number 144 | November 2010

esa

bulletin

→ space for europe

European Space Agency

The European Space Agency was formed out of, and took over the rights and obligations of, the two earlier European space organisations – the European Space Research Organisation (ESRO) and the European Launcher Development Organisation (ELDO). The Member States are Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom. Canada is a Cooperating State.

In the words of its Convention: the purpose of the Agency shall be to provide for and to promote, for exclusively peaceful purposes, cooperation among European States in space research and technology and their space applications, with a view to their being used for scientific purposes and for operational space applications systems:

- by elaborating and implementing a long-term European space policy, by recommending space objectives to the Member States, and by concerting the policies of the Member States with respect to other national and international organisations and institutions;
- by elaborating and implementing activities and programmes in the space field;
- by coordinating the European space programme and national programmes, and by integrating the latter progressively and as completely as possible into the European space programme, in particular as regards the development of applications satellites;
- by elaborating and implementing the industrial policy appropriate to its programme and by recommending a coherent industrial policy to the Member States.

The Agency is directed by a Council composed of representatives of the Member States. The Director General is the chief executive of the Agency and its legal representative.

The ESA headquarters are in Paris.

The major establishments of ESA are:

ESTEC, Noordwijk, Netherlands.

ESOC, Darmstadt, Germany.

ESRIN, Frascati, Italy.

ESAC, Madrid, Spain.

Chairman of the Council: D. Williams

Director General: J.-J. Dordain

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Paolo Nespoli during spacesuit fit and leak checks, in preparation for his MagISStra mission, at Star City, near Moscow, Russia (ESA - G. Rigon)

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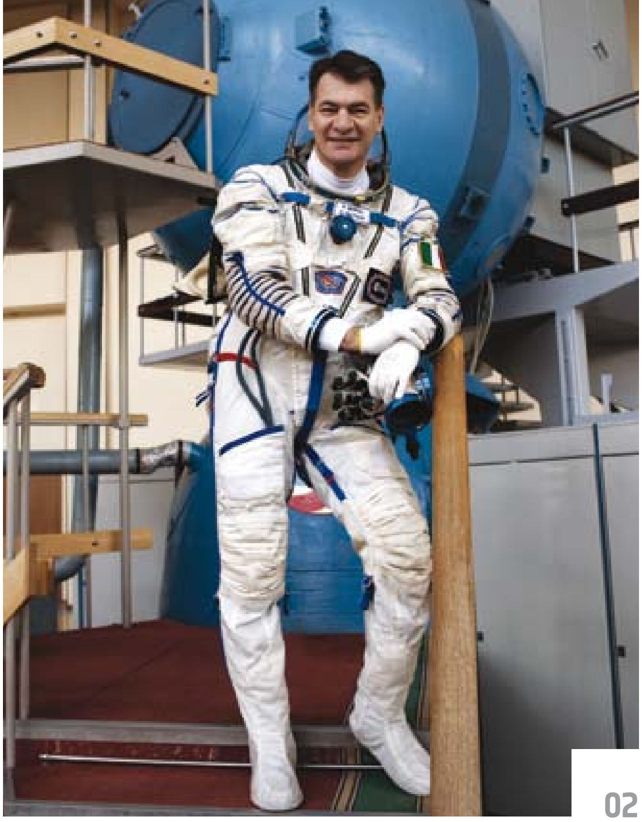

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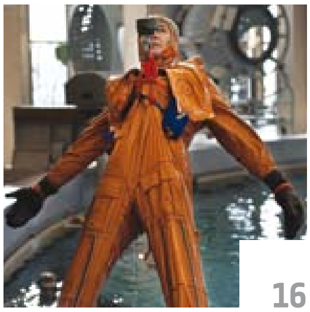

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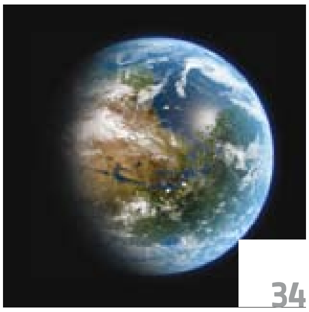

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Paolo Nespoli is Flight Engineer 1 on the Soyuz TMA-20 'MagISStra' flight to the ISS (ESA - G. Rigon)

→ MASTER OF SCIENCE

Paolo Nespoli's 'MagISStra' mission

Maurizio Nati
Directorate of Human Spaceflight, ESTEC, Noordwijk, The Netherlands

Another ESA mission to the International Space Station (ISS) is approaching. Codenamed 'MagISStra', this flight will see Italian astronaut Paolo Nespoli fly on Soyuz TMA-20 for a six-month stay on the ISS.

The launch is scheduled to take place in December from the Baikonur Cosmodrome in Kazakhstan. Two days later, Paolo's Soyuz capsule will dock with the ISS, where he and his crewmates, Russian cosmonaut Dmitri Kondratyev and NASA astronaut Catherine (Cady) Coleman, will join the other members of Expedition 26 already on board.

Paolo will be the first Italian and the third European astronaut to take part in a long-duration mission on the ISS, following the Astrolab mission of Thomas Reiter, from Germany, in 2006, and the OasISS mission of Frank De Winne, from Belgium, in 2009.

This will be Paolo's second time in space: he flew to the ISS on the Space Shuttle in 2007, on an Italian space agency flight opportunity, to deliver and install the Node-2 module, a major building block essential for expansion of the ISS.

→ MagISStra mission

Paolo's mission has been named 'MagISStra', combining the Latin word Magistra for a female teacher, with the acronym ISS. From the Latin word Magister, a male teacher, comes the English 'master', meaning also expert, proficient, or fully in control. This name was chosen to underline the very high level of competence required to undertake such missions, and the special link this mission will have with the activities of the ESA Human Spaceflight's education programme, in particular the 'Mission X: Train like an astronaut' educational project to explain to primary school children, through the example of astronauts, the importance of healthy and active lifestyles.

The chosen name was proposed by Mrs Antonella Pezzani, from Italy, and she described the motivation for her idea: "Teachers are the first to guide us in the discovery of science and technology, which, combined with the courage of astronauts like Paolo Nespoli, enable humans to achieve extraordinary undertakings such as the conquering of space and living on the International Space Station."

The logo for the MagISStra mission shows how the human presence in space benefits people on Earth. A human figure dominates the scene, embracing the three elements around which the mission revolves: science, technology and education.

This figure, representing the astronaut himself, projects from the International Space Station (ISS) to the planet in a sense of sharing, of bringing back applications to Earth, symbolised by three icons between the arms: a plant as scientific research, mechanical gears as technological development and a book as knowledge.

Paolo was a Mission Specialist on STS-120, and his mission was called 'Esperia' (after *Hesperia*, an ancient name for Italy). Qualified as the Intravehicular Activity specialist, he coordinated from inside the ISS a series of critical and unplanned spacewalks, which became necessary to repair one of the four solar arrays providing power to the ISS. On his next mission, Paolo will be a space veteran, able to capitalise on his previous experience to exploit the research capabilities of the ISS and, in particular, Europe's Columbus laboratory.

The ISS emerges from its acronym in the mission name and a sunrise seen over the crescent Earth conveys optimism about the extension of the ISS operational life to 2020. The text on the left, 'ISS/E3-3D/NESPOLI' contains the code for how the mission is identified within the Multilateral Crew Operations Panel, the top-level forum for coordination and resolution of crew matters. E3 stands for the third long-duration European mission in space, and 3D refers to the ESA-developed 3D camera that Nespoli will use to show unprecedented views of the orbital complex.

The six stars represent the six crew, the six months that Nespoli will stay in space and also the European character (recalling the stars on the EU flag). The white background symbolises the ingenuity of the human being and the willingness to learn more and search for new discoveries with an open mind.

After living and working on the ISS for the planned duration of 154 days, spanning both Expeditions 26 and 27, Paolo and his crew will return to their Soyuz capsule for undocking from the ISS on 16 May 2011. The closure of the Soyuz hatch will signal the end of Expedition 27 and the astronauts will land back on Earth a few hours later.

> **Each of these missions is a remarkable team achievement involving coordination between ESA's Directorates of Human Spaceflight, Operations and Infrastructure, ESA's corporate services and European industry, in cooperation with the ISS international partners.**

← Left: Expedition 26 is Oleg Skripochka, Alexander Kaleri, Dmitri Kondratyev, Paolo Nespoli, Catherine Coleman and Scott Kelly. Right: Expedition 27 is Ron Garan, Paolo Nespoli, Alexander Samokutyayev, Cady Coleman, Andrei Borisenko and Dmitri Kondratyev

Paolo uses a communication system on the flight deck of Space Shuttle *Discovery* during his Esperia mission in 2007

Mission activities

During the 154 days, the crew members will carry out the experiment programme, maintain and enhance both system and payload elements, receive visiting vehicles, handle the supplies delivered and carry out logistics operations. Two Russian spacewalks, called EVA Orlan R-27 and R-28, the sequential number in the ISS's operations schedule, will be performed in February 2011 by cosmonauts Oleg Skripochka and Dmitri Kondratyev. They will install Russian scientific equipment outside the Zvezda service module and launch a satellite placed in an old Orlan spacesuit, while Alexander Kaleri supports them from inside the ISS.

With the upcoming Space Shuttle retirement, now planned in Spring/Summer 2011, certain logistic operations will become increasingly difficult or impossible. For example, refilling the oxygen tanks dedicated to the NASA Extravehicular Activities (EVAs), or spacewalks. NASA has therefore decided to reduce the number of EVAs to safeguard the oxygen available, if it is needed in the event of an emergency or 'non-nominal' situation. If the latter occurs, then United States On-orbit Segment (USOS) crewmembers on the ISS are trained to operate outside the ISS.

Paolo has been trained for USOS EVA operations and is assigned as EVA Specialist 2 (EV-2). This means that, if needed, Paolo would work outside the ISS with his NASA crewmate who has the EV-1 function (Scott Kelly in Expedition 26 or Ron Garan in Expedition 27).

Paolo is the first European astronaut to go through the full Single-Flow-To-Launch (SFTL) process. In the SFTL, each crew acts as the backup for the crew assigned to the mission

→ The crew

Dmitri Kondratyev

Commander

Colonel, Russian Air Force

Graduating as a pilot-engineer from the Kachinsk Air Force Pilot School in 1990, he served as a pilot and subsequently as a senior pilot, flying Russian MiG-21, MiG-29 and Su-27 jet fighter aircraft.

He is also a Parachute Training Instructor and has made over 150 parachute jumps. In 2000, he graduated from the Moscow State University for Economy, Statistics and Computer Science as an economist. He is also a graduate of the Yuri A. Gagarin Air Force Academy.

Although he has no previous spaceflight experience, Kondratyev has twice served on back-up crews for missions to the ISS.

→

Paolo has been trained for EVA or ‘spacewalking’ operations on the US sections of the ISS, and is assigned as EVA Specialist 2 (EV-2)

Paolo Nespoli

Flight Engineer 1 (FE1)
Major (Reserve), Italian Army

Catherine Coleman

Flight Engineer 2 (FE2)
Colonel, US Air Force (retired)

A Special Forces operator (9th Battaglione d’Assalto Incursori ‘Col Moschin’, Brigata Paracadutisti ‘Folgore’), Paolo was assigned to the Italian contingent of the multinational peacekeeping force in Beirut. He is a master parachutist, parachute instructor, jumpmaster, high-altitude/low-opening parachute expert. He is a private pilot with instrument rating, and an advanced scuba and Nitrox diver.

He has a Bachelor of Science in Aerospace Engineering and a Master of Science in Aeronautics and Astronautics from the Polytechnic University of New York, 1989. In 1990, he was awarded the Laurea in Ingegneria Meccanica by the Università degli Studi di Firenze, Italy. He flew to the ISS on the Space Shuttle STS-120 mission in November 2007, spending just over 15 days space.

Having received a PhD in polymer science from the University of Massachusetts, Catherine (‘Cady’) Coleman is a veteran mission specialist of two Space Shuttle flights: the STS-73, the USML-1 scientific mission with experiments including biotechnology, combustion science and fluid physics, and STS-93, where she was in charge of placing the Chandra X-ray observatory in orbit using the Shuttle’s robotic arm. She has spent 21 days in space.

↑ As an EVA specialist, a fully suited Paolo Nespoli is seen here training on ISS airlock procedures in Houston

flying six months earlier. This process has been progressively adopted since the introduction of the six-person crew, to increase the overall operations efficiency. The Expedition 26/27 crew acted as backup to the Expedition 24/25 crew, who flew to the ISS in June 2010. In turn, Paolo's crew is backed up by the Expedition 28/29 crew, who will fly to the ISS in June 2011.

SFTL optimises the crew training for the mission where they are prime crew, by capitalising on the training they completed as backup. Furthermore, this approach secures that each backup crew is also automatically assigned to their own mission, keeping their motivation very high from assignment to launch.

ESA has another 'premiere' with Paolo's mission: he is the first European astronaut in the Direct-Return-to-Houston process, initiated by NASA with Expedition 22/23. This process brings the USOS astronauts directly back to Houston from Baikonur after being rescued from their landing site, instead of remaining for two to three weeks at the Gagarin Cosmonaut Training Centre (GCTC) at Star City, near Moscow, for post-flight activities such as rehabilitation or post-flight body data collection.

Since the Columbus laboratory became part of the ISS in 2008, ESA is fully participating in ISS activities by supporting both the continuous flow of increment preparation and round-the-clock daily operations. Although no two ISS expeditions are alike, ground operators can now regard such operations as 'routine'.

