→ SPACE FOR LIFE

human spaceflight science newsletter

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NASA

↑ ESA astronaut Luca Parmitano during a measurement session with the ESA/NASA Pulmonary Function System in the Columbus laboratory for the Energy experiment

In this issue:

→ EXPEDITION RESEARCH ACTIVITIES:

Overview of Science Achievements During Expeditions 36-39

ESA research was on-going during ISS Expeditions 36-39 which started on the night of 13-14 May 2013 with the undocking of Soyuz 33S, and concluded exactly one year later on the night of 13-14 May 2014 with the undocking of Soyuz 37S. With these Expeditions covering a full year an extensive amount of ESA research has been undertaken covering all areas of research, and including the Volare mission of ESA astronaut Luca Parmitano.

Human Research Activities

Neuroscience

In neuroscience the Reversible Figures experiment continued with ISS Flight Engineers Michael Hopkins and (NASA) and Koichi Wakata as test subjects. Hopkins completed all six of his monthly sessions between October 2013 and February 2014. Wakata completed his monthly sessions of the experiment between November 2013 and the end of April 2014. The experiment is investigating the adaptive nature of the human neuro-vestibular system in the processing of gravitational information related to 3D visual perception.

If all goes well during the post-flight measurements this will imply that the Reversible Figures experiment would have reached its conclusion with data collected for six astronaut test subjects during a time frame of two years. (This experiment is covered in detail in a separate article in this newsletter)

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

Immunology
In immunology the final on-orbit samples for the Immuno experiment (which has been on-going since Expedition 12) were returned on Soyuz 34S in September 2013. The final on-orbit blood and saliva samples had been provided by ISS Flight Expedition 35 Engineer Roman Romanenko in May 2013. The Immuno experiment is determining changes in stress and immune responses, during and after a stay on the ISS.

Nutrition, Sleep and Well-Being
The Energy experiment, was carried out during Expeditions 36-39 with ESA astronaut and ISS Flight Engineer Luca Parmitano as the 5th test subject in October 2013, and NASA astronaut Michael Hopkins as the 6th subject in January 2014. The experiment, which consists of an 11-day on-orbit period of data acquisition, aims at determining the energy requirements of astronauts during long-term spaceflight.

Four test subjects started and concluded the Space Headaches experiment during Expeditions 36-39. Expedition 36/37 Flight Engineer Luca Parmitano, Expedition 37/38 Flight Engineer Michael Hopkins (NASA), and Expedition 38/39 crew members Rick Mastracchio (NASA) and Koichi Wakata (JAXA) all completed weekly questionnaires respectively before returning to Earth. NASA astronaut Steve Swanson became the 10th and latest test subject for the experiment following his launch on Soyuz 38S. By the end of Expedition 39 he had completed 6 weekly questionnaires.

The weekly questionnaires follow on from one week of filling in daily questionnaires during the first week after launch. Headaches can be a common astronaut complaint during space flights. This can negatively affect mental and physical capacities of astronauts/cosmonauts which can influence performance during a space mission.

The Circadian Rhythms experiment (which was covered in detail in a separate article in the last newsletter) is providing a better basic understanding of any alterations in circadian rhythms in humans during long-duration spaceflight. ESA astronaut Luca Parmitano carried out all required (approximately monthly) sessions of the experiment on orbit between 8 June and 25 October. Each 36-hour session of continuous data monitoring via temperature sensors located on Parmitano's forehead and chest, and an additional sensor to monitor his activity. The experiment was also completed by Koichi Wakata by the end of Expedition 39, undertaking six successful sessions (seven sessions as two sessions were combined into one session in December). having completed his first session in December 2013 with subsequent sessions thereafter.

↑ ESA astronaut and ISS Expedition 36/37 Flight Engineer Luca Parmitano performing evening prep work whilst wearing a temperature sensor on his forehead as part of the Circadian Rhythms Experiment on 23 July 2013

One new experiment to start in the Expedition 36 timeframe was the Skin-B experiment with Luca Parmitano as the first test subject (A detailed article on the Skin-B experiment appears in this newsletter). Skin-B, which follows up an earlier study during the Astrolab mission with Thomas Reiter in 2006 will help to develop a mathematical model of aging skin and improve understanding of skin-aging mechanisms, which are accelerated in weightlessness. Following these successful sessions NASA astronaut Steve Swanson became the latest test subject of Skin-B, undertaking his first two sessions of the experiment in April 2014.

Outside of the ESA experiments Luca Parmitano was a subject of many human research experiments for ISS Partner agencies which have used facilities within ESA's Columbus laboratory (Pro K, Ocular Health, BP Reg, and Spinal protocols) and in the ISS Partner modules (Microbiome, Reaction Self Test, Biological Rhythms, and Salivary Markers). BP Reg is a Canadian Space Agency protocol and Biological Rhythms is a JAXA experiment. The remaining ISS Partner experiments are sponsored by NASA.

↑ ESA astronaut Luca Parmitano instrumented for the Canadian Space Agency's BP Reg experiment in October 2013

Biology Research

The joint ESA/NASA Seedling Growth experiment comprises three major parts, the first part of which successfully completed all four experiment runs between 21 March - 24 May 2013 (detailed article in previous newsletter issue). The experiment runs were undertaken in the European Modular Cultivation System (EMCS) which is located in a NASA EXPRESS rack in the Columbus Laboratory. Seedling Growth builds on previous space flight experiments with Arabidopsis thaliana seeds and studies the effects of various gravity levels on the growth responses of plant seedlings.

↑ NASA astronaut Tom Marshburn relocating experiment containers for the Seedling Growth experiment in the European Modular Cultivation System in May 2013

For the four experiment runs similar procedures were followed. Ground commanding hydrated the seeds in the experiment containers and hereafter the seeds were kept at 1g (on a centrifuge) with white light for 4 days to promote growth. On the fifth day, the centrifuge was either stopped (0g for run 1) or slowed (0.1g for run 2, 0.3g for run 3, 0.8g for run 4) to expose the seedlings to differing gravity levels, and at the same time, providing photostimuli (either red or blue light from the side) for 2 days whilst observing seedling growth.

There was further positive news with respect to future biology research as the Biolab facility in Columbus is again fully functional. Biolab is a multi-user facility designed to support biological experiments on micro-organisms, cells, tissue cultures, small plants and small invertebrates.

Numerous maintenance and commissioning tasks were undertaken on Biolab in Expeditions 36-39. Between July – December 2013 two Life Support Modules (which provide the experiment containers with air humidity control, filtration and water supply), were exchanged and the refurbished microscope unit was successfully installed. This was followed by a successful Biolab Commissioning Run which was concluded in December 2013 including undertaking successful testing on the centrifuges, Handling Mechanism, Life Support System, and Biolab incubator.

These Biolab activities were in advance of the Gravi-2 experiment (processed in the European Modular Cultivation System - EMCS) that made use of Biolab's thermal storage and glovebox capabilities following launch of the Gravi-2 experiment to the ISS on SpaceX-3 in April 2014. (Gravi-2 is covered in a detailed article in this newsletter). The TripleLux-B experiment will be the next experiment to make full use of the Biolab facility, currently scheduled for launch to the ISS on the SpaceX-5 spacecraft in Autumn 2014. This experiment will compare the cellular mechanisms of vertebrate (rodent) and invertebrate (blue mussel) cells which cause impairment of immune function in weightlessness.

Radiation Research

The Dose Distribution inside the ISS 3D (DOSIS-3D) experiment has continued data acquisition using the two active detectors and different sets of passive detectors installed in different locations around Columbus. One set of passive detectors were installed from 3 April – 6 September 2013. These were collected in by Luca Parmitano and returned to Earth on Soyuz 34S on the night of 10/11 September. Another set of passive detectors was installed between 1 October 2013 – 6 March 2014 before being collected in by ISS Flight Engineer Rick Mastracchio and returned to Earth on Soyuz 36S on 11 March 2014. A new set of passive detectors are in place in Columbus after being installed on 28 March by ISS Commander Koichi Wakata. These arrived on Soyuz 38S.

The passive detectors are used in order to undertake 'area dosimetry' i.e. to measure the spatial radiation gradients inside the Columbus module.

The active detectors undertake time-dependent cosmic radiation measurements for the experiment. These were undertaking almost continuous data measurement during Expeditions 36-39. Due to increased solar activity, the active detectors were switched to higher data acquisition rates from 24 – 29 May 2013 and 6-8 January 2014. A recent report and presentation material of the scientists' analysis display interesting results related to how the radiation levels on-board the Columbus laboratory vary with the Solar cycle, with altitude of the ISS and depending on the location inside Columbus and also covering the first results of the period from 24 to 29 May 2013.

↑ Passive detector package (orange) located close to the portable breathing apparatus in Columbus following installation on 28 March 2014

The aim of the DOSIS-3D experiment is to determine the nature and distribution of the radiation field inside the ISS and follows on from the DOSIS experiment previously undertaken in the Columbus laboratory. Comparison of the dose rates for the DOSIS-3D and the preceding DOSIS experiments has shown a difference in dose level which can be explained due to the different altitude of the Station during the measurements. The DOSIS-3D experiment will build on the data gathered from the DOSIS experiment by combing data gathered in Columbus with ISS International Partner data gathered in other modules of the ISS.

Solar Research

During Expeditions 36-39 12 Sun visibility windows (65th - 76th) for SOLAR, which is located on the external platform of Columbus, were undertaken for the facility to acquire scientific data when the ISS is in the correct orbital profile with relation to the Sun. This included two extended periods of science acquisition whereby windows #66/67 and windows #71/72 were joined together by slightly rotating the ISS in the intervening period (~10/11 days) to continue science acquisition. Following a similar campaign in November/December 2012 these have been the only times that the attitude of the Space Station has been changed for science reasons.

