn within ELIPS-4 though MELiSSA (Micro-Ecological Life Support System Alternative) has still achieved about 8 MEuro subscription. The partial subscription level also requires a stringent tailoring of the originally defined full programme content which keeps the main elements with its focus on flight demonstration experiments. For MELiSSA, elements prioritisation is being focussed on the design and development of a Fibre Degradation Unit (for waste processing of fibre from non-edible part of higher plants) and associated tasks; a study of the impact of endogenous and exogenous traces elements on the MELiSSA processes; the creation of a pool of expertise for MELiSSA; and the definition of preliminary flight experiments for the food production unit and CO2 recycling demonstrators.

In Conclusion

In principle the overall focus and balance of the original ELIPS-4 Programme Proposal has been, with few exceptions, basically secured with the majority of the activities focused on the 2013-2015 time frame. A reasonable balance is kept between the three main ELIPS Science Core programme blocks and a reduced but still meaningful European utilisation programme can be secured with its focus on ISS utilisation.

Prioritisation of activities within the ELIPS-4 Science Core Activities have been duly considered in order to secure the best possible European utilisation programme within the given constraints and the Human Exploration Technologies Component have focused on the near- and medium-term continuity to secure the long-range objectives. In general the ELIPS-4 prioritisation is responding well to the general key requirements of continuously optimising the scientific yield and gain of knowledge, capitalising on past investments and initiatives, developing benefits for Earth and preparing for Human Exploration. In addition it is also trying to secure the competitiveness of European space industry by the development of challenging new instrument technologies for the planned suite of flight experiments.

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An ESA Human Spaceflight and Operations Production

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