Mission-specific activities add to these 'routine' preparations and operations every time an ESA astronaut is part of a long-duration mission. Some of these mission-specific activities are dedicated personally to the astronaut, focused specifically on their mission, such as training, medical operations, crew support activities and communications. However, considering the high visibility of any ESA

↑ The Soyuz TMA-20 crew, seen here in the Soyuz trainer at Star City, with Paolo in the left Flight Engineer seat (ESA - G. Rigon)

astronaut when they are assigned to a mission, even the 'routine' operations take on a special flavour, and more attention is given to virtually every aspect of the mission. This is particularly true for the experiment and education programmes: all facets of the entire increment preparation and execution process become crucial.

Nespoli's tasks

Paolo was assigned to his mission in November 2008. His training has taken him from Houston, to Cologne, to Star City near Moscow and to Tsukuba in Japan. He has had to train on ISS systems, the Soyuz launch and reentry vehicle, USOS Extravehicular Activity, Automated Transfer Vehicle (ATV) and HII-Transfer Vehicle (HTV) operations, and all the European, NASA and Japanese system and experiment operations.

Paolo is assigned to fly in the left seat of the three-seat Soyuz capsule, a seat traditionally assigned to European astronauts serving as Flight Engineer 1. In this Soyuz pilot role, he will assist the Dmitri Kondratyev, the Soyuz Commander, during both the ascent and descent phases.

As Flight Engineer on the ISS, Paolo has several assignments, ranging from system aspects to payload operations. Paolo has the task of 'USOS Segment Lead', meaning he is the USOS crewmember reporting to the Russian Commander, in particular in case of contingency scenarios for Expedition 27. Paolo's training has also included emergency and contingency procedures, things that are not planned in normal circumstances, such as treating a medical emergency with any of his crewmates (he is the Crew Medical Officer), or even piloting an emergency landing of the Soyuz.

Paolo is the prime operator for the rendezvous and docking operations of ESA's second ATV. ATV is a cargo craft designed to deliver over seven tonnes of experiments, fuel, water, food and other supplies from Earth to the ISS. While docked, ATV can use its thrusters to periodically boost the ISS orbit (which decays with time), and it can also be used for debris-avoidance manoeuvres. This capability saves the onboard attitude control propellant of the ISS. After about three and a half months, ATV will undock from the station and burn up harmlessly in the atmosphere over an uninhabited area of the Pacific Ocean.

When ATV *Johannes Kepler* is docked with the ISS, Paolo is in charge of logistics operations on the vehicle, for example ingress and egress, system monitoring and commanding, etc.). Paolo will enter the pressurised environment of *Johannes Kepler* and carry out the required outfitting operations inside, including preparing the ATV for undocking from the ISS. ATV *Johannes Kepler* will also accommodate two mini-satellites from the US Department of Defense inside its cargo bay. These satellites will be activated one week before undocking and will autonomously collect and download data during their own reentry after separation from the ATV.

Paolo will also be the prime operator for berthing other visiting vehicles, once they have been captured by his crewmate Cady Coleman using the large Canadian robotic arm (Canadarm-2). Paolo will assist as second operator for this task. The first of these vehicles will be the second Japanese cargo HII-Transfer Vehicle (HTV-2), an unmanned spacecraft used to resupply the Japanese Kibo laboratory on the ISS.

HTV-2 is currently planned for launch on 20 January 2011. It will be berthed to the ISS on 27 January and remain there until 24 February.

Visitors

Expeditions 26 and 27 will see intense traffic during their time on board. Besides the ATV *Johannes Kepler* and the Japanese HTV-2, another ESA astronaut, the Italian Roberto Vittori, will visit the ISS on the STS-134 mission. He flies as part of the crew on the last flight of the Space Shuttle *Endeavour*, on a flight opportunity provided by the Italian space agency.

STS-134 (ULF-6) is targeted for launch in February and will carry the Alpha Magnetic Spectrometer to the ISS, a state-of-the-art cosmic ray particle physics detector,

→ ESA astronaut Roberto Vittori, in training for his STS-134 mission, will join Paolo in February

designed to examine fundamental properties of matter and the origin of the Universe. The duration of this Shuttle mission will be around 12 days, during which the crewmembers will also perform three spacewalks.

In March, the Russian Soyuz TMA-21 (26S) will carry the Expedition 27/28 crew (Andrei Borisenko, Ron Garan and Alexander Samokutayev) to the ISS, while the unmanned Russian Progress cargo vehicles 41P and 42P will carry supplies to the ISS.

Utilisation

The ISS has many more years of use ahead – at least until 2020 – and Paolo will contribute to the scientific utilisation of Europe's Columbus laboratory. From December 2010 to May 2011, he will carry out an intensive programme of experiments. With more than 30 experiments planned during his mission, to be accommodated both inside and outside the ISS, his programme will include research in many different fields, such as human physiology, fluid physics, radiation, biology and technology demonstrations.

“European space science is driven by the quest to improve life on our planet.”

↑ Paolo will be responsible for berthing the second Japanese cargo HII-Transfer Vehicle (HTV-2) – here HTV-1 is seen nearing the ISS in 2009

Paolo has been trained on all facility racks develouped by ESA and accomodated in the Columbus laboratory: Biolab, European Drawer Rack (EDR), European Physiology Modules (EPM) including the Portable Pulmonary Function System (PPFS), Fluid Science Laboratory (FSL) and the Microgravity Science Glovebox (MSG). He also trained on ESA experiment modules integrated in NASA racks: the Materials Science Laboratory (MSL), the European Modular Cultivation System (EMCS), which were developed by ESA taken up to the ISS before Columbus was launched. He will be test subject for the 3D-Space, Passages, Neurospat and CARD experiments. He also received specific training on maintaining Biolab and EPM and will perform the on-orbit commissioning of the new ESA MARES rack (Muscle Atrophy Research and Exercise System).

Paolo will be test subject for various human physiology experiments covering neuroscience, cardiovascular, metabolism and fitness evaluation research. He will operate, and in some cases be the test subject of, experiments designed to test how astronauts interpret visual information in weightlessness and how this affects their perception (3D-Space). Measuring different parameters, ground-based European scientists will also study space data about how weightlessness changes the circulatory system (CARD, Vascular), bone metabolism (Pro K, Nutrition) and even brain functions such as memorisation or decision-making during a prolonged stay in weightlessness (Neurospat, PVT).

The physical sciences experiments include studying the diffusion phenomena in complex fluids in order to understand the properties of oil fields and possibly improve oil recovery techniques in petroleum reservoirs (SODI-DSC). A simulation of geophysical fluid flow under microgravity will help scientists to understand better the

↑ Paolo will also have the chance to 'shake hands' with Robonaut, the new NASA robotic crewmate, conceived to be used inside the ISS or on other space exploration initiatives, seen here during training in Houston

global-scale flow in the atmosphere, the oceans, and in the liquid nucleus of planets, enlightening some aspects of Earth's magma convection modelling (GEOFLOW2).

Interactions between ionising radiation and brain functions are among the major concerns when planning a long stay in space. The light flashes observed in space – first reported by the crew of the Apollo 11 mission in 1969 – are an example of such interactions. ALTEA-Shield is a multi-disciplinary research project aimed at getting a better understanding of the light flash phenomenon.

In the DOSIS experiment, Paolo will measure the nature and distribution of the radiation field inside the spacecraft, and the Sun's irradiation will be studied with unprecedented accuracy from the European Columbus laboratory.

He will also be the main operator for complex biological experiments, addressing specific issues, such as the immune response in plants during growth in microgravity. In particular, he will observe the effects of centrifugal acceleration on lentil seedling roots in the GRAVI-2 experiment.

Paolo will not only carry out experiments for ESA, but also several for NASA, JAXA and the Canadian Space Agency. Samples of his hair will be collected to study the gene expression in a human body exposed to a long-duration spaceflight (HAIR) and advanced technology will monitor his sleep patterns to treat insomnia on Earth (Sleep). Studying flame behaviour and combustion experiments are also among his tasks, as well as the study of a very resilient and lightweight material when stretched into very thin fibres in microgravity.

The Vessel Identification System is testing a new way to track global maritime traffic from space, by picking up signals from large ships and all types of passenger vessels. Paolo will help with the assembly of a new mechanism to demonstrate the space-based capability for identifying international shipping.

↑ The ESA ERB-2 stereoscopic camera

A mission with stereoscopic view

Paolo will open a new window onto the ISS using the stereoscopic eyes of a novel ESA-developed, high-definition 3D video camera – the Erasmus Recording Binocular 2 (ERB-2). The ERB-2 camera will provide a vastly improved 3D video result for mapping the ISS, with 3D images that will change our whole viewing experience and can be used in supporting ISS science operations.

These stereoscopic views will be used both to take better pictures of the experiments and as a tool to support communication activities. They will offer unprecedented views of the ISS, including details of the Columbus scientific racks and external large items, to give experts on Earth a very accurate impression of life on the ISS. Trainers will also use these images as a tool for future astronaut training. Paolo will also take other 3D pictures and short movies with a smaller, handy, easy-to-operate camera, certified by ESA for use in space.

Keeping in touch with kids

Students around the world will have the chance to ask the crew questions about life in space and other space-related topics by using amateur radio ground stations. They will be able to talk directly with the crew for roughly 10 minutes at a time, the duration of an ISS overhead pass. The two-way voice contact is conducted by crewmembers who are licensed amateur radio operators, by using the ISS Ham Radio transceiver installed in Columbus.

Lessons from space are ready to be organised on different topics, depending on the time and resources available, and also on scientific activities, EVA schedules and the setting up of video educational demonstrations using hardware already on the ISS.

One of the possible solutions to survive-long duration space missions could be to enable the astronauts to produce fresh food and become partially self-sufficient. There will be a need to develop special greenhouses on travelling spacecraft, orbiting stations or the newly explored planet's surface itself.

As part of his educational activities, Paolo will grow flowering small edible plants (lettuce and *Arabidopsis thaliana*) inside a small greenhouse, the Education Payload Operation (EPO) Greenhouse, accommodated in the Columbus aisle. He will follow their evolution over a two-month period. The seeding will be followed live by children aged 12 to 14, who will also be invited to start the Greenhouse in Space activity at the same time. Students on ground will make observations of their activity and compare the results with Paolo's space experiment, by means of both recorded and live-link activities for educational events.

Ambassadors and role models

Many current astronauts will say that becoming an astronaut was their childhood dream, inspired by their predecessors when they watched on TV the spaceflight pioneers orbiting Earth or landing on the Moon. Flying into space has been the dream of humankind since ancient times, as we can see in the literature and art of many cultures. Such dreams became a reality almost 50 years ago, with an enormous impact on the entire human race, and capturing imaginations in the latter half of the 20th century.

↑ Mission X is an educational programme developed by ESA with several space agencies and institutions (currently from Italy, Spain, France, the Netherlands, Germany, Austria, Norway, UK and USA, with NASA as a coordinator), plus Belgium, Czech Republic, Russia and Japan as observers

↑ At Star City, Moscow, Paolo enjoys swimming to keep fit. The example set by astronauts is being used to promote regular exercise and healthy nutrition among young people in 'Mission X – Train like an astronaut' (ESA - G. Rigon)

Astronauts in particular have been rightfully perceived as having a unique blend of qualities required to accomplish highly complex and often physically demanding missions. They have high levels of education, fitness and determination; they follow healthy and active lifestyles, they have practical as well as human skills and a sense of team spirit, to mention only a few.

These qualities make them perfect ambassadors and role models for conveying important and positive messages to youngsters, making young people dream and proving that dreams can become a reality. Messages such as commitment to studying, remaining healthy, the importance of proper nutrition and keeping fit, are made even more credible when transmitted to future generations by heroes who live and train accordingly in order to achieve their objectives.

Now ESA is using this example set by astronauts to promote regular exercise and healthy nutrition among young people around the world.

One of Paolo's responsibilities during his long stay is to be ambassador of 'Mission X – Train like an astronaut'. An educational programme aimed at primary schools, Mission X is encouraging physical activity and healthier diets for pupils. Children can perform a number of physical exercises and classroom lessons, competing with teams from around the world to become as fit as an astronaut.

But Paolo will not only inspire school children while on board the ISS, he will be 'ambassador' of spaceflight for all humankind. He is scheduled to participate in a wide range of public relations activities, including making in-flight calls with key stakeholders and decision makers on the ground.

Astronaut health and wellbeing

While promoting healthy lifestyles to us on the ground, Paolo and his crewmates also need to stay fit while they are in space. ESA Medical Operations is providing clinical and operational medical support to the ESA ISS Programme for both ESA astronauts and the mission crew.

With an ESA astronaut on the ISS and the docked operations of ATV-2, the extra tasks add to those of a generic expedition. Overall medical operations support requires a minimum of 2.5 years to complete the activities. This time includes launch and landing medical support, medical testing for flight certification, in-flight healthcare and post-mission rehabilitation and return-to-flight duties.

A team of ESA specialists, including surgeons, biomedical engineers, exercise, rehabilitation, psychology and environmental control specialists, is supporting each ESA mission crew's health and wellbeing, as well as monitoring the environmental integrity of the ESA modules during different mission phases.

As part of the astronaut wellbeing, ESA also has a Crew Support Programme that takes care both of the astronaut's personal matters and of their family during the time they are assigned to a mission, including training, the time they are in space and on their return, up to the end of their mission duties.