As the Sun visibility windows last for around 12 days these bridging events make it possible to undertake solar measurements during a full Sun rotation cycle (which lasts around 26 days at the Solar equator and up to 36 days at the solar poles). The extended period with windows #66/67 undertook successful scientific measurements for the whole scheduled period from 18 June – 23 July. For the extended period with windows #71/72 measurements were successfully undertaken from 17 November – 11 December. However the day after the start of window #72 a problem with the ISS External Thermal Control System caused loss of Columbus Power

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

Distribution Unit 1 which forced the Solar payload into survival mode (hence not undertaking science acquisition) due to loss of power. The instruments were powered back up following reactivation of Power Distribution Unit 1 on 31 December. It was unsure whether the three week extremely cold period without power may have affected the SOLAR instruments but this was not the case as science acquisition was successfully undertaken during window #73 (15-27 January).

All other Sun Visibility Windows completed in the Expedition 36-39 timeframe successfully undertook data acquisition. On 11 May, just before the end of Expedition 39, a new Sun Visibility Window opened.

The SOLAR payload facility is studying the Sun's irradiation with unprecedented accuracy across most of its spectral range. This has so far produced excellent scientific data during a series of Sun observation cycles. An extension to the payload's time in orbit could see its research activities extend up to early 2017 to monitor the whole solar cycle with unprecedented accuracy.

Fluid Science

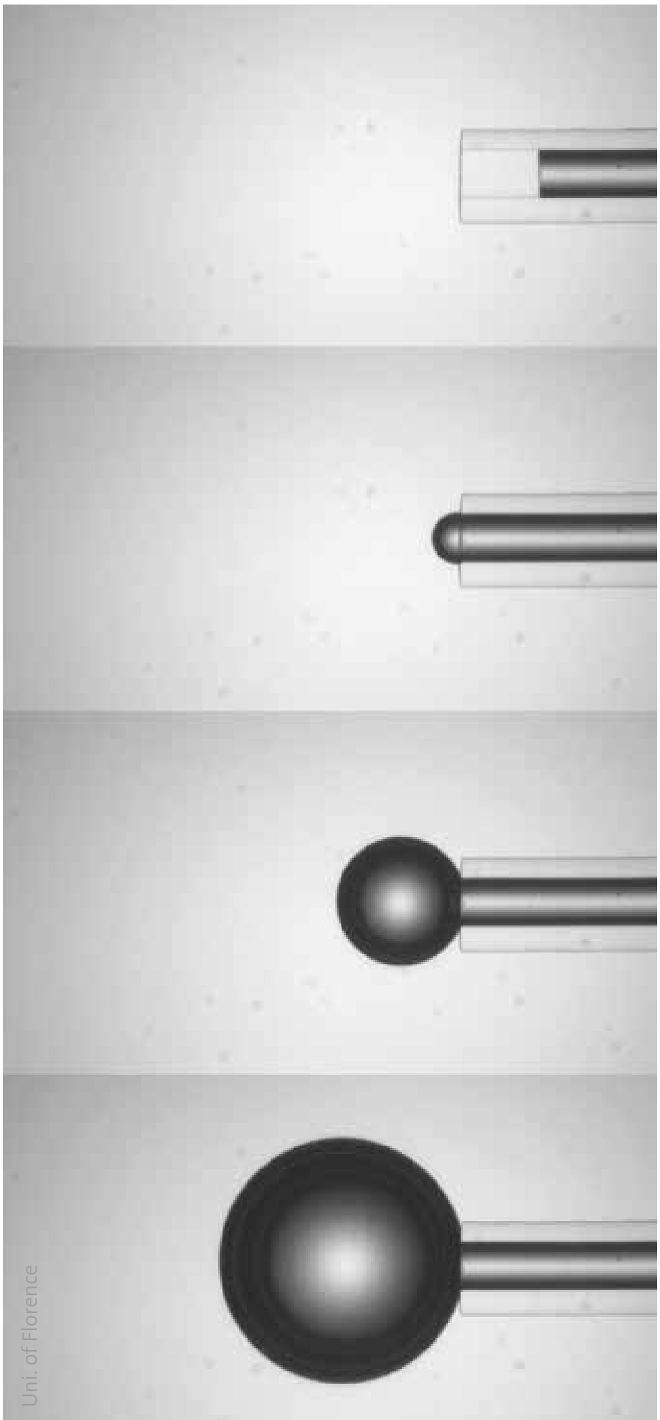
Expeditions 36 and 39 saw the start of the FASES (Fundamental and Applied Studies of Emulsion Stability) and FASTER (Facility for Adsorption and Surface Tension) experiments both of which are studying different aspects of emulsions.

The FASES experiment investigates the effect of surface tension on the stability of emulsions. The FASTER experiment is a Capillarity Pressure Tensiometer developed for the study of the links between emulsion stability and characteristics of droplet interfaces. Results of these experiments hold significance for oil extraction processes, and the chemical and food industries.

ESA/NASA

↑ ESA astronaut Luca Parmitano during FASES experiment installation in the Fluid Science Laboratory in the European Columbus Laboratory on the ISS in June 2013

For FASES thin emulsions of different compositions are sealed inside 44 individual sample cells through which the emulsions are optically and thermally characterised. The FASES Experiment Container was transported to the ISS on ATV-4 in June 2013 and installed inside the Fluid Science Laboratory in Columbus by ESA astronaut Luca Parmitano on 19 June 2013. Troubleshooting activities have been undertaken as only one of two symmetric branches of the thermoelectrical temperature controls has been operative since shortly after the installation and more recently also a Fluid Science Laboratory Video Management Unit high rate data link issue has been experienced.



Uni. of Florence

↑ Formation of pure water droplet inside paraffin oil at the start of the FASTER experiment

However, many scientific runs have still been possible in the past year during Expeditions 36-38 with samples of varying compositions of: water and paraffin with different concentrations of surfactant; and water and hexane with different concentrations of surfactant. Some good quality images/emulsions have been assessed by the science team. Image analysis of samples processed will allow the extraction of the emulsion structure with deduction of droplet size and droplets cluster with respect to time. Expedition 39 activities for FASES were temporarily on hold in order to start activities for the FASTER experiment.

The FASTER payload was launched on 18 April 2014 on board the SpaceX-3 Dragon spacecraft which docked with the ISS two days later. The two drawers of the payload were installed into the European Drawer Rack in Columbus on 29 April by NASA astronaut and ISS Flight Engineer Rick Mastracchio.

Following successful checkouts the critical step of opening the main valve to create the fluid-fluid interface inside experiment chamber #1 (pure water inside paraffin oil) was undertaken on 1 May and fine tuning activities were undertaken for different pressure, temperature, and magnification settings with zero surfactant concentration.

The first surfactant injection inside experiment chamber 1 was undertaken on 4 May. Hereafter measurements were taken at three different temperatures (+20degC, +30degC, +40degC) for the specific surfactant concentration up until 7 May.

↑ NASA astronaut Michael Hopkins during installation activities in the Microgravity Science Glovebox in November 2013 for the Selectable Optics Diagnostic Instrument - Diffusion Coefficient in Mixtures 2 (SODI-DCMIX 2) experiment

Following data analysis the second injection (of 11) to increase surfactant concentration in experiment chamber 1 was undertaken.

Processing at this surfactant concentration was put on temporary hold just prior to the end of Expedition 39 due to the partial rupture of the liquid interface (meniscus) at the capillary tip between the water droplet and the paraffin oil bulk area and the off-nominal presence of paraffin oil inside the capillary tube. Troubleshooting activities were ongoing to resolve these issues by the end of Expedition 39.

Turning outside of Columbus the Selectable Optics Diagnostic Instrument Diffusion Coefficient in Mixtures 2 (SODI DCMIX-2) experiment started in Expedition 38. SODI DCMIX-2 is supporting research to determine diffusion coefficients in different petroleum field samples and refine petroleum reservoir models to help lead to more efficient extraction of oil resources and follows up the SODI DCMIX-1 experiment which concluded in January 2012.

ISS Flight Engineer Michael Hopkins installed ESA's SODI Instrument inside the Microgravity Science Glovebox in the US Laboratory on 14 November 2013.

Following successful optical tests the DCMIX-2 cell array was installed inside the Glovebox on 30 November after arriving on Progress 53P the previous day. Numerous science runs were undertaken from 1 December consisting in the application of a temperature gradient to various ternary toluene, methanol and cyclohexane composition mixtures and acquiring Mach-Zehnder Interferometry images of the mixtures during Soret thermodiffusion processes.

The nominal DCMIX-2 experimental programme was very successfully accomplished and this allowed for an additional series of shorter science bonus runs with new parameters to be performed hereafter. These bonus runs assess if any change in sample compositions would have occurred with time since filling. These were successfully completed by the end of January 2014. Following data backup on 3-5 February, three SODI flash disks and 1 external hard disk drive were returned to ground on Soyuz 36S on 11 March 2014.

Materials Research

Within materials research eight different metal alloy samples successfully completed processing for the so-called Batch 2a experiments in the Solidification Quenching Furnace (SQF) of ESA's Materials Science Laboratory (MSL) in the US Laboratory during Expeditions 36-39. MSL is jointly operated and scientifically shared with NASA. Unfortunately processing for the Batch 2a experiments (for the CETSOL-2, MICAST-2, SETA-2 projects) didn't start very positively as the Materials Science Laboratory laptop suffered an unplanned reboot during processing of a SETA-2 sample in May 2013 and it was thought that this sample could not be reprocessed. However subsequent ground analysis and safety certification has determined that it will be possible to reprocess the SETA-2 sample and this was being planned for a future Expedition.

After the go ahead was given to restart the Batch 2a experiments, four CETSOL-2 samples and four MICAST-2 samples were processed between September 2013 and March 2014. By the end of Expedition 39 a MICAST-2 sample was installed inside the Materials Science Laboratory awaiting processing. Sample exchange procedures were undertaken during Expedition 36/37 by Luca Parmitano and during Expedition 38 by Rick Mastracchio.

The Batch 2a experiments are studying different aspects of solidification in metal alloys which will help to optimise industrial casting processes.

NASA

↑ ESA astronaut Luca Parmitano during a sample cartridge exchange in August 2013 for the Batch 2a solidification experiments in the Materials Science Laboratory on the ISS

Technology Research
Successful data acquisition is still on-going for the Vessel Identification System (commonly known as the Automatic Identification System, AIS), using its Norwegian receiver, and telemetry data is still being successfully received by the Norwegian User Support and Operation Centre (N-USOC) in Trondheim via ESA's Columbus Control Centre in Germany. By the end of Expedition 39 the hardware has been operating for almost four years in orbit.