As an example of crew support, personal items of the astronaut, including a very limited amount of food of their own choice, can be made be available on the ISS when they are needed, provided they meet the applicable safety requirements. Communication tools are available to ensure regular communication with the astronaut's family and medical operators on the ground.

↑ Paolo and his crewmates pay tribute to Yuri Gagarin during a visit to their launch site in Baikonur, Kazakhstan

Special celebrations

Last but not least, two events will be celebrated on board during Paolo's stay that will be special for him, both as an astronaut and also as an Italian citizen. On 20 April 2011 falls the 50th anniversary of Yuri Gagarin's first orbital flight, an event that marked the start of the human spaceflight era. 2011 will also be the 150th anniversary of Italy's unification as a modern European state.

Now that the mission is approaching and the final round of training simulations are being made, closing in on the real flight operations, all the participants are looking forward to a successful mission. Another flight that will be inspirational to new generations, it will underline again the value of the ISS as a unique research laboratory.

It will confirm the value of European astronauts in monitoring and operating the ISS, and preparing the steps for more ambitious missions. Each of these flights brings us closer to future space exploration and expands our knowledge of the Universe. ■

Acknowledgments

- Stressing again the tremendous team effort required to prepare and execute any astronaut mission, the author would like to mention, as a sign of recognition, all the functions and individuals who are contributing to the mission preparation and soon will be active in the mission implementation. The list of people is so long that, unfortunately, it cannot be published here in the limited space of this article, which has only been made possible thanks to their achievement and inputs.

Paolo leaves the Soyuz simulator at Star City, near Moscow

→ PAOLO'S TRAINING FOR SPACE

Astronaut training is one of the most challenging parts of Human Spaceflight programme to organise. If you consider that 30 to 40 astronauts and cosmonauts undergo training at five different sites each year, you realise that this calls for a tremendous organisational effort.

You have to coordinate the content of the international training sessions and the different teaching approaches, as well as bear in mind the multicultural backgrounds of the astronaut trainees and their instructors.

All this has to fit into one overall training schedule, which is a challenge of its own – remember that all astronauts and cosmonauts have individually tailored training plans, meaning that no two astronauts have exactly the same training at the same time.

The ISS partner space agencies have managed this training successfully now for almost 10 years. So what do the astronauts have to go through to qualify for a flight to the International Space Station?

← The full Extravehicular Activity (EVA or spacewalk) training for the ISS is traditionally done in the giant pool of NASA's Neutral Buoyancy Laboratory, Houston. Here Paolo gets into a training version of his 'Extravehicular Mobility Unit', his white spacesuit worn during spacewalks which is like a personal 'mini-spacecraft'

↑ Paolo taking part in suit pressure leak checks and Soyuz seat fit checks at Star City

↖ Paolo and Catherine Coleman practice docking procedures in the Soyuz at Star City

↖ Paolo and Catherine Coleman in routine operations training in the Space Vehicle Mock-up Facility, Houston

← Multi-segment training, carried out at the Space Vehicle Mock-up Facility at NASA's Johnson Space Center, in Houston, USA. This is a replica of the whole ISS in which the astronauts can train for emergency situations affecting the whole Station

After around 16-18 months Basic Training at EAC, ESA's astronauts go on to ISS Advanced Training. This takes around one year to complete, conducted in international astronaut classes and including sessions at all ISS partner training sites. The astronauts learn to service and operate the different modules, systems and subsystems. They learn how to fly and dock spacecraft, such as the Russian Soyuz or ESA's Automated Transfer Vehicle (ATV).

Only when an astronaut completes this phase of training are they eligible for assignment to a mission. They then begin Increment-specific Training, which includes dealing with problem situations and learning how to run the experiments scheduled for their mission.

In November 2008, Paolo Nespoli was assigned to Expedition 26/27 and started his ISS Increment training in Russia and USA straight away. Since then, he has been travelling between each training centre, gradually honing his skills for several weeks at a time, either in Houston, Star City near Moscow, Tsukuba near Tokyo, Montreal in Canada or at the European Astronaut Centre (EAC) in Cologne, Germany.

↑ Paolo in the centrifuge at Star City, used for
→ simulating the g-forces due to acceleration during launch and landing

← Wearing an orange water survival suit, Paolo is hoisted from his liferaft as he would be by helicopter if his spacecraft had to splashdown in the ocean (ESA - G. Rigon)

↓ Paolo and his Soyuz Commander, Dmitri Kondratyev, during emergency water landing practice at Star City (ESA - G. Rigon)

↑

Proba-2 in orbit

→ BIG YEAR FOR SMALL SATELLITE

ESA's second in-orbit technology demonstration mission: Proba-2

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Less than a cubic metre in volume, Proba-2 is one of the smallest missions ever flown by ESA. But judged by performance per kilogram, Proba-2 can also claim to be among the most scientifically and technically productive.

Proba-2 stands for Project for On-Board Autonomy-2 and, following in the footsteps of Proba-1, its successful first year in orbit has confirmed that a microsatellite can provide the required performance for challenging missions.

This 120 kg microsatellite is the second mission in ESA's In-Orbit Demonstration (IOD) series, part of ESA's General Support Technology Programme. Proba missions offer a low-cost opportunity to prove new space technologies, equipment and techniques in the actual space environment. They also provide verification of novel operational concepts such as spacecraft autonomy, ground segment autonomy and experimental attitude control algorithms, as well as previously untried Earth observing techniques or formation flying methods.

Proba-2 has shown specifically that a small mission can combine technology demonstration with new and advanced small payloads delivering science data to users. It proved that a mission and system design which uses embedded onboard autonomy and an automated ground segment can allow reactive missions with high flexibility and fast response time; that advanced development methods (such as code generation) are cost-efficient and robust; and that an attitude control system based only on an autonomous star tracker is sufficient for the pointing and stability needs of science and Earth observation missions.

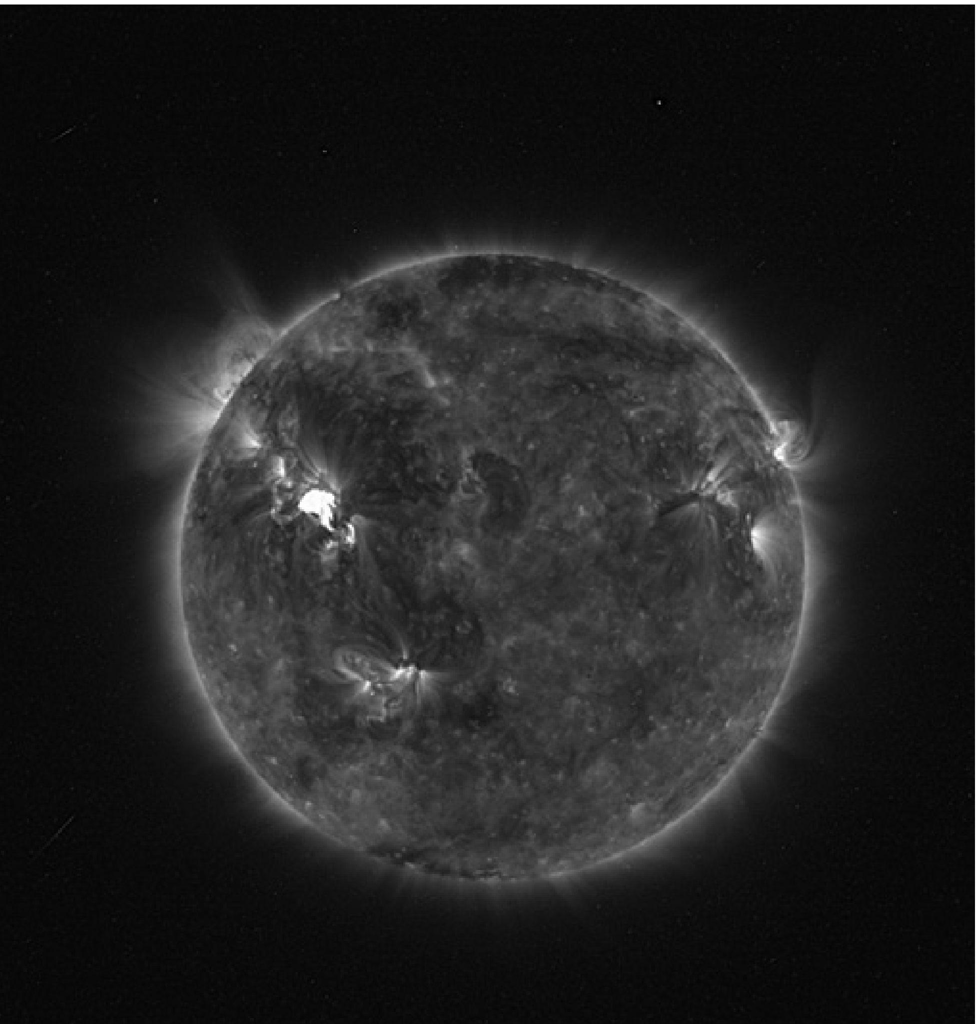
Proba-2 also hosts seventeen technology demonstrators – some of which form part of the platform and system baseline design, others being 'guest' payloads – as well as set of compact scientific instruments, monitoring the Sun and Earth's orbital plasma environment.

The mission is currently in its nominal two-year operational phase. If a picture is worth a thousand words then the spectacular ultraviolet images of the Sun routinely returned by Proba-2 speak volumes on the excellent performances of the platform and its solar imaging instrument.

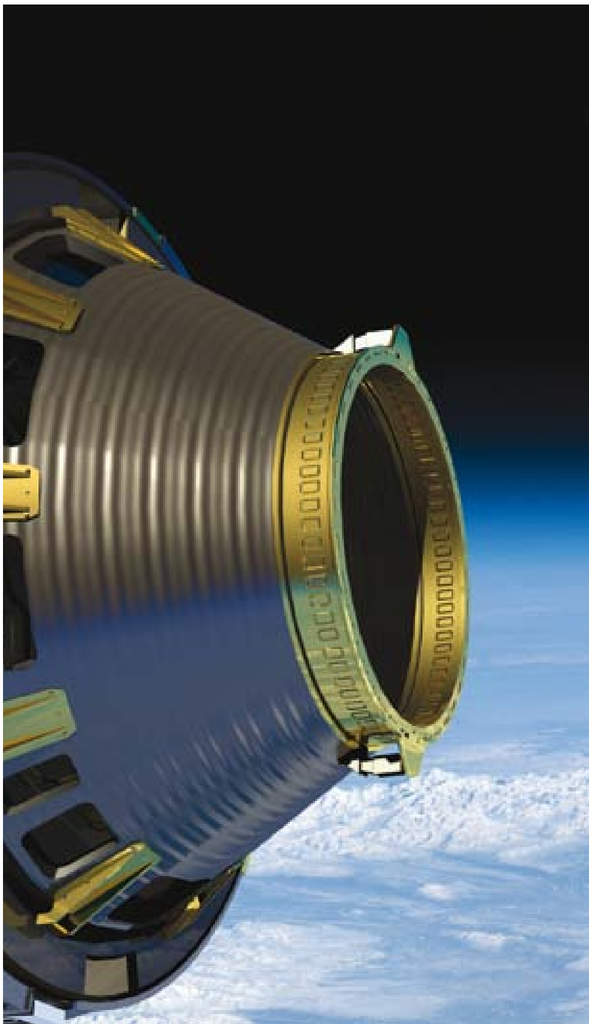
The spacecraft and its technology demonstrators are operated from ESA's Redu ground station in Belgium, with science operations conducted by the Royal Observatory of Belgium (ROB). Overall mission and science planning is co-ordinated and managed by ESA's Directorate of Scientific and Robotic Exploration.

Mission and spacecraft summary

Proba-2 was launched from Plesetsk Cosmodrome in northern Russia on 2 November 2009, sharing its Rockot launcher with ESA's larger SMOS satellite. Proba-2 separated from the rocket's upper stage to be placed in a circular orbit at an altitude of 730 km.



↑ One of the spectacular ultraviolet images of the Sun routinely returned by Proba-2



Because its two largest scientific payloads require continuous observation of the Sun, the orbit was selected to be 'solar eclipse-free' for most of the year, with a limited eclipse season between the middle of November and the end of January.

Within an overall size of 65 x 65 x 85 cm, the Proba-2 platform has full redundancy while also including a suite of technology demonstrators and various innovative aspects. Its structure comprises a combination of aluminium and carbon-fibre reinforced plastic (CFRP) honeycomb panels.

Triple junction gallium arsenide solar cells (mounted onto one body panel and across two deployable panels) can supply 120 W end-of-life (EOL) peak power. A battery-regulated, centrally switched 28 V bus distributes this power to all platform units and instruments, while a new type of lithium-ion battery provides 16.5 Ah of energy storage. Proba-2's S-band telecommunication subsystem is based on a redundant set of receivers, transmitters and omnidirectional coverage.

Proba-2's platform and instrument management and control, data handling and processing and power management and distribution functions are combined in the platform's Advanced Data and Power Management System (ADPMS) computer based on ESA's standard radiation-tolerant processor, the LEON2-FT.

The satellite's onboard software provides a high level of autonomy. Proba-2 is capable of handling all its routine operations, only interacting with the ground station to downlink science data and obtain new observation requests. Its software can compress, process and prioritise images of interest, automatically adjusting spacecraft attitude as required.

In addition, a large quantity of potential onboard anomalies can be handled if needed without ground intervention, because of Proba-2's integrated Failure Detection, Isolation and Recovery (FDIR) capabilities.