The Vessel Identification System is testing the means to track global maritime traffic from space by picking up signals from standard AIS transponders carried by all international ships over 300 tonnes, cargo vessels over 500 tonnes and all types of passenger carriers.

During re-entry of the fourth Japanese H-II Transfer Vehicle (HTV-4) on 7 September 2013 Vessel ID System data was used to refine position knowledge of the re-entering spacecraft as part of the overall strategy for ensuring a safe deorbiting of the ISS at the end of its life.

NASA

↑ ESA NightPod tracking device supporting a Nikon D3s camera at one of the windows in the Cupola Observation Module

Turning to imaging technologies the full check out of the new firmware of the NightPod 'tracking device' was carried out by ISS Flight Engineer Koichi Wakata on 16 January 2014. After setting up NightPod in the Cupola Observation Module, Wakata successfully acquired images of the coast of Mexico and North America under low light conditions. The NightPod 'tracking device' supports a Nikon D3s camera in taking high-definition pictures of the Earth, especially at night. In a global outreach effort, the footage will be available for the public on the internet.

Additionally ESA's HAM video hardware was installed in the Columbus laboratory on 6 March 2014 by ISS Flight Engineer Rick Mastracchio. On 8/9 March ISS Flight Engineer Mike Hopkins performed commissioning of the new hardware, with passes over the ARISS ground station in Matera, Italy which successfully tested video and audio signals with different frequencies via different ISS antennas. This was followed up by adjusting the frequency settings three times up until 6 April 2014.

ESA

↑ Image of the Netherlands taken using NightPod

Commissioning activities were successfully completed by ISS Commander Koichi Wakata on 13 April with an ISS pass performed with four ground stations two in Italy, and one each in France, and the UK. The ground stations received Wakata's DATV signal transmission for about six minutes and the video was streamed over a public server. The recorded video of this historical transmission is now available on You Tube (http://youtu.be/EpFzbKvK1pk).

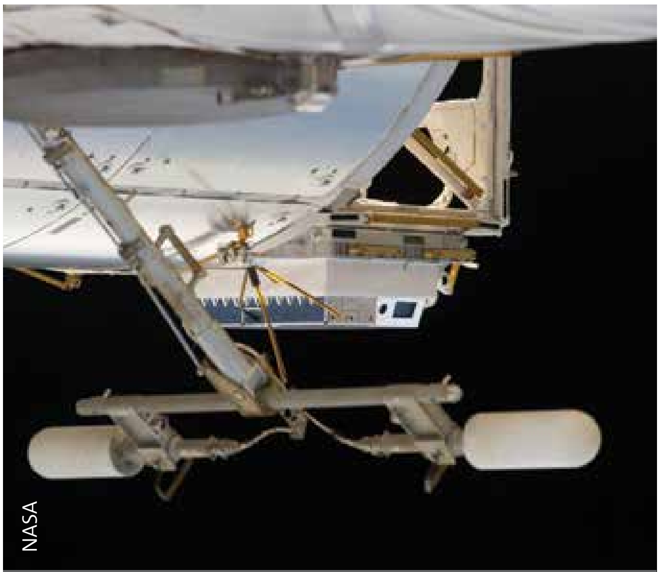
↑ Screenshot from Youtube video of ISS Expedition 39 Commander Koichi Wakata during ISS Ham Video commissioning on 13 April 2014

The NightPod and ISS HAM video payloads will produce valuable imagery for use in education and promotion activities. Footage will help to stimulate the public interest in the International Space Station in general, and more specifically generate an interest in children through providing a means to promote an interest in scientific research topics.

Additional ISS Partner Research

In addition to the Human Research activities mentioned, Luca Parmitano was also involved in many research activities for the ISS Partners in the areas of biology, the physical sciences and technology. Two highlights from the NASA activities include retrieval of two MISSE-8 (Materials International Space Station Experiment-8) experiments during a spacewalk on 9 July 2013 (involving Parmitano), which Parmitano hot sealed for return to Earth, and conducting a Surface Telerobotics session in July 2013 during which Parmitano remotely operated a robot on ground from the ISS as part of preparations for future exploration missions. This experiment along with ESA's METERON experiment is discussed in detail in another article in this newsletter.

↑ NASA astronaut Karen Nyberg (left) and ESA astronaut Luca Parmitano sealing two MISSE-8 experiments in preparation for their return to Earth



↑ The HDEV payload (lower, middle. Partially obscured) installed on the Earth-facing location of the Columbus External Payload Facility on 7 May 2014

One major highlight after Parmitano's Volare mission activities for ISS Partner Agencies was the installation of NASA's High Definition Earth Viewing (HDEV) experiment on the nadir position of the External Payload Facility of Columbus (on which ESA's SOLAR facility is also located on the zenith position) on 30 April 2014. This was carried out using the Station's principal robotic arm (Canadarm 2) after HDEV arrived on the SpaceX-3 Dragon spacecraft. Hereafter the Columbus Control Centre in Oberpfaffenhofen in Germany started receiving the first telemetry from the new payload. HDEV is a system of four commercially available HD cameras on the exterior of the Space Station which will be used to stream live video of Earth for viewing online.

Other Activities

In support of the ISS research activities a fleet of ISS logistics spacecraft have helped to supply the ISS with research equipment, samples and other necessary supplies during Expedition 36-39. Following undocking of Progress 51P and 50P in June and July 2013 respectively four additional Progress flights have been launched to the ISS, Progress 52P in July 2013, Progress 53P in November 2013, Progress 54P in February 2014, and Progress 55P in April 2014. Progress 52P undocked two days prior to the arrival of Progress 54P, Progress 54P undocked 2 days prior the arrival of Progress 55P. Progress 53P which was still docked to the ISS by the end of Expedition 39 additionally carried out the first tests of an upgraded navigation system for use on future Progress and Soyuz flights. ESA's fourth Automated Transfer Vehicle (ATV-4) "Albert Einstein" carried out a successful mission at the ISS from June to October 2013 during which time the ISS also saw the arrival and departure of the fourth Japanese H-II Transfer Vehicle (HTV-4) in August/September 2013 and the first demo flight of the Cygnus spacecraft in September/October 2013. This was followed up by the first commercial Cygnus flight to the ISS in January/February 2014. The third commercial SpaceX Dragon spacecraft (SpaceX-3) became the final logistics spacecraft to be launched in the Expedition 36-39 timeframe on 18 April 2014, docking two days later.

↑ ATV-4 "Albert Einstein" during rendezvous and docking with the ISS in June 2013

Of course just as ISS supplies need renewing and refreshing, the crew also need to be rotated in order to continue the work on the ISS. Expedition 36 started with the undocking of Soyuz 34S on 13 May 2013 leaving ISS Commander Pavel Vinogradov (Roscosmos) and ISS Flight Engineers Alexander Misurkin (Roscosmos) and Chris Cassidy (NASA) on the ISS. They were joined on 29 May by ISS Flight Engineers Luca Parmitano (ESA), Fyodor Yurchikhin (Roscosmos) and Karen Nyberg (NASA) after docking of Soyuz 35S. The situation remained in this configuration until 11 September 2013 with undocking of Vinogradov, Misurkin and Cassidy in Soyuz 34S signifying the start of Expedition 37 with Yurchikhin as the ISS commander. Three more Expedition 37 Flight Engineers arrived at the ISS two weeks after in Soyuz 36S, Oleg Kotov (Roscosmos), Sergey Ryazanskiy (Roscosmos), and Michael Hopkins (NASA).

↑ Soyuz 36S following undocking on 11 March 2014

The crew of Expedition 37 increased to nine for a few days with the arrival of Koichi Wakata (JAXA) Mikhail Tyurin (Roscosmos), and Rick Mastracchio (NASA) at the ISS in Soyuz 37S on 7 November 2013 (along with the Olympic torch for the Sochi Winter Olympics) for a direct crew handover. Expedition 37 transitioned to Expedition 38 with the undocking of Soyuz 35S with Parmitano, Yurchikhin and Nyberg on 11 November with Oleg Kotov assuming command of Expedition 38. Expedition 38 concluded with the undocking of Soyuz 36S with Kotov, Ryazanskiy and Hopkins on 11 March 2014 signifying the start of Expedition 39 with Wakata as the first Japanese ISS Commander. Two weeks later three more Expedition 38 Flight Engineers arrived at the ISS in Soyuz 38S, Steve Swanson (NASA), Alexander Skvortsov and Oleg Artemyev (both Roscosmos). Expedition 39 transitioned to Expedition 40 with the undocking of Soyuz 37S with Wakata, Tyurin and Mastracchio on 13 May 2014 with Steve Swanson assuming command of Expedition 40.

↑ NASA astronaut Mike Hopkins during second spacewalk to replace a faulty water pump outside the ISS on 24 December 2013

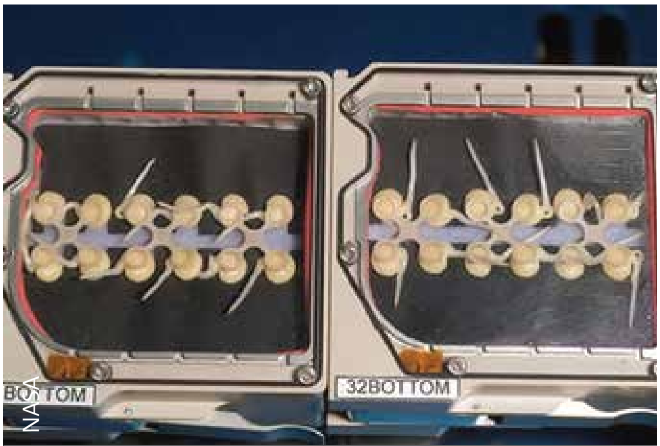
During Expeditions 36-39 there have been a couple of events that have had an impact on ISS Research activities. The most significant was the failure of one of the two loops (Loop A) of the ISS External Thermal Control System, which helps in the removal of excess heat from the ISS, on 11 December 2013. As such, contingency power downs were undertaken. Power Distribution Unit (PDU) 1 in Columbus was powered down. This feeds different Columbus payloads. As such EXPRESS Rack 3, the Fluid Science Laboratory, and the SOLAR Facility were deactivated as were a Station Support Computer, DOSIS-3D, the Vessel ID System, and the HAM radio equipment. Alternative power supplies were found for the last four pieces of hardware, while other non-critical systems were configured with no back up. Due to the failure many planned activities in Columbus involving the Columbus Control Centre were put temporarily on hold. Following EVA's to replace a suspect pump module, standard thermal control was returned to Columbus by 25 December. PDU 1 was reactivated on 31 December and all systems were returned to their required nominal configuration.

On 20 November 2013 the ISS marked 15 years in orbit following the launch of its first element (Zarya) on 20 November 1998.

→ MILESTONES IN GRAVITATIONAL BIOLOGY:

The Gravi-2 Experiment

ESA's Gravi-2 plant biology experiment has been successfully performed following its arrival at the ISS on the SpaceX-3 logistics spacecraft in April. This continued important research into the gravity sensitivity of lentil seedlings, which will have an impact for future human exploration missions, and also signified the return to functionality for ESA's Biolab facility in Columbus.



↑ Cultivation chambers from the Gravi-1 experiment in the US laboratory, carrying out research to determine the gravity perception threshold in lentil seedlings

↑ Experiment container exchange in the European Modular Cultivation System

On Earth, plants respond to gravity so that stems grow up and roots grow down. Lack of gravity causes plant growth problems in orbit. Many plant physiologists have undertaken experiments to estimate the gravity perception of plants with respect to the threshold acceleration level leading to a gravity response; the minimum duration of constant gravity leading to a gravity response; and the minimum duration of repeated gravity stimuli leading to a gravity response.

The Gravi-2 (Threshold Acceleration for Gravisensing 2) experiment follows very positive research coming from the Gravi-1 experiment undertaken during ISS Expedition 14 in 2007. The goal of the Gravi experiments, which are under the scientific lead of Dominique Driss-Ecole, from the University Pierre-et-Marie Curie, in Paris, France, is to investigate gravitropic response (a tendency to grow toward or away from gravity) for better understanding of the perception of the gravistimulus (reorientation within the gravity field) during initial plant growth.

The Gravi-2 experiment was principally processed inside the European Modular Cultivation System in Columbus but also used the thermal storage and glovebox capabilities of the Biolab facility, also in Columbus. The Biolab facility had undergone a major maintenance and commissioning period in 2013 which included successfully repairing its microscope and returned full functionality to the facility. The Gravi-2 experiment was then scheduled to take place on conclusion of these repair and commissioning activities.

↑ SpaceX-3 Dragon spacecraft berthed to the International Space Station on 20 April 2014

Prior to the launch of the Gravi-2 experiment there was slight concern about the viability of the samples as, following sample preparation, the original launch date of the SpaceX-3 Dragon logistics spacecraft slipped from March to April. This was firstly due to a problem at a radar site in the US needed for the launch and secondly due to a helium leak associated with the launcher that pushed the launch back by a further few days.

However, following a ground test on spare samples, the viability of the seeds was still confirmed and the experiment proceeded as planned. The samples arrived at the ISS on SpaceX-3 on 20 April following its launch two days earlier. ESA's Biolab facility was activated and one of its two Thermal Control Units set to 4 deg C. The Gravi-2 seeds and fixatives were placed inside this Thermal Control Unit on 22 April by ISS Commander Koichi Wakata. This was for an initial thermal conditioning stage prior to processing in the European Modular Cultivation System (EMCS).

The EMCS has two centrifuges which can be set to different g-levels. For run 1 of Gravi-2 four experiment containers were placed on centrifuge 1 and four on centrifuge 2 with two culture chambers per experiment container. These were all hydrated with the same amount of water. For the first 21 hours after hydration the experiment containers were kept under weightless conditions. For the remaining 9 hours of run 1, centrifuge 2 was still kept under weightless conditions for comparative purposes while centrifuge 1 was set to 0.01g. The samples were then automatically fixed and stored back in Biolab at 4 deg C. For run 2, eight experiment containers were again placed across the two centrifuges and hydrated. This time however, centrifuge 1 was kept weightless for 29 h 45 min while centrifuge 2 was kept weightless for 29 h 55 min. For the remainder of the 30h run the centrifuges were set to 2g (15 min for centrifuge 1 and 5 min for centrifuge 2) before being automatically fixed and stored back in Biolab.

↑ Sample hydration activities from the Gravi-1 experiment in 2007, undertaken by NASA astronaut Sunita Williams

↑ Video snapshots from the Gravi-2 experiment: disassembling Culture Chambers from an experiment container in the Biolab facility Bioglovebox.

From a preliminary science team assessment, good seed germination, good root growth and clear chemical fixation of the samples have been obtained for both run#1 and run#2 leading to a positive scientific outlook. The samples were returned to Earth on SpaceX-3 on 18 May 2014 and returned to the science team's laboratory for analysis.

↑ SpaceX-2 spacecraft just prior to splash down in 2013

Gravi-1 was the observation only phase of the investigation. In Gravi-1 lentil seedling roots were grown under various gravity conditions generated by centrifuge in the European Modular Cultivation System (EMCS) on the ISS, to determine the amount of acceleration force sufficient to stimulate the direction of root growth. During stimulation the gravitropic response (root curvature) was recorded by time-lapse video during centrifugation to determine the threshold acceleration at which the root responds to the gravity stimulus.

The experimental procedure of Gravi-2 was similar to that of Gravi-1. However, in Gravi-2 after the stimulation period, the roots were chemically preserved before return to earth, rather than being disposed as in Gravi-1. The Gravi-2 samples are being analysed to determine the movement of amyloplasts in lentil root cap cells (at the tip of the root) under influence of the stimulation. In these root cap cells (called statocytes) there are some specialized amyloplasts (statoliths) involved in the perception of gravity. It is thought that the sedimentation of these statoliths under the influence of gravity sends a gravitropic signal leading to auxin redistribution in the root cap and root and hence differential growth of the root tissues to follow the direction of the gravity stimuli. (Auxins are a class of plant hormones with a principal role in many plant growth processes and essential for plant body development).

The results will provide insight into the fundamental organization and operation of the gravity response system of plants and determine if, other than the root cap, other parts of the plant require cues for directional growth. Increasing knowledge of growing plants in partial gravity environments is also relevant to planning future plant cultivation for growing sufficient edible crops on future long duration space missions to, for example, the Moon and Mars.

In the first part of the Gravi-1 experiment seedlings were grown in weightlessness in eight experiment containers, each containing 2 cultivation chambers or 48 seeds following hydration for 15 hours. Hereafter the seedlings were centrifuged for almost 14 hours in the European Modular Cultivation System at gravity levels ranging from ~0.003g to 0.01g. In the second part of the Gravi-1 experiment seedlings were grown for 21.5 hours in weightlessness followed by 9 hours of induced gravity by centrifuge at levels ranging from 0.012g to 0.2g (0g control samples were also grown in weightlessness).

↑ The Norwegian User Support and Operations Centre (N-USOC) in Trondheim, Norway

The time lapse photography was analysed at the Norwegian User Support and Operations Centre (N-USOC) in Trondheim, Norway. The imagery showed that the embryonic roots curved away from the cotyledons and then slowly straightened from 17 hours to 30 hours after hydration. Due to this straightening the root tip was oriented close to an optimal angle of curvature (120 – 135 deg) during a 2-hour period of centrifugation. One interesting point is that lentil roots grown in weightlessness were more sensitive to stimulation than lentil roots grown under 1g conditions. The gravity threshold perceived by these plants was determined to be between 0 and 0.002g. In addition by using a hyperbolic model, the gravity threshold was estimated to be 1.4 x 10-5 g.

As previously mentioned the conclusion of on-orbit activities for Gravi-2 not only marked the successful follow-up to the Gravi-1 experiment, it also signified the successful return to action of ESA's Biolab facility which completed successful

↑ ESA astronaut Luca Parmitano during during Biolab microscope installation activities in July 2013.

maintenance and commissioning activities on orbit at the end of 2013. The Gravi-2 experiment did not use the repaired functionality of Biolab (only the thermal storage and glovebox capabilities) though the repairs have opened the way for other research to take place.

The repairs included installation of a modified gripper for the fixation syringes of the handling mechanism (in 2012) replacing Life Support Modules of the Biolab incubator, and installing the refurbished microscope unit plus extensive testing.

With this complete a commissioning run was successfully undertaken at the end of 2013. This included functional testing of the Handling Mechanism Arm, both centrifuges, the Biolab Life Support System with different settings of temperature, humidity, airflow, CO_2 and O_2 and a test of the temperature behaviour of the Biolab incubator.

The TripleLux-B experiment will be the next experiment to make full use of the Biolab facility, currently scheduled for launch to the ISS on the SpaceX-5 spacecraft in Autumn 2014. The TripleLux-B experiment will compare the cellular mechanisms of vertebrate (rodent) and invertebrate (blue mussel) cells which cause impairment of immune function in weightlessness.

Publication(s)

- D. Driss-Ecole, V. Legué, E. Carnero-Diaz, G. Perbal, (2008), "Gravisensitivity and automorphogenesis of lentil seedling roots grown on board the International Space Station", Physiologia Plantarum, 134, pp. 191-201.