↑ Artist impression of Proba-2 leaving the Rockot launcher adapter after reaching orbit in 2009

Autonomous navigation, guidance and control functions

Proba-2's Attitude, Control and Navigation Subsystem (ACNS) hardware is based on four reaction wheels, two magnetometers, a redundant miniaturised µ-ASC star tracker with two hot-redundant camera heads to improve measurement accuracy, a cold-redundant GPS receiver and internally redundant magneto-torquers.

The satellite's main ACNS guidance law is known as 'Sun mode', and used routinely during operations for the SWAP and LYRA payloads' nominal pointing. The payload stays pointed at the Sun while the satellite performs four rotations of 90° around the payload's line of sight per orbit (avoiding the star trackers being blinded by Earth).

Proba-2's ACNS capabilities are not only limited to the Sun-pointing mode, but also support most of the pointing modes required by any Earth observation or science mission (such as 'inertial', 'Earth target point and stare', etc.)

Besides the nominal Sun-pointing mode, the satellite can be put in a stand-by mode that only uses a limited set of ACNS units, is simpler to control and guarantees stable incoming power and coverage of Earth. As in the case of Proba-1, this mode is based on the 'Bdot algorithm', a tried and tested method that employs magnetometers to sense Earth's magnetosphere and magnetotorquers to control the satellite.

In addition, the ACNS software allows full onboard autonomous orbital and attitude navigation, and onboard time management and correlations, for autonomous predictions of all manoeuvres' execution times, and of all relevant Sun or Earth-related events (eclipse entry and exit times, node crossing and target flyby times).

It also allows estimation of environmental perturbation torques and remnant spacecraft magnetism for improved pointing. The control module is based on a state-feedback controller for fine control and on a sliding mode controller for large manoeuvres.

Developing such a complex ACNS system within such a small mission was only made feasible by high-level modelling tools and advanced autocoding techniques. These allowed very efficient generation and testing of the ACNS software and integration and validation with the onboard software.

↑ Bigger than SMOS? From this perspective view, Proba-2 in the foreground seems bigger than its much larger cousin, the SMOS satellite, seen mounted on its launcher adapter (Proba-2 fits inside this structure)

Project organisation and development flow

Small low-cost missions offer access to space to smaller companies, providing them with the essential experience for European industry to stay competitive and innovative. The Proba-2 industrial consortium therefore mainly consisted of small and medium-sized enterprises from ten European countries and Canada.

Belgium-based prime contractor QinetiQ Space (formerly Verhaert) had broad responsibility for mission and spacecraft design, platform development and manufacturing and platform technologies selection (such as batteries, reaction wheels, star tracker, solar cells, on-board computer). They also conduct the integration, assembly, integration and testing of the complete spacecraft and overall system-level testing, ground segment development, as well as the Launch and Early Orbit Phase, commissioning phase and operational activities completion.

Proba-2 subcontractors included Spacebel (BE), developing the mission's onboard software as well as its System Verification Facility (SVF) and its ground segment, NGC Aerospace (CA) developing the ACNS algorithms and Dynacon (CA) developing the reaction wheels.

The solar panels came from Selex Galileo (IT), the CFRP structural elements were from APCO (CH), the batteries from SAFT (FR) and the star tracker was from DTU (DK).

As with Proba-1, an innovative approach was taken to the development and assembly, integration and verification of the satellite and ground segment, with the same system and tools being used incrementally for ground verification and system-level testing and for operations. This approach increased the cost efficiency, avoided duplication of development and validation activities and provided a more extensive validation coverage.

Software validation was performed across all project phases, using incremental versions of the flight software and SVF, including accurate models of the onboard computer and processor, as well as all platform units.

↑ Proba-2 in the cleanroom at Verhaert (now QinetiQ Space), in Belgium, just before shipping for launch

→ Laser-tagging Proba-2

Among its 17 technology payloads, Proba-2 carries two innovative GPS receivers: the Topstar 3000 (specifically developed by Thales under an ESA/CNES contract for Earth observation and telecom satellites) and the highly miniaturised Phoenix, developed by the German Aerospace Center (DLR).

Another advanced onboard technology provided the opportunity to assess performance of these receivers: Proba-2 has a laser retro-reflector (the Russian LRR) on its underside to support highly accurate laser ranging measurements.

In a dedicated campaign conducted by the International Laser Ranging Service, Proba-2 was tracked by 15 laser stations around the world for a two-week period in March and April. Some 2000 observation points were collected during 120 passes.

Using these results, it was demonstrated that GPS-based precise orbit determination processed on the ground achieved an accuracy of 0.5 m – smaller than the satellite itself. Even on board, a remarkable 1–2 m positioning accuracy could be achieved with advanced real-time navigation filters embedded into the GPS receivers. This was a major milestone in the art of spaceborne navigation, and has proven these technologies for future European missions.

The SVF was then extended into a complete system simulator, including interfaces with the ground operations system.

The SVF included a complete dynamic model of the orbital environment, incorporating perturbing forces and torques acting on the spacecraft, illumination conditions, sensor performance and attitude-dependent blinding, and so on, allowing mission performance to be realistically evaluated.

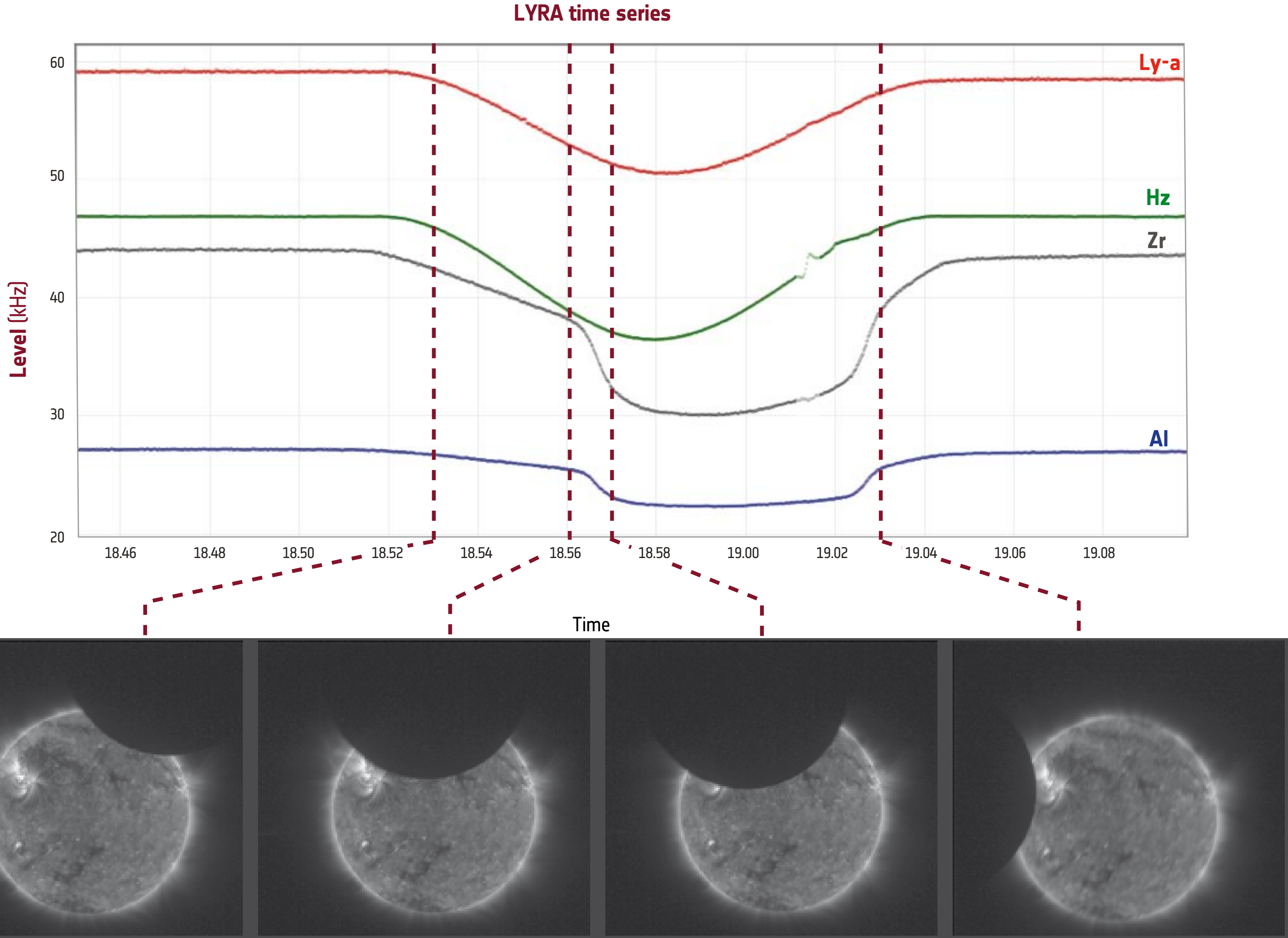
Compatibility of the hardware and of the whole system was verified using a mixture of simulator tests, 'hardware-in-the-loop' tests and system validation exercises. This development approach needed close collaboration between industry teams and the ESA project members across all levels and disciplines.

Scientific payload

SWAP

SWAP is a telescope for observing the solar corona in the extreme ultraviolet (EUV), corresponding to an emission temperature of around one million degrees. The instrument was developed and tested under the supervision of the Centre Spatial de Liège (BE) for the Royal Observatory of Belgium, and builds on the heritage of the Extreme-ultraviolet Imaging Telescope (EIT) on the ESA/NASA SOHO solar observatory.

Its development was driven by the accommodation on Proba-2, and it had strict limits on mass, power and size: it weighs 10 kg, it measures 570 x 150 x 110 mm in size and has a power consumption together with the LYRA instrument of 6 W.



↑ A set of images taken by the SWAP telescope and corresponding LYRA signals for one lunar transit of the solar disc at about 19.00 on 7 July 2010. The signal drops in the four wavelengths, and they are not always symmetric. During these transits in particular, the aluminium and zirconium channels (Al in blue, Zr in black) show a very asymmetric drop in signal. This is caused by the fact that these channels are sensitive to the shortest EUV wavelengths and thus highest temperature plasma. The active regions on the Sun radiate in these wavelengths. The steepest drop and rise in the Zr and Al signal is found when the one and only active region disappears and then reappears. The long-wavelength channels Lyman-alpha (Ly-a) and Herzberg (Hz) show the overall radiation of the 'quiet' Sun (more interesting for long-term variations). They show a symmetric drop at the times of lunar transits, directly related to the size of the solar disc area being obscured

SWAP demonstrated that it is possible to build a small reliable telescope for space weather monitoring with limited power and thermal requirements.

To save power, the detector is an Active Pixel Sensor (APS) detector – the first used for in-orbit solar physics – with special coatings enhancing its EUV sensitivity. To minimise SWAP's electronics, the mission's main ADPMS computer oversees onboard data processing including image compression, solar event detection and image prioritisation.

SWAP's scientific goal is to monitor all 'space weather' relevant phenomena in the solar corona, taking pictures at a rate of one image per minute, an order of magnitude faster than its EIT predecessor, and with a larger 54 arcmin field of view.

The spatial resolution of SWAP is complementary to the high temporal resolution of the LYRA instrument.

More than 130 000 images have been taken since launch until August 2010, and SWAP remains in excellent health. Although a compact instrument on a small platform, SWAP has demonstrated promising results when used for space weather forecasting activities.

It can be used for detection of CMEs and the study of weak, dim structures in the corona (such as dimming, coronal holes and so on). SWAP's higher rate of imaging also provides more dynamic information on birth of active regions, flares, prominences, jets, EIT-waves, off-limb eruptions and inflows.

↑ Artist's impression of Proba-2 fully operational in its final orbit

↑ The ESA Redu ground station

→ Highly automated ground segment

Proba-2's ground segment consists of three main elements: antenna ground stations, the Mission Operation Centre (MOC), including the Mission Data Server (MDS) and the Science Operation Centre (SOC).

Flight dynamics, operations planning and spacecraft operations are conducted from the MOC at Redu in Belgium, which also hosts one antenna ground station. A second station is at Svalbard in Norway, used to increase the satellite/ground contact time and to maximise scientific data return.

The MOC is designed to perform routine automated operations, including satellite pass prediction, pass activity scheduling, scientific request processing, spacecraft data collection and distribution. Operator intervention is only needed for 'off-nominal' activities, such as specific test requests for any of the technology demonstrators. The facilities at the MOC (such as ground antennas, pass planning system, web server) are shared between Proba-1 and Proba-2.

The SOC is hosted by the Royal Observatory of Belgium in Ukkel, near Brussels. Planning requests for the two main payloads (SWAP and LYRA) are sent from there to the MOC where they are automatically taken into account by the pass planning system. Scientific data from the spacecraft are automatically transferred to the SOC for further processing, allowing the flexible and fast interactions of solar specialists with their payloads.

→ In-orbit performances

Pointing accuracies	Position accuracy:	Power budget:	CPU usage:
Well within mission and payload requirements - End-to-end (SWAP instrument) measured Absolute Pointing Performances (APE): 87 arcsec (2σ). Requirement 100 arcsec (2σ) - Measured Relative Pointing Performances (RPE): 2 arcsec/5 s (2σ) and 5 arcsec/60 s (2σ).	Kinematic navigation solution (used for autonomous onboard navigation by the ACNS software): 2 m (position) and 5 cm/s (velocity) (3D rms) Real-time navigation filter (embarked as technology demonstration item): 1 m (position) and 4 mm/s (velocity) (3D rms).	Demonstrated sufficient margin at beginning of life between consumption during the nominal platform and payload operations (<80 W) and the total incoming power (>120 W) providing a lot of flexibility for the operation of the onboard technology demonstrators.	About 40% for all the nominal platform activities, more than 60% is available for onboard payload processing and data compression.
Although there were no data availability requirements in view of the experimental nature of the mission, the overall mission design (spacecraft and ground segment) has proven that it is capable of acquiring and delivering science data on a continuous daily basis, (about 70 SWAP images per contact, delivered within 30 minutes to the SOC).			
In addition, thanks to the ground segment automation, the SOC is able to interact in an almost direct way with the payloads and can submit modifications to payload operations up to 20 minutes before each contact.			

↑ Proba-2 commissioning confirmed that the mission is well within its anticipated performance requirements

It is capable of imaging and tracking of erupting prominences above the solar limb using its larger field of view and the platform three-degree off-pointing capability, beyond the regions that are imaged by comparable missions such as SOHO, TRACE and the Solar Dynamics Observatory (SDO).

It can be used in the generation of high-resolution 3D images of solar events outside the solar disk, with SWAP serving as a 'third eye' for the twin STEREO satellites, which are now too far apart to continue stereoscopic viewing without Proba-2's assistance.

It complements the data from solar imagers on other missions, providing context images of the corona at one million degrees for the JAXA Hinode satellite and off-disc context image information for SDO's Atmospheric Imaging Array images. Its images of coronal structures during solar eclipse events in the EUV also complement visual data gathered on the ground.

LYRA

LYRA is a solar ultraviolet radiometer manufactured by a Belgian/Swiss/German consortium including the Royal Observatory of Belgium, the Centre Spatiale de Liège and the World Radiation Centre in Davos. It monitors solar radiation intensity in four ultraviolet pass bands. The channels have been chosen for their relevance to solar physics, aeronomy and space weather. The instrument contains three units which each possess four channels for redundancy and calibration.

LYRA makes use of novel 'wide bandgap' detector technology, based on diamonds. Diamond sensors have a high 'radiation hardness', useful in making instruments tougher against EUV as well as ionising radiation. LYRA's demonstrates technologies that are important for future missions, such as ESA's Solar Orbiter, which is intended to go closer to the Sun than any other mission.

→ Proba-1 operating for ten years

Launched in November 2001, and originally designed for only one year of life, Proba-1 is now entering its tenth year of operations. The platform and instruments are still in good health. So far there has been no need to use redundant units and there has been very limited degradation of its solar cells and battery.

Constructed as a technology testbed, Proba-1 is being operated by ESA today as an Earth Observation 'Third Party' mission. A dedicated user community has grown, with 18 m resolution multispectral imagery being produced by Proba-1's main Compact High Resolution Imaging Spectrometer (CHRIS) instrument on a daily basis. Even higher-resolution 5 m imagery comes from the monochromatic High Resolution Camera (HRC). Controllers specify the latitude, longitude and altitude of their desired target and the largely autonomous and highly agile satellite does the rest itself.

↑ Proba-1, Project for On Board Autonomy, demonstrates the potential and feasibility of small satellites for advanced scientific and Earth Observation missions

→ Technology demonstrations payloads

Payload	Company	Notes
Digital Sun Sensor	TNO (NL)	Both Star Tracker and Sun Sensor are digital attitude sensors based on APS technology, as well as micro-mechanical devices and folded optics. The latter design is a demonstration model for ESA's forthcoming mission to Mercury.
BepiColombo Star Tracker	Selex Galileo (IT)	
Fibre sensor demonstrator	MPB (CA)	Fibre optics interfacing with the propulsion module to measure temperature and pressure levels
Science Grade Vector Magnetometer	DTU (DK)	Directly controlled by the μ-ASC electronics, delivering real-time magnetic field components with a very high precision. This prototype is paving the way for an operational version to be flown on ESA's Swarm mission.
Experimental Solar Panel	CSL (BE)	With a solar flux concentrator, studying temperature behaviour and ageing effects resulting from concentrated solar flux. In-flight results show a 55% increase in cell efficiency, with measurements being repeated to monitor solar cell degradation.
Dual-frequency GPS receiver	Thales Alenia Space (FR)	Radiation-hardened and dual frequency, intended for use on many future missions
Exploration Micro-camera	SpaceX (CH)	A powerful miniaturised micro-camera with a large optical field of view
Laser Retro-Reflector (LRR)	Federal Unitary State Enterprise (RU)	
ZMM set of magnetometers	ZARM (DE)	
Credit Card Magnetometer	Lusospace (PT)	This and the Zarm set are new developments in high-precision, high-rate three-axis magnetometers
Additional innovative Guidance, Navigation & Control algorithms	NGC (CA)	
TDM	QinetiQ Space (BE)	Measuring radiation effects, featured inside an additional ADPMS board
Lithium ion battery	SAFT (FR)	
Advanced Data and Power Management System	Verhaert Space (BE)	Containing many new technologies, including the LEON processor
Structural panels	Apco Technologies SA (CH)	Combined carbon-fibre and aluminium panels
Reaction wheels, star trackers and GPS receivers	Dynacon (CA), DTU (DK), DLR (DE)	
Telecommand system	SST-SystemTechnik GmbH (DE)	Upgraded with a decoder largely implemented with software
A PROPULSION MODULE CONSISTING OF:		
Cold gas 'resistojet' thrusters	SSTL (UK)	Using xenon as propellant
Cool gas generator experiment	Bradford Engineering/ TNO (UK/NL)	A solid-state gas generator that produces nitrogen to repressurise the propulsion module tank. This COGEX system contains four solid-state cartridges which, when ignited, repressurise the propulsion tank of the resistojet system and squeeze out more performance.

↑ Proba-2 is demonstrating a several new technologies in orbit

From January, LYRA provided a stream of solar irradiance measurements, taken every 20 milliseconds, or more or less continuously. LYRA is the only detector in space with such a high time resolution. LYRA serves to confirm all flares observed by other space sensors. For some very energetic flares, an extra component of activity in longer wavelengths has been discovered.

LYRA is currently used for continuous flare detection (since May all flare events are reported and Level 5 data for flare events can be found online), Earth atmosphere studies, reconstructing atmospheric ozone distribution during the yearly eclipse season (December to February), and temporal analysis of magnetic reconnection and the investigation of potential millisecond UV structures as known from solar radio bursts.

The latest SWAP and LYRA data can be found on the Proba-2 science web pages at **http://PROBA2.sidc.be/index.html/**

DSLP/TPMU

The Double Segmented Langmuir Probe (DSLP) experiment measures plasma around the satellite. This instrument was developed by the Institute of Atmospheric Physics, part of the Czech Republic Academy of Sciences. The DSLP is based on a novel development of classical electrostatic probes, comprising two identical spherical sensors mounted with short booms on tips of one of Proba-2's deployable solar panels. The main scientific objective is to identify the response of ionospheric plasma response to variable solar activity and space weather.

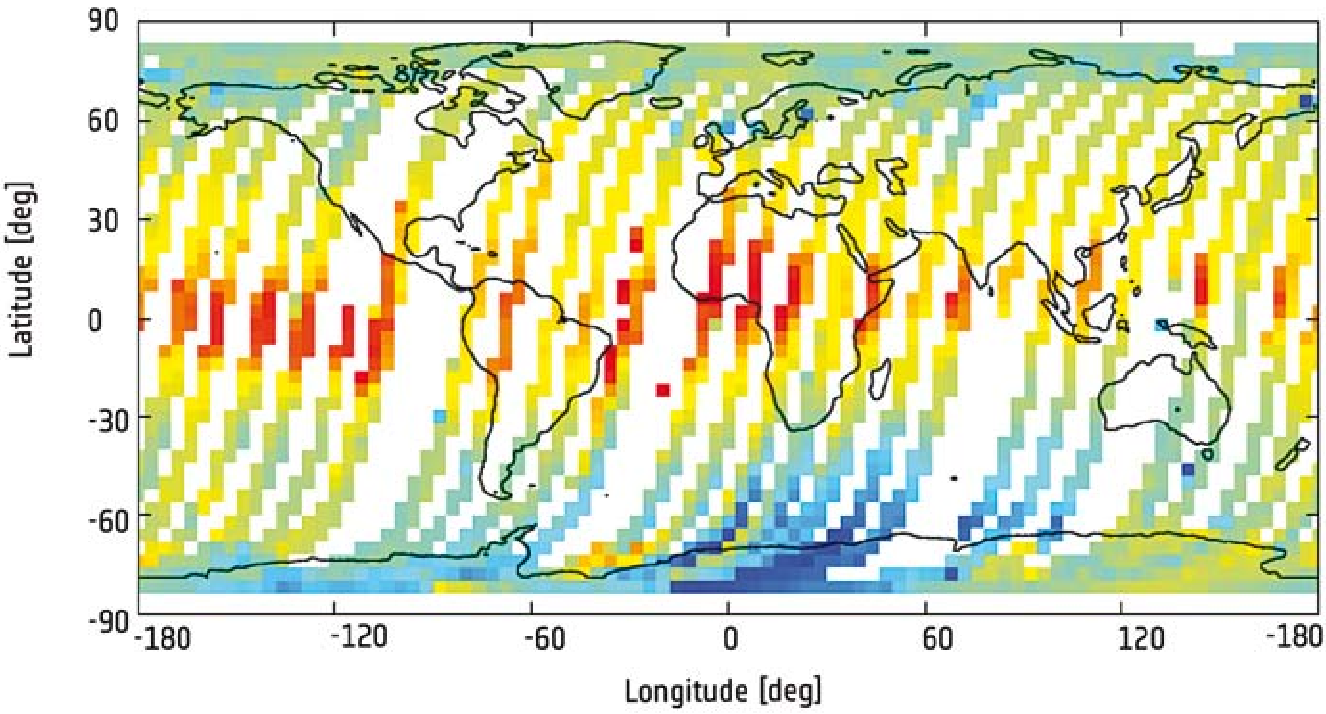
After commissioning, the DSLP sensors have been used on a continuous basis, providing measurements along Proba-2's orbit.

The Thermal Plasma Measurement Unit (TPMU) contains three experiments that measure the total ion density and electron temperature, ion composition and temperature, and the floating potential of the satellite body.

This instrument was also developed by the Czech Institute of Atmospheric Physics. The TPMU field of view is aligned with the flight direction of the spacecraft as far as the satellite's Sun-pointing attitude allows. ■

Acknowledgements

The authors would like to thank the Proba-2 teams at ESA, Redu, QinetiQ Space, Royal Observatory of Belgium (ROB), all subcontractors and suppliers, the universities and research institutes providing units or instruments, for their invaluable contribution to the mission and spacecraft design, development, verification and testing and day-to-day operations.



↑ Electron density map based on DSLP measurements

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A possible future Mars? This is what Mars could look like if 'terraformed', meaning we modify its atmosphere and surface to be similar to those of Earth. Assessing the impact of different greenhouse gases on the martian climate is just one topic under study by the ACT. The long timescales and practicality of 'terraforming' are the subject of wider debate with many unanswered questions on the ethics, politics and economics of altering the environment of an extraterrestrial world (D. Ballard)

→ THE SEEDS OF DISRUPTIVE INNOVATION

ESA's Advanced Concepts Team

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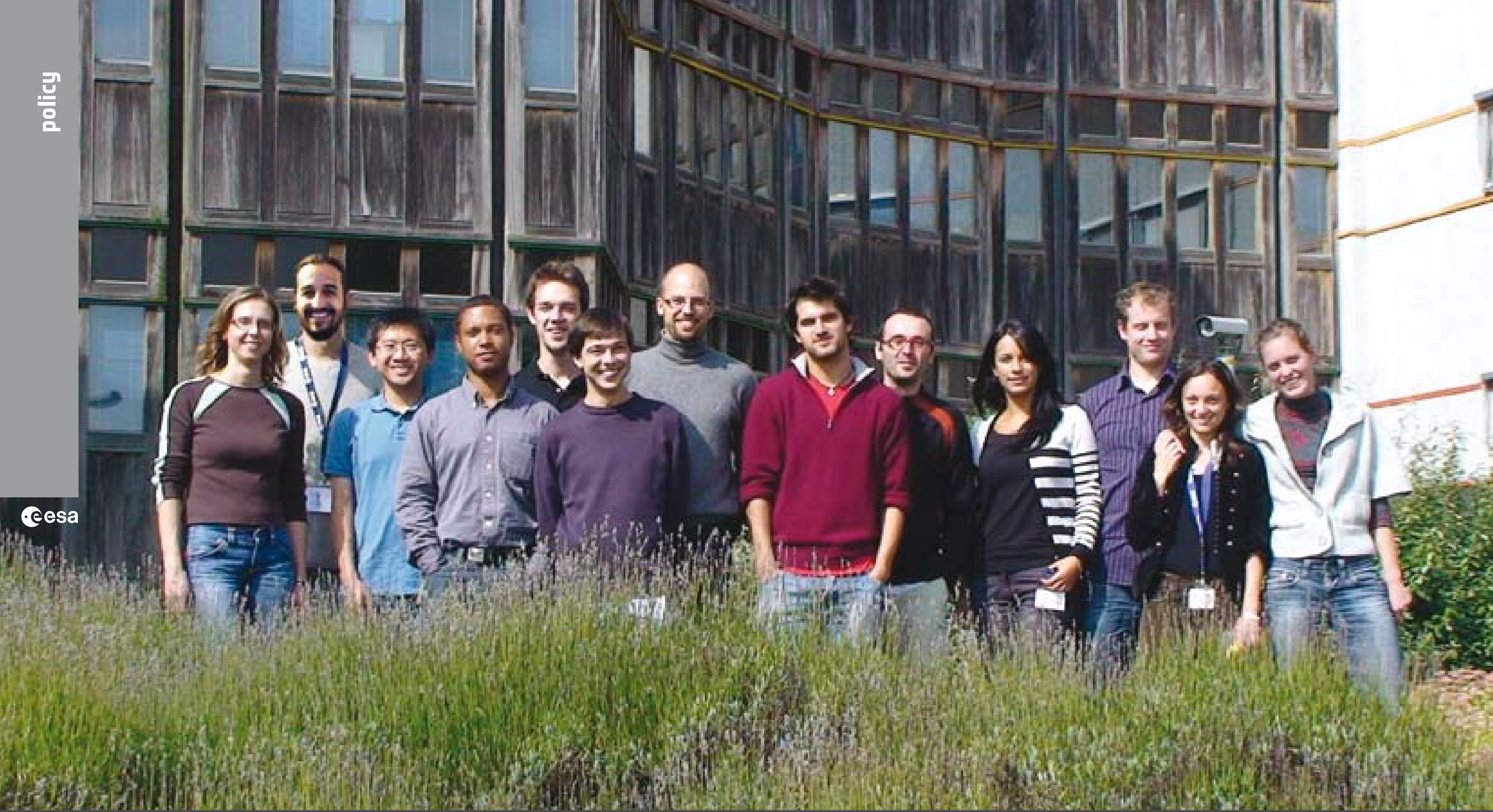
Space activities will likely be very different in the future, influenced by innovation in sectors and areas that are not necessarily on the 'radar screens' today of space agencies and industry. By creating, maintaining and evolving the Advanced Concepts Team, ESA continues to innovate and to show the way to prepare for potentially disruptive changes.