→ MILESTONES IN NEUROSCIENCE:

Reversible Figures experiment on its way to completion

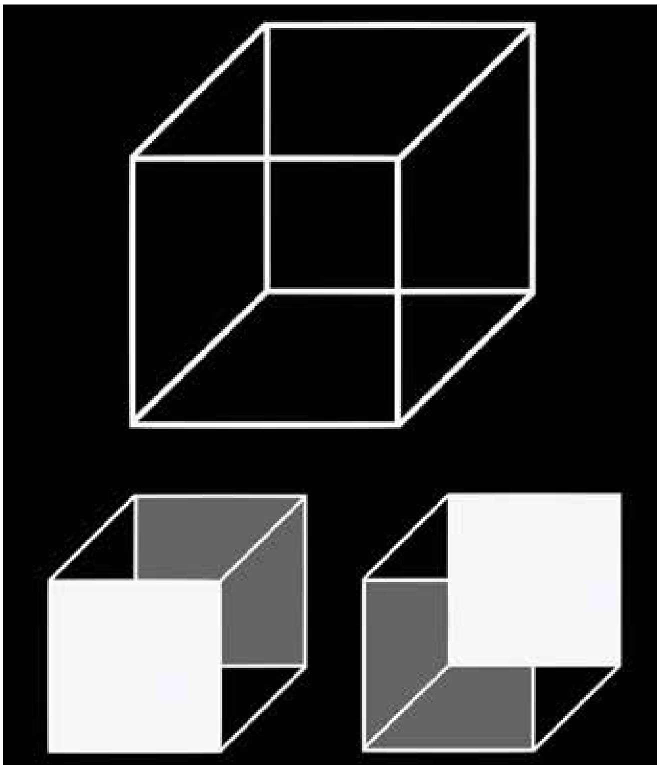
ESA's Reversible Figures neuroscience experiment, which started in July 2012, has just been successfully completed with the final human test subject returning from orbit in May 2014. Following in a long line of ESA neuroscience research in orbit the experiment is providing an insight into our altered, and maybe even more balanced, neural processing in weightlessness.

ISS Expedition 39 Commander and JAXA astronaut Koichi Wakata undertook his final on-orbit session as the 6th test subject for the experiment on 30 April 2014. If the post-flight data collection proves valid this will bring the Reversible Figures experiment to a successful conclusion of activities prior to data analysis. The experiment is investigating the adaptive nature of the human neuro-vestibular system in the processing of gravitational information related to 3D visual perception. It involves the comparisons of pre-flight, in-flight, and post-flight perceptions of ambiguous perspective-reversible figures to assess the influence of weightlessness on these neural processes.

One example of an ambiguous figure is the Necker cube (bottom of next page). 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.

Ambiguous / reversible figures can be seen in two different ways, but with a known statistically preferential way in 1g on Earth. The hypothesis is that the perceptual instability generated by ambiguous figures is reduced in 0g compared to 1g, because gravity "gets in the way" for cognitive processes on Earth.

↑ ISS Expedition 38 flight engineer and JAXA astronaut Koichi Wakata participating as the final test subject in a session of the Reversible Figures experiment in ESA's Columbus laboratory on the International Space Station in November 2013



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

Recent studies revealed that the number of perceived reversals in patients with otolith-dependent disorders is smaller (i.e., there is less perceptual instability) than in healthy subjects. Because the otolith organs are not stimulated during free-floating in weightlessness, it is hypothesized that the number of perceived reversals will be smaller in 0g than in 1g. A long-term adaptation is possible, as seen in the Image Reversal in Space (IRIS) study on the ISS. IRIS was a pilot study of Reversible Figures performed by CSA astronaut Bob Thirsk during Expedition 20 in 2009, under the science lead of Dr. Gilles Clément (International Space University, ISU), following parabolic flight and ground-based tests.

The hardware for the Reversible Figures experiment was flown to the ISS on Soyuz 31S in July 2012 along with three members of the ISS Expedition 32 Crew which included NASA astronaut Sunita Williams who became the first test subject of the experiment. The hardware (visor and trackball) was also used as part of the 3D-Space experiment, the first neuroscience experiment to take place in the Columbus Laboratory (from 2008-2011). In fact there is a close link between the two experiments with Dr. Clément the lead scientist on both 3D-Space and Reversible Figures. In addition to Dr. Clement and the ISU science team members, Bob Thirsk is also a principal science team member for the Reversible Figures experiment.

Sunita Williams started Reversible Figures on 20 July 2012, three days after arriving at the ISS, connecting the hardware to a multipurpose laptop in the Columbus module, before donning the dedicated visor and conducting the experiment protocol in a free-floating position (to ensure no stimulus on the otolith organs in the inner ear). To assess the adaptation in neural processing across the long-duration mission, four sessions of the experiment were carried out in total with Williams undertaking her three additional sessions in August, September and October. These four mandatory sessions had to occur within flight days 0 - 15, 16 - 45, 76 - 105, and 136 – 180. There was also the option to undertake two subsidiary sessions within flight days 46 - 75 and 106 - 135.

During each experiment session a series of 10 ambiguous figures are displayed for 60-120 seconds and the subject is prompted to specify by pressing pushbuttons on the mouse which percept they visualize first, and then every subsequent change in perception of each figure. The measurements include the time it takes for the astronaut to identify the first percept of each ambiguous figure; which percept of the ambiguous figure is identified first; the time it takes to then experience a percept reversal of each ambiguous figure; and the number of percept reversals experienced in total for each figure.

On the day of Williams' last session on 29 October 2012, NASA astronaut Kevin Ford started as the second test subject, undertaking a further three sessions until February 2013. Ford was followed up by NASA astronaut Tom Marshburn and CSA astronaut Chris Hadfield who completed their four sessions of the experiment from December 2012 until April 2013.

↑ Video snapshots. Top 3 images: from ESA's 50th Parabolic Flight Campaign in 2009 showing tests prior to the IRIS experiment on the ISS. Bottom image: CSA astronaut Bob Thirsk participating in the IRIS experiment on the ISS in 2009

↑ Top: ESA astronaut Paolo Nespoli participating in the 3D-Space experiment in the ISS Columbus laboratory in February 2011. Bottom: Clear view of experiment visor worn by NASA astronaut Tom Marshburn during a session of the Reversible Figures experiment on the ISS

They were subsequently followed up by NASA astronaut Michael Hopkins who became a member of the Expedition 37/38 crew, and was the first astronaut to undertake six sessions of the experiment, between October 2013 and February 2014. Finally Koichi Wakata started as the last test subject in November 2013 and also completed six sessions by the end of April 2014, two weeks prior to his undocking and landing on 14 May.

The data gathered is being evaluated against pre- and post-flight data gathered from the same test subjects to help evaluate the transition to weightlessness and the transition back to 1g conditions. The (up to) three post-flight data sessions are undertaken within the first 10 days after return. Now that all test subjects have completed all in-orbit and ground sessions of the experiment we should get a clearer idea of the type of adaptation occurring through adaptation to and from weightlessness.

↑ Close up of mouse with pushbuttons used by astronaut test subjects to provide feedback for the Reversible Figures experiment

→ TECHNOLOGY RESEARCH: THE METERON EXPERIMENT

Developing Human/Robotic Capabilities for future Exploration Missions

Human Exploration missions beyond low-Earth orbit are becoming a greater focus of ESA activities in human spaceflight. Constructing such missions using astronauts together with robotics technologies such as surface rovers holds greater benefits for exploring the near neighbours of Earth such as Mars than can be achieved with purely robotics missions controlled solely from Earth or human exploration missions without robotic technologies. One major step forward in this area is ESA's "Multi-Purpose End-To-End Robotic Operations Network" (METERON) project which started in 2011. Following the first experiment of the project (OPSCOM-1), the second one (OPSCOM-2) is scheduled to take place on the ISS as part of the mission of ESA astronaut Alexander Gerst who arrived at the ISS on 29 May 2014.

The history of remotely controlled robotic rovers dates back to the Russian Lunokhod 1 and 2 rovers which landed on the surface of the Moon in November 1970 and January 1973 respectively with the latter functioning for four months and covering a distance of 42 km. Hereafter the focus was mainly on Mars with NASA's Sojourner rover (Mars Pathfinder mission) in 1997, the two Mars Exploration Rovers (Spirit and Opportunity) which landed on Mars in January 2004 (Opportunity is still functioning after more than 10 years), and the Mars Science Laboratory 'Curiosity' rover which landed on Mars in 2012 and is expected to explore 20-50 times more area than either of the Mars Exploration Rovers. China also landed its first rover on the Moon in December 2013.

What all these rovers have in common is that they were/are remotely controlled from Earth, involving extensive ground control teams integrating a wide variety of expertise. However the remote control of surface rovers from orbiting spacecraft may offer advantages. It would enable astronauts to expand their sphere of influence far beyond the confines of a flight vehicle; it would enable astronauts to safely perform surface work via a robotic avatar; and it would reduce the expenditure of precious consumables (oxygen, fuel for crew ascent, etc.). A variety of surface science and engineering tasks could be performed in this manner, including sample collection, scouting, site preparation, instrument deployment, and repair and maintenance.

↑ Robotics rovers on Mars. Top: Sojourner rover from NASA's Mars Pathfinder mission in July 1997. Bottom: Curiosity rover from NASA's Mars Science Laboratory mission in October 2012

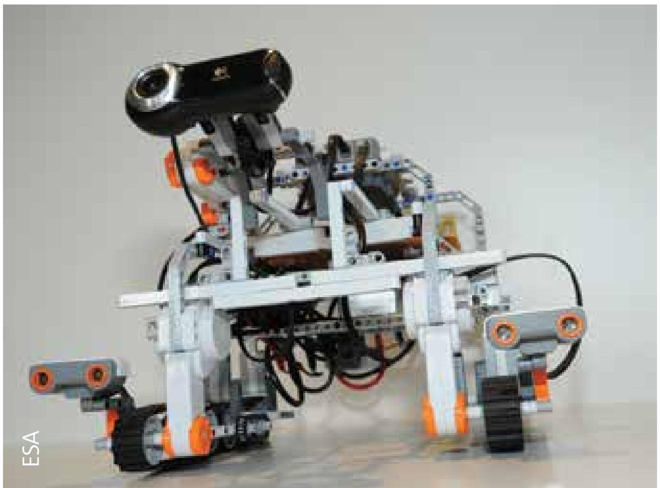
To support this concept of operations, technology preparation is required to enable astronauts to effectively and efficiently control surface robots with a high degree of situation awareness and low workload.