In 1930, Frederick Edwin Smith, First Earl of Birkenhead, the former UK Lord Chancellor and one of the best friends of Sir Winston Churchill, published a book called *The world in 2030*. He started his preface with: "If one looks back a hundred years and in so looking compares the world of that day with the world of today, one becomes almost equally conscious of the equal risk of underestimating and of overestimating the developments which lie in front of us. That man only is wise who does not dogmatise and who proclaims nothing impossible."

Some of his predictions have indeed become true already, but others are still to be realised, even though very few actually sound entirely unrealistic. Daring to think differently, not accepting dogmatic truths and not being bounded by the heritage of past solutions while remaining solidly grounded in the realm of science are key to such an exercise. This is also true for any attempt that focuses not on incremental or sustaining changes, but also radical and potentially disruptive ones.



↑ The ACT in September 2010, left to right: Fairouz Nasr, Francesco Biscani, Chit Hong Yam, Joris Olympio, Frazer Barnsley, Luis Simoes, Leopold Summerer, Eduardo Martin Moraud, Dario Izzo, Loretta Latronico, Duncan Barker, Giuseppina Schiavone, Cynthia Maan

ESA's Advanced Concepts Team (ACT) is not about predicting the future, nor about 'future science', 'futurism' or 'futurology'. The ACT is about contributing to the preparation of ESA and the European space sector for different futures. In this sense, our team tries to follow the French writer and aviator Antoine de Saint-Exupéry, when he said, "As for the future, your task is not to foresee it, but to enable it."

How do we work?

The ACT was created in 2002 with the explicit mission to 'monitor, perform and foster research on advanced space systems, innovative concepts and working methods'. As part of its goal, the team has to deliver rigorous and rapid assessments of advanced concepts that are not necessarily yet linked to space.

Preparing for the future is nothing new. We all prepare for our futures, and it is done in almost every successful organisation. So what is different about the ACT? The long lead and operational times of space projects, preparing for the 'future' of the space sector means looking further into the unknown than in probably any other sector: the current programmatic horizon of the space sector is already extending 10 to 15 years ahead, substantially longer than most other industries.

Preparing missions and technologies to be launched in a few years and which are designed to remain not only operational, but also competitive, with fast-evolving terrestrial alternatives for a decade and longer is in itself a fantastic challenge. Every part of ESA and the space sector must stay abreast of latest developments in its core technologies.

"He who innovates will have for his enemies all those who are well off under the existing order of things, and only lukewarm supporters in those who might be better off under the new."

Niccolò Machiavelli

History has shown, however, that large and especially successful organisations are particularly prone to either failing to recognise or to underestimating the impact of initially small developments that appear on the fringes of their core activities. Such organisations risk being taken by surprise once their core market is affected by what scholarly literature calls 'disruptive innovation'.

With current programmatic horizons extending already 10 years ahead and limited possibilities to introduce new technologies in late phases of space projects, the preparation for over-the-horizon futures requires not only understanding and extrapolating current trends and their interactions, but also anticipating upcoming new evolutions that are still in their very infancy today. It is therefore important to create a structure and mechanisms where these weak early signs of upcoming changes can be detected, researched, analysed and interpreted. As the principal actors for extending general knowledge, universities are common birthplaces and 'hotbeds' for such signs and provide 'sandboxes' for their early stages. Tapping into these and intelligently extracting useful information for the future of the space sector is how the team contributes to the preparation of the future of ESA.

Therefore the team's work is deliberately not within a specific programmatic or technical context, but looking outside the traditional scope of ESA, further into the future as well as outside of the thematic areas of space.

When deciding how to structure our team, it was natural to learn from other innovation leaders, taking into account what was working well and benefiting from lessons learned. An analysis was carried out of the approaches adopted by the NASA Institute for Advanced Concepts (NIAC was operational form 1998 to 2007 and has just recently been re-established in a slightly different configuration as part of the office of the NASA Chief Technologist in 2010.), DARPA, the central research and development organisation in the US Department of Defense, the MIT Medialab, Starlab, Lockheed's Skunk Works and some of its imitators, as well as the set-ups of highly innovative companies such as Google, IBM and others.

Based on this analysis, the following key aspects of a successful implementation were identified:

- Interdisciplinarity is a key requirement since most 'game-changing' developments emerge and progress initially on the fringes and intersections of disciplines.
- Regular renewal of personnel is beneficial to keep such teams on the leading edge.
- Taking risks needs to be encouraged and rewarded.
- Scientific rigour and competence is key to avoid drifting into the realms of science fiction.
- Clear support from top-management, without which such groups struggle to survive, especially in successful organisations. Such teams and activities tend to be ridiculed, admired, not taken seriously or seen as a threat by the core of the establishment – depending on relative interests at stake.
- Close ties with academia are important. While small and medium-sized enterprises and start-up companies seem to be key for disruptive innovation in a 5–10 year time-span, the most relevant ideas and concepts for longer than 10–15 years are generated within academia and research centres.

Implementing these within the possibilities of the ESA environment, led to the following main parameters of the ACT.

The team was set up as a group of researchers, mainly research fellows (post-doctoral researchers joining the team for two years) and young graduates (recent master's-level graduates joining the team for one year),

→ The Advanced Concepts Team (ACT)

This technical corporate research 'think tank' within ESA's Future and Strategic Studies Office, is exploring advanced concepts, techniques and working methods that are beyond the horizon of regular ESA activities and projects.

It is an integral part of the preparation of the future of and for ESA, coherent and consistent with the General Studies Programme. Our team relies on the interdisciplinary cooperation of a dynamic group of young researchers, who join the group for one to two years as part of their academic career, thus adding constantly new competence and a fresh standpoint to the team and ESA.

Our research areas currently covered are: biomimetics, fundamental physics, computer science and applied mathematics, mission analysis, computational management science, artificial intelligence and advanced energy systems. These themes evolve over time and the teams' competence base and its topics are constantly adapted to the evolving needs of ESA.

Internal and collaborative research with academia are at the core of the ACT activities, providing the basis for those activities related to opening the horizon of ESA towards new areas, offering an entry point for innovative academic research ideas, bridging these to operational technical expertise and deriving trends and strategic directions from research progress.

who originate from a broad variety of academic fields and are aiming at an academic career. The pursuit of highest scientific standards is therefore as much in their own interest as it is in the interest of the team. The steady renewal of researchers (one- or two-year periods within the team) allows a continuous, flexible adaptation of our team's competence base to the needs of ESA and to evolutions in science and technology. It is also the basis for fresh unbiased assessments and re-evaluations, while avoiding, empire-building, and preventing ESA-career considerations from influencing the orientation and conduct of research.

Consequently and contrary to classical approaches, the management of the team consists essentially in providing the right frame conditions, strategic perspectives, ensuring consistency and quality, putting the research into a larger context and interfacing with external groups but not on directing the individual researchers and their research activities. Externally, we interact almost exclusively with universities and specifically small, innovative research labs, often with no prior link to ESA or the space sector.

Based on the success models of other innovation leaders, administratively, we have always been situated at corporate level, outside the missions and programme and support directorates, and independent from the core technical strategies and 'road-maps'. Originally the team was created as an integral part of the ESA General Studies Programme (GSP) and is currently contributing to the goals of the GSP. Together with the GSP, we sit in the Future and Strategic Studies Office, itself part of the Director General's Policy Office of ESA.

As far as is known, the combination of temporary in-house researchers from a multitude of disciplines, the reliance on empowered young researchers who are encouraged to propose and relatively free to pursue new ideas, together with the framework to perform collaborative research in ad-hoc virtual teams, is quite unique and innovative in itself. The value of this combination has been recognised internationally and some initiatives have emerged at national level inspired by the ACT model.

→ The team and the Advanced Concepts community

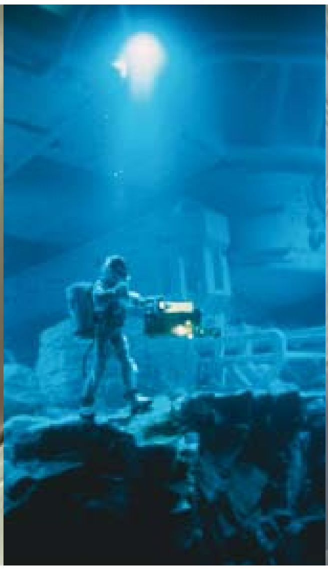
Similar to one of the goals of ESA's Young Graduate Trainee programme (sponsoring young graduates in a space discipline and providing them with a good working knowledge of ESA for a career in the European space industry) but focusing on academia and research institutes, ACT researchers (who originate mainly from non-space related fields) pursue their academic careers after leaving the team with a better knowledge of ESA's needs and of the space sector in general.

What topics do we look at?

The research directions of the group come from three sources: the daily team activities, which naturally provide a detailed outlook on advances and trends in research, from discussions within the Director General's Policy Office and from the interaction and discussions with the rest of ESA. To stimulate innovation and creative thinking, ACT members are asked to continuously propose new ideas and research subjects and are encouraged to dedicate a certain percentage of their time on new, self-defined topics.

We have one 'golden rule': whenever something is done by anyone else within ESA, it becomes 'off-topic' for us, and we move on to new areas. In practical terms, via our

→ Ideas we have seen in popular science fiction are not always far from possibility. Liquid breathing, seen in TV's UFO (1970) and the movie The Abyss (1989), and human hibernation, in the movie 2001: A Space Odyssey (1968) and Alien (1979), and many other concepts like these are studied by ACT, either to debunk flawed 'breakthroughs' or to assess their feasibility



> **The term 'disruptive innovation' is used in business and technology literature to describe innovations that improve a product or service in ways that the market does not expect.**

research, we act as a cross-departmental 'pathfinder' to explore novel or potentially promising areas for ESA and the space sector, ranging from applied to basic fundamental ones.

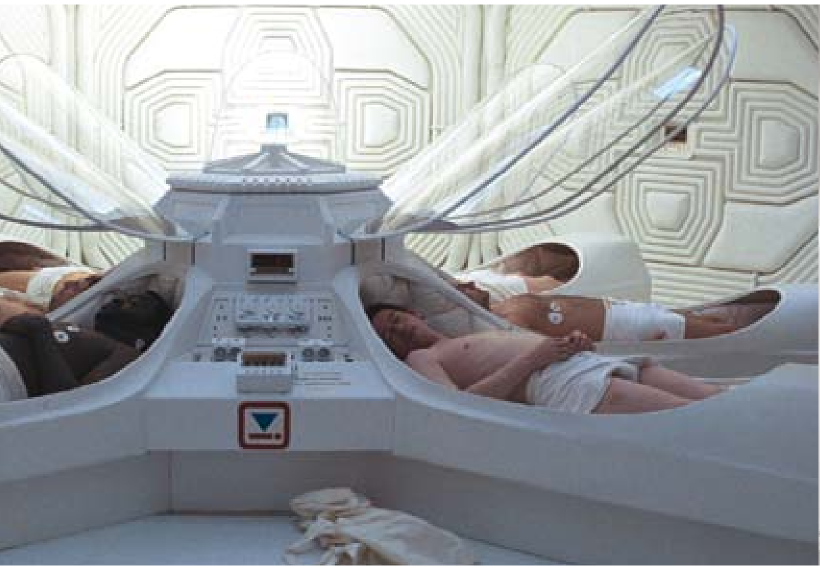
These are generally:
- concepts and techniques from areas with no current links to the space sector (e.g. biomimetic approaches to engineering, brain/machine interfaces, liquid breathing, curiosity cloning, peer-to-peer computing, crowd-sourcing gaming, innovation diffusion and dynamics);
- emerging directly from recent, cutting-edge basic scientific research (e.g. mathematical global optimisation techniques, cloud-based uncertainty modelling, helicon thrusters, pure general relativistic approach to GNSS constellation design, vibrating systems in general relativity, 'metamaterials' in the optical frequency range, distributed/swarm intelligence);
- areas where ESA is likely to build up competence but is hesitating due to the lack of concrete short-term programmatic needs (e.g. space nuclear power sources, asteroid deflection or planetary protection research; and
- far-reaching subjects in which ESA is expected to have a technically solid position but which are too immature to be taken up by regular ESA programmes or projects (e.g. solar power from space, use of hypometabolic states for space travel ('hibernation'), asteroid deflection, active removal of space debris, novel working methods based on new IT tools such as virtual collaborative environments, 'terraforming' and 'geoengineering').