The International Space Station is the ideal test bed for trials of such technologies and concepts, providing a good simulation to a spacecraft orbiting a planet on a future human exploration mission. In fact it is the only facility available able to confirm in-flight that all significant environmental conditions, operational constraints, and other factors (including weightlessness and space environmental effects) are replicated.

ESA's METERON project is aiming to demonstrate communications and operations concepts and technologies for such missions accounting for issues such as disruption in network connectivity, communications delays caused by distance, efficient bandwidth usage, human-in-the-loop operations, multi-rover operations, multi-operator interaction, supervisory control and haptic teleoperation to name a few. Haptic teleoperation is the remote operation of technologies involving tactile feedback in the human/technology interface (i.e. an operator exerting/feeling forces through a joystick)

↑ NASA astronaut Sunita Williams using a laptop on the ISS in October 2012. Williams undertook the on-orbit operations for the OPSCOM-1 part of the experiment, controlling a prototype rover on earth

The first METERON experiment to be carried out was called OPSCOM-1. The purpose of this joint ESA/NASA/CU Boulder experiment was to validate the suitability of the Delay Tolerant Network (DTN) protocol for crew-controlled telerobotics. DTN is an approach to overcome technical issues in networks that may lack continuous network connectivity (such as missions in space). The experiment began in mid-2011 and culminated in a test on 22 October 2012, when Sunita Williams successfully controlled a small prototype rover from the ISS called MOCUP (METERON Operations and Communications Prototype). This prototype was located at ESA's European Space Operations Center (ESOC) in Germany for the test.



↑ The MOCUP test robot from ESA's European Space Operations Centre, Darmstadt, Germany. MOCUP is an acronym of METERON Operations and Communications Prototype and was controlled from the ISS in 2012 as part of the METERON series of experiments. Its purpose was the proper reception, execution and reporting of a simple set of commands

↑ Screenshot of the METERON Operations Environment interface

The experiment successfully demonstrated the suitability of DTN for future METERON activities. It is important to note that the primary objective of this first experiment was validation of communications protocols and not telerobotics or operations. MOCUP was developed solely to provide the communications system with a representative data flow between the control software and the rover.

In the follow up experiment, OPSCOM-2, validation of key DTN features for telerobotics will be performed. The experiment will demonstrate the benefits of DTN, including reliable data transfer, automatic "Loss of Signal" handling, efficient bandwidth use, and the automatic routing of the data packets if more than one communication path is available.

↑ The Eurobot Ground Prototype and Aouda.X spacesuit mockup being tested in Mars-like terrain of Spain's Rio Tinto mines in April 2011

OPSCOM-2 will also validate control of ESA's Eurobot rover from the ISS and will introduce the METERON Operations Environment (MOE), the first end-to-end monitoring and control system for a complete mission including humans and rovers. This activity is scheduled to take place in mid-to-late 2014.

MOE is based on infrastructure used for mission operations for unmanned missions controlled from ESOC. MOE elements interface with dedicated software systems involved in the experiment chain, including the control system of each robot (MOCUP, Eurobot, etc).

OPSCOM 1 and 2 will be followed up by the two HAPTICS experiments. On a distant planet a robot will need to know how much force to apply when, for example, picking up rock for further analysis and installing complex equipment. With haptic feedback an astronaut controlling the robot could automatically adjust the force needed to grip the object remotely and thereby undertake very fine and precise tasks.

HAPTICS-1 will be the first ISS experiment that specifically focuses on investigating how human feedback (proprioceptive/kinesthetic) changes after extended exposure to weightlessness. This will help to answer the question: how will an astronaut experience haptic feedback in weightlessness?

HAPTICS-1 is scheduled to be performed by five astronauts on the ISS within increments 41 and 43 with the hardware due to arrive at the ISS on the ATV-5 flight in August 2014. The crew input to the experiments will be undertaken on a touch-screen tablet computer using a novel robotic control software suite with guided procedures. This is the first time a touchscreen-tablet will be used to control a robot from the Space Station and marks a new era of interactive experimentation, not only in space, but also on ground. Astronauts will move a

↑ Haptics-1 body-mounted operations

↑ André Schiele, leading ESA's telerobotics lab, demonstrating remote robotic operations wearing an exoskeleton that weighs just 10 kg

bar on the tablet screen as quickly and precisely as possible under different feedback settings. Questionnaires will gather information on the minimum force they can feel and how realistic each setting feels.

The HAPTICS-1 experiment will provide a complete dataset of human motor control behaviour in the human upper extremities in weightlessness. HAPTICS-1 will also provide data on perception threshold changes that are expected to occur in weightlessness. This data is directly relevant for the design of advanced human-robot interfaces. In particular, HAPTICS-1 results will support the design of a full exoskeleton arm controller, which will be tested on the ISS during a later METERON experiment.

3D augmented reality is also to be used to augment a remote operation setup with critical system information to enhance operator performance. For instance force and torque information from a robot interacting with an environment can be displayed to increase operator awareness of magnitudes of forces being exerted. This information feedback can improve robustness and safety of haptic teleoperation.

The central subsystem of the HAPTICS-1 hardware is a high fidelity force reflecting joystick, used for manual interaction of the crew during the experiment protocols with the virtual simulated environments. This will be mounted via standard Space Station interfaces to a body harness which itself is a first step to a new harness design for more advanced haptic devices. The joystick's mechatronic hardware architecture is identical to the intended future architecture for one joint of a full exoskeleton and features all required safety features. This allows verification of the safety concept for such highly interactive and human-in-the-loop robotic devices. Additionally, this will provide a necessary first step towards the in-orbit validation of robotic bilateral (two-way) control devices.

The HAPTICS-1 experiment will be followed by the HAPTICS-2 experiment in 2015. In HAPTICS-2, the force reflective joystick on-board the ISS will be used to perform a first bilateral control demonstration involving ISS and a ground robot system. Testing will use the same protocols as HAPTICS-1 and will measure the specific influences of force reflection on human task performance.

As with many initiatives pertaining to human exploration missions NASA are also testing and demonstrating crew-controlled communications, operations, and telerobotic technologies that are needed for future deep space human exploration missions. NASA's 'Human Exploration Telerobotics' (HET) project is complementary to METERON.

One element of the HET project is 'Surface Telerobotics', which examines how astronauts in space can remotely operate a planetary rover using a combination of manual and supervisory control. In 2013 three Expedition 36 astronauts (including ESA astronaut Luca Parmitano) on-board the ISS remotely operated NASA's "K10" planetary rover in the "Roverscape" (an analogue lunar terrain) located at the NASA Ames Research Center. This simulated four phases of a lunar mission concept: pre-mission planning, site survey, simulated telescope deployment, and inspection of a deployed telescope.

A second phase of Surface Telerobotics will assess system refinements, or new features, by making comparisons against the baseline coming from the first phase of the experiment.

The primary objective for METERON and HET is to ensure that Europe and the USA are in a position to properly plan for future human-robot exploration missions in deep space. Both projects

↑ ESA astronaut Luca Parmitano, uses a computer on the ISS in July 2013 to remotely control a surface rover at NASA's Ames Research Center in California. This 'Surface Telerobotics' experiment was part of NASA's Human Exploration Telerobotics (HET) project

have already allowed ESA and NASA to gain experience in the fields of communications, operations and crew-controlled telerobotics without having to fly demonstrator missions. The use of the ISS for such experiments has made this possible.

Looking forward, the data collected and lessons learned from ISS testing will provide mission planners with crucial information about what kinds of human-robot collaboration can improve and enable future missions. In particular, information about the respective merits of supervisory control and haptic teleoperation will be instrumental for the space agencies to make informed architectural decisions for human-robot exploration.

Although METERON and HET are independent efforts, both projects share a common goal. Moreover, ESA and NASA are drawing up a cooperation agreement to closely coordinate their development and test plans to ensure that both complement each other. This type of collaboration allows both ESA and NASA to follow its own programmatic process and schedule, while enabling joint exploration of the "crew-controlled telerobotics" design space without duplication of effort. Moreover, because future deep space human-robot exploration missions will require international cooperation, METERON and HET are laying the groundwork to make systems integration and interoperability possible.

→ HUMAN PHYSIOLOGY: SKIN AGING MECHANISMS

The Skin-B experiment, one year and counting

ESA's Skin-B experiment started on the ISS in June 2013 with ESA astronaut Luca Parmitano undertaking monthly sessions as the first test subject. With NASA astronaut Steve Swanson starting the experiment in April 2014 and further test subjects awaiting launch, the experiment is now fully established in order to provide an insight into skin physiology and cellular adaptation to weightlessness in general.

The skin is the largest organ of the human body with a myriad of different functions. It provides the first line of defence in immunology by providing a barrier to prevent pathogens entering the body; it plays a key element in thermal regulation by sweating when we get hot; it regulates water balance; it contains numerous nerve cells in order for us to sense and interact safely with our environment; and it protects the body from ultraviolet radiation.

After headache and dizziness, dry and scaly skin and itching rank high on the list of astronauts' health complaints, according to NASA studies. Other skin-related complaints are delayed wound healing and allergic reactions to some materials. This has not been studied to any significant degree previously. As such undertaking the Skin-B experiment may not only provide insights into the skin physiology mechanisms during spaceflight, it may also provide an insight into changes in other tissues of the body such as in the muscles, heart or lungs and could help to draw conclusions to the effect of longer human exploration missions, e.g. to the Moon and Mars, on the body.

↑ ESA astronaut Thomas Reiter (now ESA's Director of Human Spaceflight and Operations) on the ISS. Thomas was the test subject for the Skincare experiment in 2006 on the ISS

The Skin-B experiment follows up from the pilot SkinCare experiment, carried out by German ESA astronaut Thomas Reiter on the ISS as part of the Astrolab mission in 2006.

The experiment is under the scientific lead of Prof. Dr. Ulrike Heinrich from the Institute of Experimental Dermatology/ DermaTronnier at the Witten/Herdecke University in Germany and is a cooperative research project between ESA and DLR.

The results from the SkinCare experiment showed that, during a six-month mission on the ISS, the skin of an astronaut undergoes changes similar to the aging process in humans on Earth though at an accelerated rate. The surface structure becomes coarser, the elasticity decreases and the various layers of the skin (stratum corneum, epidermis and dermis) age as well. These changes appear to be reversible, as the skin returns to a normal pre-flight condition in the first year after return from space.

The Skin-B experiment will provide a greater insight and more significance in this area by undertaking additional research on more test subjects (minimum of three, maximum of five).

The instruments for the Skin-B experiment, which were modified for use in orbit by Kayser-Threde, were launched to the ISS in March 2013. This preceded the arrival of Luca Parmitano as the first test subject. The skin on the inside of the astronauts' forearms is examined up to eight times during test subjects' stays on the ISS, as well as before and after their flight.

↑ ESA astronaut Luca Parmitano undertaking measurements for the Skin-B experiment on the ISS in 2013 using the visioscan device

↑ Demonstration of the use of the Tewameter device

↑ Close-up of the VisioScan device with the UV light camera switched on

Parmitano started procedures on orbit with his first session on 7 June 2013 and followed this up with six (approximately monthly) sessions with the final session on 7 November 2013 before return to earth. This data is analysed against pre- and post-flight measurements.

Each session consisted of three different non-invasive measurements taken on the inside part of the forearm: skin moisture measurement with a corneometer; trans epidermal water loss measurement to determine barrier function of the skin with a tewameter; and surface evaluation of the living skin with a UVA-light camera (visioscan).

Before and after the astronauts' missions, researchers at the Witten/Herdecke University take additional measurements of the capillary blood flow, referred to as microcirculation, as well as the deep structure of the skin and its elasticity.

With NASA astronaut and ISS Flight Engineer Steve Swanson already started as a test subject the following two (potential) test subjects have already undertaken pre-flight data measurement prior to their launch at the end of May 2014 as members of the Expedition 40/41 crew. This is ESA astronaut Alexander Gerst who is a prime subject for the experiment and NASA astronaut Reid Wiseman who is currently a reserve subject for the experiment.

Even though it is central to the experiment, the skin is not the only subject under consideration as organs that are lined with epithelial tissue and the connective tissues will also be studied, since early-stage lesions may provide clues about other systemic diseases.

If the results from SkinCare are confirmed within the Skin-B experiment, the skin aging process and the effectiveness of anti-aging treatments could be tested at an accelerated pace on board the Space Station.

↑ ESA astronaut Alexander Gerst (foreground) and NASA astronaut Reid Wiseman during training in March 2014. Gerst and Wiseman will become the next two test subjects for the Skin-B experiment following their launch in May 2014

→ CURRENT MISSIONS: ALEXANDER GERST ON EXPEDITION 40/41

A Blue Dot on the Horizon

↑ ESA astronaut Alexander Gerst during EVA training at the Neutral Buoyancy laboratory of the Johnson Space Centre in Houston, Texas in September 2013

ESA astronaut Alexander Gerst became the second ESA astronaut from the class of 2009 to undertake a space mission, following launch on ESA's Blue Dot mission on 28 May. A core part of Gerst's mission will be a complete science programme for ESA and the ISS Partners, on top of his standard ISS responsibilities and tasks as an ISS Flight Engineer on the Expedition 40/41 crews. For ESA, Gerst's mission has been named 'Blue Dot' after American astronomer Carl Sagan's description of Earth from a photograph taken by NASA's Voyager spacecraft six billion kilometres from our planet.

Gerst's mission started in earnest when he was launched to the ISS on the Soyuz TMA-13M spacecraft from the Baikonur Cosmodrome together with his fellow Expedition 40/41 crew members: ISS Flight Engineer Reid Wiseman (NASA) and Expedition 40 Flight Engineer/ Expedition 41 Commander Maxim Suraev (Roscosmos).

↑ ESA astronaut Alexander Gerst (left) along with fellow ISS Expedition 40/41 Flight Engineer Reid Wiseman (right) and ISS Expedition 40 Flight Engineer and 41 Commander Maxim Suraev (centre)

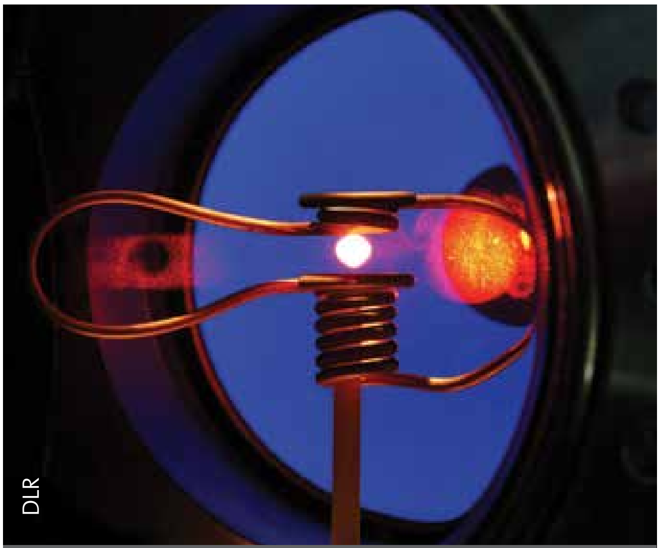
Human Research

Within Human Research Gerst is a test subject of numerous on-going ESA experiments, which have already been discussed in the overview article for Expeditions 36-39. This includes the Cartilage (pre- and post-flight) experiment, researching the effect of weightlessness on cartilage morphology; the

↑ NASA astronaut and Expedition 34 flight engineer Tom Marshburn, undertaking normal daily activities on the ISS whilst wearing Thermolab sensors as part of a 36-hour session of the Circadian Rhythms Experiment

Circadian Rhythms experiment studying circadian rhythm variations with a focus on core body temperature amongst astronauts; the Energy experiment researching astronaut energy requirements in weightlessness which will have an impact on future human exploration missions beyond low-Earth orbit and help optimise mission planning; the Skin-B skin physiology experiment (discussed in a detailed article in this newsletter); and the Space Headaches experiment researching the incidence and occurrence of headaches during a long-duration mission.

↑ Processing of the sample cassettes on the ISS for the Seedling Growth 1 experiment



↑ Core element of the ground-based Electromagnetic Levitator

Biology

The first biology experiment to involve on-orbit participation of Alexander Gerst is part 2 of the joint ESA-NASA Seedling Growth experiment. Seedling Growth 2 continues the research undertaken with Arabidopsis thaliana seeds in Spring 2013 as part of the Seedling Growth 1 experiment in studying the effects of combined light and various gravity levels on plant development by identifying changes in the mechanisms and regulation of essential cellular functions (detailed article in previous newsletter). Understanding how plants can adapt to environments with different gravity levels will help researchers to provide a complete and sustainable human life support in space. Gerst will undertake the on-orbit activities (sample preparation and installation in the European Modular Cultivation System, post-processing activities and placing samples in conditioned storage) after the samples arrive at the ISS on the SpaceX-4 Dragon spacecraft which is scheduled for launch in August 2014.

The following SpaceX Dragon launch (SpaceX-5) scheduled for October 2014 will transport ESA's next major biology experiment to the ISS, Triplelux-B. This has been made possible following successful maintenance activities to the Biolab facility in 2013. Prior to the SpaceX-5 launch Gerst will prepare the Biolab facility for research activities. Upon the experiment arrival on the ISS Gerst will prepare the Triplelux-B advanced experiment containers and install them in Biolab, as well as remove them on completion of the experiment and place the samples in conditioned storage prior to their return on the SpaceX-5 spacecraft (Processed samples for Seedling Growth 2 will also return on SpaceX-5). The objective of the Triplelux-B experiment is to further understand the cellular mechanisms underlying the aggravation of radiation responses and the impairment of the immune functions under spaceflight conditions, through induction of gene activation, phagocytosis, and DNA repair, following DNA damage in vertebrate and invertebrate immune cells.

Materials Science

Materials is one area that will get a big boost during the Blue Dot mission with the launch of the Electromagnetic Levitator (EML) on ATV-5. The EML will be installed inside the European

Drawer Rack in Columbus by Alexander Gerst and will be used for undertaking container-less solidification studies on different spherical metal alloy samples. Investigations carried out with the Electromagnetic Levitator will provide both reference data on thermophysical properties and microstructure formation for the same metallic alloy samples. (The microstructure in an alloy influences its characteristic properties such as strength, flexibility and resistance to fatigue). This information is of importance for feeding accurate data into current numerical models on one side, and also testing these models aiming to predict the solidification profile and related microstructure formation in the alloy samples. This concerns structural steels, magnetic materials, intermetallic materials, glass forming metallic alloys etc.

With the first batch of seven experiments for the EML also due to start during Gerst's mission following check out and commissioning activities, the outlook in ESA's materials research is very promising, building on the research already undertaken within ESA's Materials Science Laboratory in the US Laboratory within the CETSOL, MICAST and SETA experiments. These experiments which are currently on the second batch of samples are also set to continue during the Blue Dot mission.

Fluids research

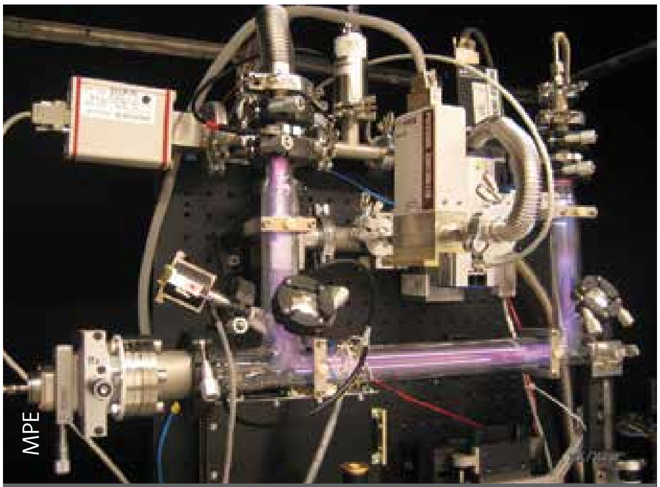
Alexander Gerst will play a vital role within fluids research with respect to finalising activities for currently on-going fluid science experiments. Within foams and emulsions research ESA's Fundamental and Applied Studies in Emulsion Stability (FASES) experiment has been on-going since the Summer of 2013 and the Facility for Adsorption and Surface TEnsion Research (FASTER) started research activities in April 2014. Gerst will be central to completing the activities for these experiments including de-installation of the FASES experiment from the Fluids Science Laboratory and the FASTER payload from the European Drawer Rack.