Many of these subjects require skills that are not readily available in other parts of ESA.

ACT research

Most of our research is performed within the team in small subgroups. If a subject requires additional expertise not readily available within the group or within ESA, the topic is proposed for a collaborative study together with researchers from European universities via the Ariadna scheme.

In conducting their research, ACT members take advantage of a unique environment, which offers:
- Strong links with European universities. Researchers typically arrive to the ACT directly from their universities and the work in the team offers them the opportunity to consolidate and broaden their links with the academic world. A continuous feedback from the



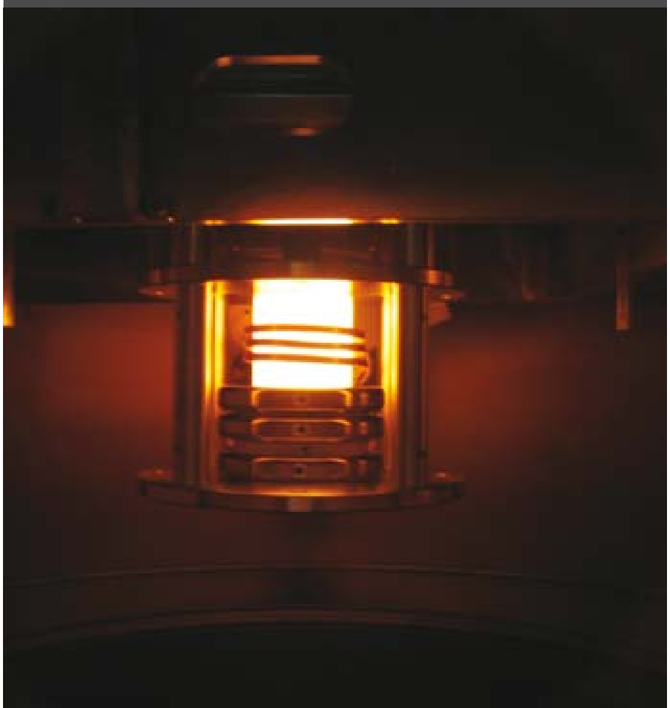
academic community is thus available to stimulate and improve the outcome of the team research activity. Special links are maintained with the former members of the team (ACT community).

- Interdisciplinarity of the team. The daily exchange of ideas with people having radically different research and personal backgrounds, stimulate the individual ACT member to transversal thinking, setting a fertile ground where innovative thinking can grow.
- Direct contact with ESA scientists and engineers. Working at ESTEC, research fellows usually establish relatively quickly personal contacts with ESA staff in the field of specialisation closest to theirs. This provides them with direct insight into the ongoing developments in the space sector as well as its expected future needs. Furthermore it also allows an uncomplicated, personal information exchange and link to other ESA teams preparing the future.

For the benefit of ESA and the European space sector

Some of the activities of the ACT are oriented to providing a critical analysis on technical subjects for which a specific knowledge does not exist in any ESA directorate, or for which appropriate manpower is not rapidly available. This has the effect of anticipating ESA needs by providing 'entry points' to potentially disruptive ideas (e.g. neuromorphic computing, dual-stage four-gridded ion thrusters (DS4G), distributed evolutionary computing and 'space tourism') while at the same time debunking flawed 'breakthroughs' (e.g. assessment of breakthrough propulsion concepts from a theoretical physics standpoint).

↓ A very new concept in electric propulsion, the Dual Stage Four-Gridded (DS4G) ion thruster for interplanetary spacecraft, was successfully tested in 2005 by ESA and the Australian National University



→ Ariadna: A framework for advanced cooperative research

Ariadna is an initiative aimed at establishing stronger links with the European scientific community by carrying out joint research projects between the ACT and selected academic institutions. During Ariadna projects, researchers from European academia explore, together with ACT researchers, some emerging fundamental questions as defined by the ACT in an Ariadna Call for Proposal. Universities have also the possibility to propose their own research ideas if relevant to a larger theme described in an Ariadna Call for Ideas. A short description of the results obtained in each Ariadna project can be found in the Ariadna brochure, available on the Ariadna web site (**www.esa.int/ariadna**).

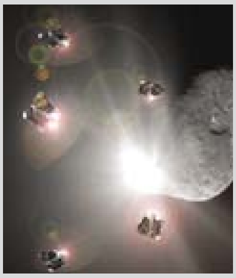
Since the first studies in 2004 and until end 2009, the team has studied 54 different topics together with universities institutes, on average nine new topics per year. Since some of these research projects, especially the high-risk ones are done in parallel studies with different departments, 78 Ariadna studies have actually been performed.

Disruptive changes normally emerge when disciplinary boundaries are crossed and concepts and techniques are applied out of their context (e.g. Google Earth and Earth observation data, participatory networks of news/media content generation versus centrally organised one-way communication). Therefore, one of the most important qualities of a 'think tank' is its interdisciplinary nature – and this is experienced in the ACT as an integral part of their daily work. The research done by the team is thus planting the seeds for 'disruptive innovation' in the European space sector and at the same time trying to keep ESA alert of potentially disruptive innovation emerging on the fringes of the traditional space sector.

From short reports responding to needs of policy and decision makers, documents analysing trends and advances in niche areas potentially interesting for ESA (e.g. space tourism) to hands-on trials of new ways of working in ACT (e.g. Web 2.0 methods for internal organisation, group and data management), ESA benefits from the essential independent and objective way of thinking of a team made up of constantly renewed young researchers unconstrained by an ESA career-oriented approach.

ACT researchers are encouraged to take some substantial risk with their research topics and concepts and not all of the research of the team leads to tangible results that can be taken up by other parts of ESA. Some projects

Ariadna Study Titles:



Mission analysis

- Advanced global optimisation tools for mission analysis and design
- Study on libration points of the Sun and the interstellar medium for interstellar travel
- Assessment of mission design including utilisation of libration points and weak stability boundaries
- Feasibility study for a spacecraft navigation system relying on pulsar timing information
- Electrostatic forces for satellite swarm navigation and reconfiguration
- Spiral trajectories in global optimisation of interplanetary and orbital transfers
- The 'Flower Constellation Set' and its possible applications
- Space webs
- Global trajectory optimisation: Can we prune the solution space when considering deep space manoeuvres?
- Asteroid centrifugal fragmentation
- Dynamics and stability of tethered satellites at Lagrangian points
- NEO Encounter 2029: Orbital prediction via differential algebra and Taylor models
- NEO Encounter 2029: 'Mirror bees' concept for asteroid deflection
- NEO Encounter 2029: Determination of asteroid fragmentation energy from an impactor and post-fragmentation dynamics

Biomimetics

- EAP-based artificial muscles as an alternative to space mechanisms
- Biologically inspired joints for innovative articulations concepts
- Bio-inspired distributed system for thermal (or particles) transport
- Strain sensors inspired by campaniform sensilla
- Attaching mechanisms and strategies inspired by spider legs
- Bio-inspiration from plant roots
- Neuromorphic computation of optical flow data
- Quantifying the landing reaction of cockroaches
- Path planning strategies inspired by swarm behaviour of plant root apexes

Bioengineering

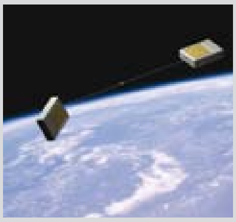
- Mammalian hibernation mechanisms: Relevance to a possible human hypometabolic induced state
- Curiosity cloning – Neural modelling for image analysis
- Non-invasive brain/machine interfaces
- Machine/animal hybrid controllers for space applications

Fundamental physics

- Theoretical study of the interaction of mesoscopic systems with gravity
- Lorentz-invariant description of the Feigel process for the extraction of momentum from a vacuum
- A search for invariant relative satellite motion
- On the effect of the global cosmological expansion on the local dynamics in the Solar System
- Non-perturbative effects in complex gravitationally bound systems
- Mapping the spacetime metric with a global navigation satellite system

Energy systems

- Laser power-beaming feasibility: Non-mechanical beam-steering options, laser phase-locking and control
- Environmental impacts of high-power density microwave beams on different atmospheric layers
- Sponge iron process for manned space exploration
- Biomass-based fuel cells for manned space exploration



Propulsion

- Helicon Double Layer Thruster concept for high-power NEP missions
- Open magnetic fusion for space propulsion
- Numerical simulation of the Helicon Double Layer Thruster concept
- Advanced concepts of electromagnetic generation, confinement and acceleration of high-density plasma for propulsion
- Advanced injectors for chemical rockets inspired by ink-jet printing technology
- 'On-a-chip microdischarge thruster arrays' inspired by photonic device technology for plasma television
- Understanding of the physics and numerical simulation of Helicon Double Layer Thruster concept
- Electrodynamic tether microsats at the giant planets

Nanotechnology

- Microstructured radiators
- Metamaterials for space applications

Artificial intelligence

- Natural language techniques in support of spacecraft design
- Evolution in robotic islands: Enhancing the potential of automatic design techniques through a parallel distributed environment
- Evolving a collective consciousness for a swarm of pico-satellites

Computer science

- Efficient use of self-validated integrators for space applications
- Application of clouds for modelling uncertainties in robust space system design
- Assessing the accuracy of interval arithmetic estimates in spaceflight mechanics
- 'Gossip-based' strategies in global optimisation

end with 'just' an academic knowledge gain in form of a publication, others are shelved if the analysis reveals that the original idea was not as promising as initially expected or others turn out to be too far-fetched to warrant further investigation at this stage. Similar to venture capital seed funding, only a few of the concepts developed by the team are expected to make significant changes and have an impact in the space sector.

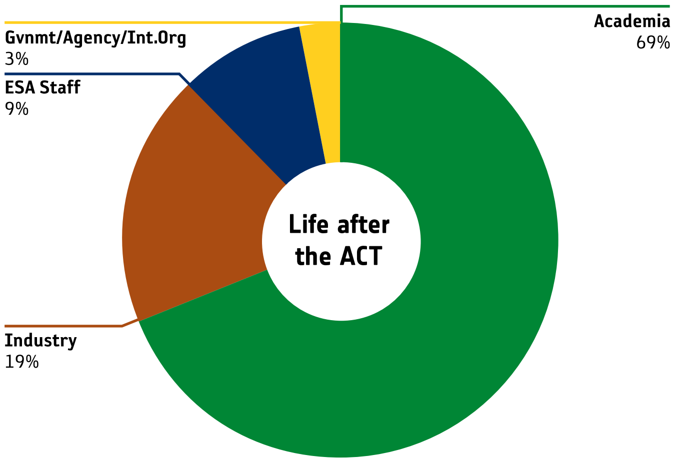
Since we are operating in an academic way, publishing all our research and encouraging feedback, ideas and concepts are not only taken up by ESA, but also by external researchers. These could take the form of small programmes funded further at national level (e.g. tether research in Spain, space webs in Scotland and Sweden, further development and testing of the four-grid ion thruster in the UK), concepts taken up by start-up companies (e.g. metalhydride fuel cells) or large EU framework programme activities (e.g. €3.5 million 'helicon' thruster EC FP7 activity directly based on a €25 000 Ariadna study).

ESA also derives some substantial indirect benefit from these activities with research groups having no prior link to the space sector. Often, universities are surprised by the interest of a space agency in their research, and thus continue their work after such contacts with a better understanding of the space sector and its requirements.

Publications

As for all research teams, the feedback from peers and the international research community is very important for us. In total, we published 349 scientific documents (between 2002 and August 2010). These include 65 peer-reviewed single articles, 7 book chapters, 3 books, 182 conference papers and 92 other publicly available scientific documents (essentially research project reports). The steady increase of the ratio of peer-reviewed publications (including books and book chapters) to all scientific publications we authored can be seen as indicating an increase of the overall quality of ACT-authored publications (increase from 17% in 2002 to 48% in 2009).