Additional fluids research that will be started during Expedition 40/41 is the SODI DCMIX-3 experiment which will build upon the DCMIX-1 and -2 experiments in determination of diffusion coefficients in selected ternary mixtures, which is of direct interest for example to oil companies that use computer simulations to model underground oil reservoirs and to optimise their exploitation.

Complex Plasma Physics

The PK-4 experiment will increase our knowledge of the processes influencing/ controlling plasmas, a state of matter (like solids, liquids and gases) which account for more than 99% of the visible matter in our universe.

Even though PK-4 is principally a fundamental experiment, understanding how complex plasmas can be influenced will give us a better understanding of how we could make improvements in areas and industries where plasmas are used. The main interest in this experiment lies in the investigation of the liquid phase and flow phenomena of complex plasmas for which PK-4 is especially suited. Prior to the arrival of the PK-4 experiment (currently scheduled on Progress 57P in October 2014), Alexander Gerst will undertake preparatory activities with the European Physiology Modules (EPM) facility in which the PK-4 hardware will be located including EPM reconfiguration and assisting ground teams with commissioning of its Video Unit.

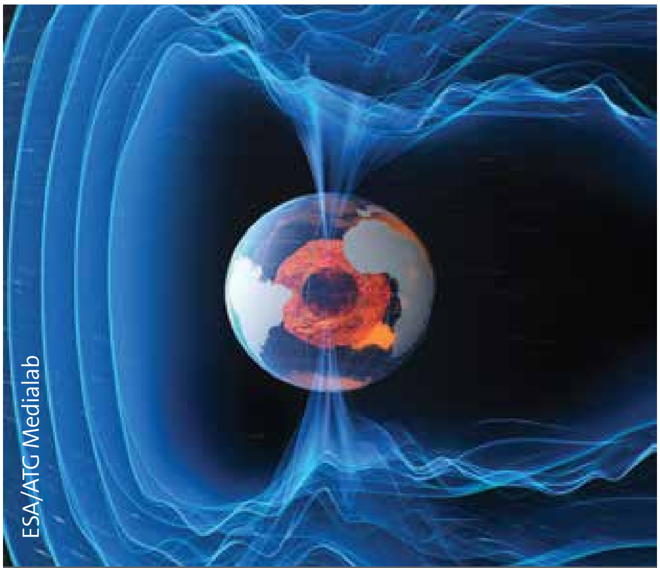


↑ Plasma inside PK4 hardware: the 'positive column' of a DC glow discharge

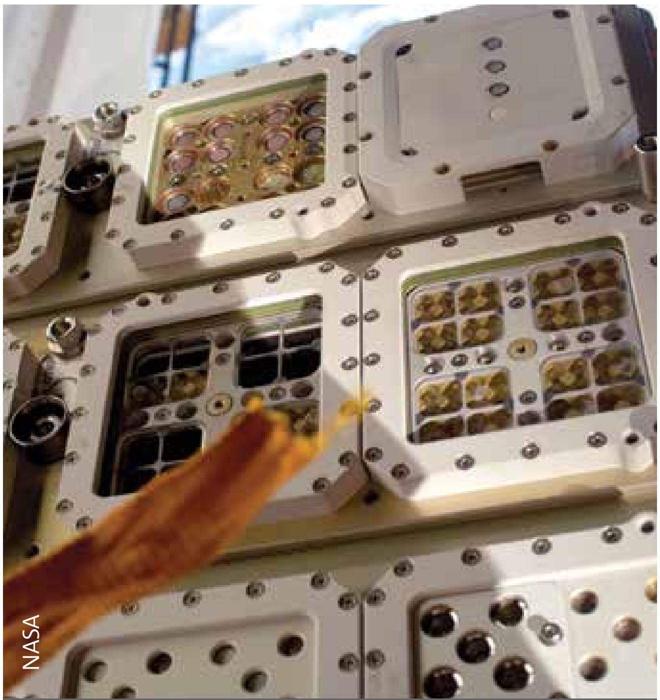
Space Environment Monitoring

Two long-duration experiments/payloads which will continue during the Blue Dot mission are the DOSIS-3D radiation monitoring experiment and the SOLAR facility. Though the second is undertaken purely through ground control as an external payload, for the DOSIS-3D experiment, which relies on data from active and passive radiation detectors, Gerst will be involved in swapping out passive detectors, in order to return a set to Earth for analysis of absorbed dose.

One further experiment is the new MagVector (MGX) technology experiment from DLR, for which Alexander Gerst will be responsible for installing in the European Drawer Rack (EDR) and undertaking various post-installation activities once the hardware arrives on ATV-5 in August. The MagVector experiment will study the interaction between a moving magnetic field (of Earth origin) and a very good electrical conductor. MagVector will use highly sensitive magnetic sensors to detect the changes in strength of the magnetic field to simultaneously measure the magnetic field on either side



↑ The magnetic field and electric currents near Earth generate complex forces that have immeasurable impact on our everyday lives



↑ The Expose-R facility following installation on the outside of the Zvezda Service Module on the ISS in March 2009

of the electrical conductor. This will include measuring the disturbances from magnetic sources in neighbouring research racks and from Earth's magnetic field.

Astrobiology

In astrobiology, the Expose-R2 samples will be launched on Progress 56P in July 2014. Once assembled into their sample trays on-orbit the Expose-R2 facility will be installed outside of the Russian Zvezda Service Module during a Russian EVA. Expose-R2 consists of four separate experiments determining the effect of the space environment on different samples, three experiments from ESA and one experiment from IBMP in Russia. The experiments will help to shed new light on the quest for the origin of life in the Universe. The ESA experiments are studying the evolution of organic molecules in the solar system, testing a wide range of organic compounds (Photochemistry on the Space Station experiment), as well as studying to what extent there is resistance to space and Mars-like conditions in certain organisms such as lichens, fungi, and bacteria and their constituents, such as pigments and cell wall components (Biology and Mars experiment, Biomex) as well as biofilm-forming microbes (Biofilm Organisms Surfing Space, BOSS, experiment). The Expose-R2 experiments follow on from the great success achieved within the Expose-R experiments which undertook almost two years of exposure of samples outside the ISS until January 2011 (results pending publication in a special issue of the Astrobiology Journal) and the Expose-E experiments which completed more than 18 months of exposure on the EuTEF facility, and produced very positive results with respect to survival rates of different sample organisms, before being returned to Earth in September 2009.

Technology Demonstrations

Within the area of technology a number of experiments have direct bearing on future exploration missions beyond

↑ ESA's fourth Automated Transfer Vehicle (ATV-4) called Albert Einstein during docking procedures with the ISS low-Earth orbit with Alexander Gerst scheduled to undertake the METERON Opscom-2 and Haptics-1 experiments which are both testing out procedures and technologies for future joint human robotics missions (these are discussed in detail in a separate article in this newsletter).

Gerst will also install the Wireless-Sensor Network (WiSe-Net), which is scheduled to arrive on ATV-5. This experiment will use low power consumption sensors to monitor environmental conditions like temperature, pressure, humidity, accelerations etc. with the aim to evaluate the possibility of “energy harvesting” and hence help develop techniques to improve energy consumption on the ISS and future spacecraft.

Another new experiment which will arrive on ATV-5 is the LIRIS Demonstrator which will demonstrate the performance of European in-flight imager sensors to help design better sensors for a future rendezvous with a space station or an asteroid. These new navigation sensors will be tested on an ISS fly-around prior to ATV-5 docking and the data recorders will be retrieved by Gerst and downloaded on the next Soyuz return flight.

One new DLR-sponsored experiment that will be performed by Alexander Gerst is the SpaceTex experiment which will test new fabrics which will increase not only our basic knowledge about the heat transfer/heat exchange from the human body to the environment under terrestrial and micro-g conditions, especially the evaporative part of heat loss in space during rest and physical exercise, but also improve the overall comfort and well-being of the astronauts on board of the ISS.

Outside of these new experiments the Vessel ID System maritime traffic monitoring experiment and the NightPod tracking device (both already mentioned in the Expedition 36-39 overview article) will continue use during Expeditions 40/41 with NightPod being used as part of the Earth Guardians education project which will educate pupils (aged 7–12 years) about the causes of climate change, the loss of biodiversity, and the human habits of consumption and promote possible solutions.

ISS Partner Research

Outside of the ESA research package Alexander Gerst will be involved in a whole programme of experiments for the ISS partners. This includes numerous experiments in the areas of human research for NASA (Biochemical Profile, Body Measures, Cardio Ox, Microbiome, Ocular Health, Repository, Salivary Markers), JAXA (Biological Rhythms 48hrs, Hybrid Training), and CSA (BP Reg)

In biology the majority of experiments for which Gerst will undertake research activities on orbit are for JAXA (Aniso Tubule, Cell Mechanosensing-2, JAXA PCG, Plant Gravity Sensing-2, Resist Tubule, Zebrafish Muscle experiments) with one experiment for NASA (Micro-8 experiment).

In physical sciences Gerst will also perform research tasks for one JAXA experiment in materials sciences (Alloy Semiconductor), one NASA experiment in combustion physics (Burning and Suppression of Solids experiment), and three experiments in fluids research for NASA (Capillary Flow Experiment) and JAXA (Dynamic Surf, Soret-Facet)

↑ ESA astronaut Luca Parmitano (left) undertaking an ultrasound eye scan in ESA's Columbus laboratory on the ISS for NASA's Ocular Health protocol assisted by NASA astronaut Chris Cassidy

Finally technology and education research will take up a part of Alexander's time with projects for NASA (Crew Earth Observations, ISS HAM Radio, IVA clothing study, SPHERES) and JAXA (Super-Sensitive High Definition TV).

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