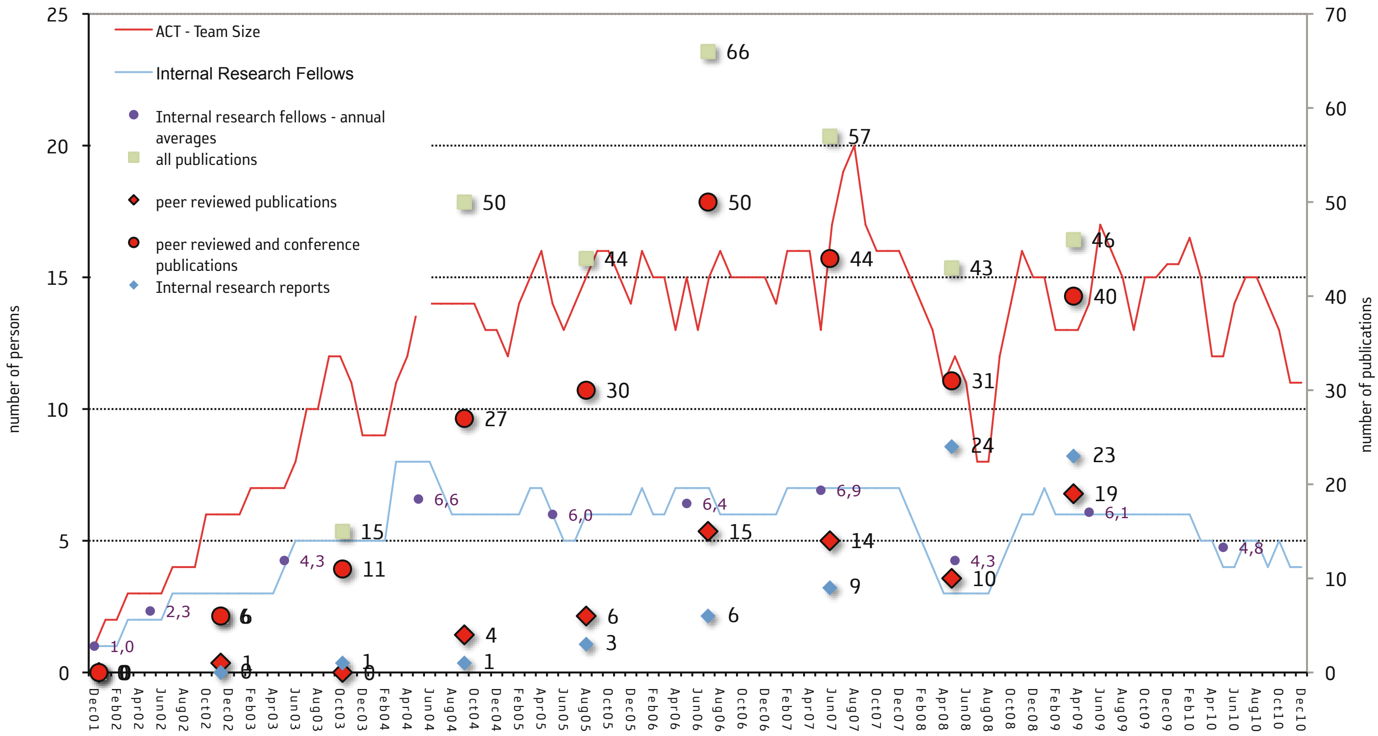
Links to all ACT publications are available on web-based database at the ACT website (**www.esa.int/act**)



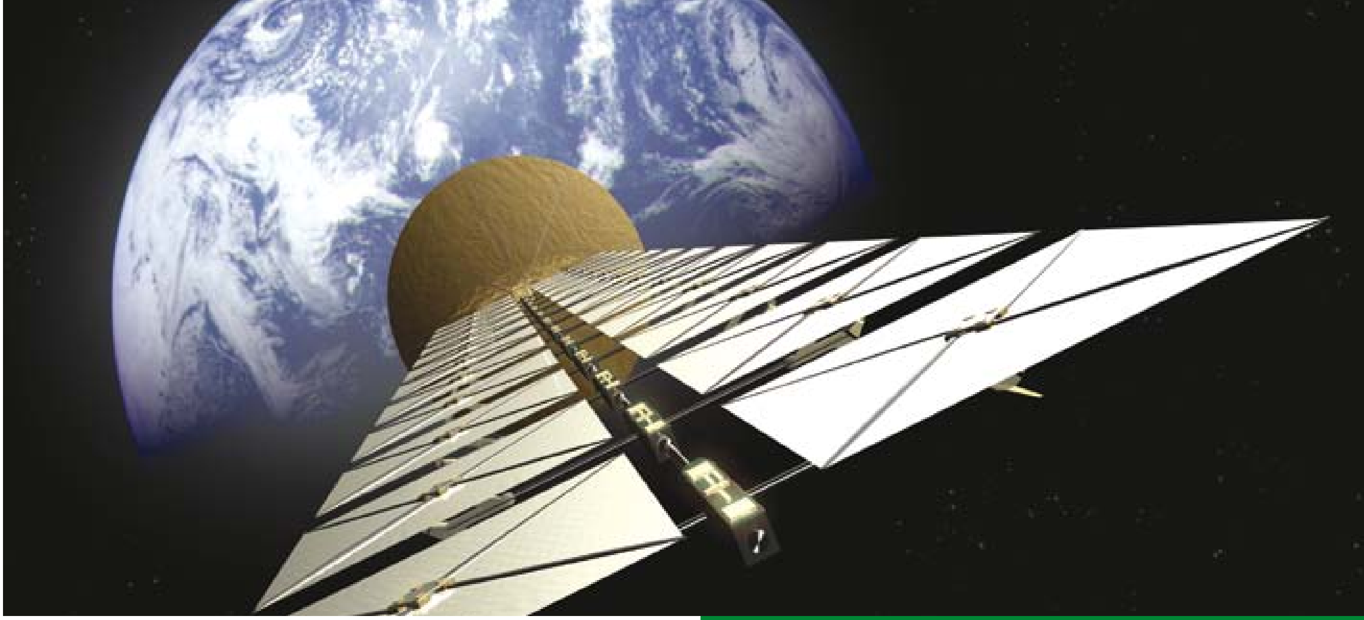
↑ Life after leaving the team: post-ACT affiliations

Research network

We can only host a limited amount of in-house expertise. An active network of universities and external researchers is therefore important to achieve its goals and since the topics of the team are located on the fringes of space activities and beyond these, such a network includes many research centres not specialised in space. This has turned out to be itself a valuable asset, especially since the space sector has for a long time been thought of as a 'lonely forerunner' and experienced difficulties in engaging and cross-fertilising with other sectors.



↑ Evolution of the ACT publications record, per research fellow (RF) , with data until and including 2009



This research network is neither static nor fixed, but evolving with the team, its orientations and its members. One quantitative way to measure its size is represented by the 444 unique co-authors of publications published by the team (available at **www.esa.int/gsp/ACT/publications**)

These are people who have actively worked with one or several researchers of the team in a successful project that led to a publication. It is therefore a conservative low estimate; the number of actual research contacts and loose co-operations is higher. Since practically all members of the team are temporary researchers, the alumni network is constantly growing. 69% of ACT members go back to academia immediately after leaving the team and of all the team members 54% are at time of writing still within an academic career.

Hic futura parantur...

Here we prepare the future. Detecting the signs that announce changes and opportunities to come, understanding their importance and performing research on them with a view to take full advantage for ESA and the European space sector, is a daunting task. The secret lies in persisting to innovate and take risks, to challenge the status quo and to continue to seek new ways to do things, new concepts and new solutions. While space will remain essentially the same, the scope, purpose and type of our use of space and our activities in space are likely to be very different. With its innovative way of operating, the Advanced Concepts Team helps ESA and the European space sector to not only foresee, but also to enable our future in space.

Further reading

- *The World in 2030*, The Earl of Birkenhead, Hodder and Stoughton, London 1930
- *The Innovator's Dilemma*, Clayton M. Christensen, Harvard Business School Press, Boston 1997
- *The Innovator's Solution*, Clayton M. Christensen and M. Raynor, Harvard Business School Press, Boston 2003

JAPANESE CLOTH

Deploying very large structures

The idea of generating large amounts of carbon-free energy in space by harvesting solar radiation and wirelessly transmitting power to Earth had already been described by the early space visionaries of the first half of the 20th century before a first engineering concept was published in 1968.

We analysed the general validity of these concepts compared to terrestrial alternatives and worked especially on the integration of space and terrestrial-based solar power plants. All of these concepts rely on the deployment of relatively homogeneous very large structures in space, a technology for which there is equal interest from many other space applications, such as very large antennas. As an example of our hands-on research activity, we participated in the Japanese 'Furoshiki' sounding rocket experiment (named after a traditional Japanese wrapping cloth), launched by JAXA in 2006.

This experiment deployed a 130 m² net in microgravity. The European contribution was two small robots, which moved on the deployed net simulating the movement of future phased array microwave antenna elements. Following this experiment, conducted together with the universities of Tokyo, Kobe and the Vienna University of Technology, the team has studied together with the Universities of Glasgow and Stockholm (KTH) the dynamics of very large nets rotationally deployed in microgravity. A second sounding rocket experiment to test such a deployment is currently in preparation at these universities.

MASS INNOVATION

Open source development of a massively parallel engineering optimisation platform

‘Mass innovation’ is a relatively new term indicating a process of creative thinking based on modern media resources to organise and increase the communication flow within the largest possible interested community. Being a novel path to innovation, and previously unavailable because it is based on technology that was created only recently, mass innovation has attracted the interest of many groups seeking to control and channel it towards synergies with corporate core businesses. In an effort to better understand the potential of this innovation process, we have been experimenting for four years with open source software developments.

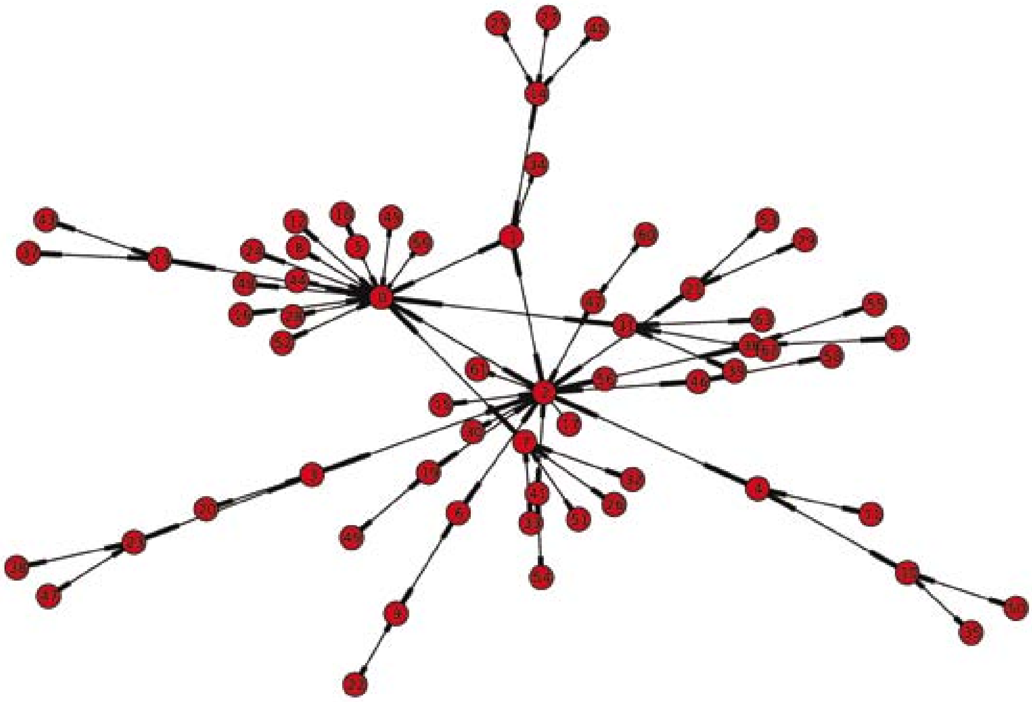
One of four projects looked at by our team is the ‘Parallel Global Multiobjective Optimiser’ (PaGMO). It was developed to benefit from the increasing availability of large computer CPU clusters and to allow engineers and scientists to take full advantage of these new massively parallel and distributed architectures. The guiding principle is to let the scientists focus on defining their optimisation problem, while the code first takes care of making the optimisation process ‘massively parallel’ efficiently, taking full advantage of the underlying network of CPUs, and then defining the optimisation strategy.

According to the problem type, the PaGMO can use a number of algorithms, including ‘meta-heuristic’ techniques, such as ant colony or genetic strategies, but also more classical approaches based on sequential quadratic programming or interior point methods. Solutions to the problem, as defined by the user, migrate among different instances along an underlying topology defined over the CPU network.

The team has successfully used the PaGMO in a number of projects, including ionospheric data processing, inverse engineering of micro-structured radiators, evolution of robotic neuro-controllers in niche island populations and the optimisation of interplanetary trajectories (during its participation to the Global Trajectory Optimisation Competitions).

In 2010, the PaGMO was accepted as an open source project to participate to the Google initiative ‘Google Summer of Code’ alongside projects such as Ubuntu, Open Office, Facebook and others.

→ Various aspects of the behaviour of ants and ant colonies are used in computer science and operations research for solving computational problems. A scale-free topology in PaGMO (here the Barabasi-Albert model is used to grow the network). Each node represents a CPU and the arrows represent possible migration routes for solution (design points) being optimised by different techniques/algorithms



INSPIRED BY INSECTS

A neuromorphic approach to spacecraft landing

The term 'neuromorphic', referring to electrical circuits, was first introduced to indicate devices mimicking neuro-biological circuits and copying the functions of a biological system. The resulting devices are often created either in analogue or digital integrated circuits (very large-scale integration system or field-programmable gate arrays) and are characterised by low power consumption and reduced mass. Because of the biological origin of the principle used in neuromorphic circuits, information of interest at a behavioural level (i.e. control and guidance) are often extracted directly and without any further processing. Thanks to these particularities, neuromorphic chips have found applications in fields such as prosthetic medicine and visual guidance of 'micro air vehicles'.

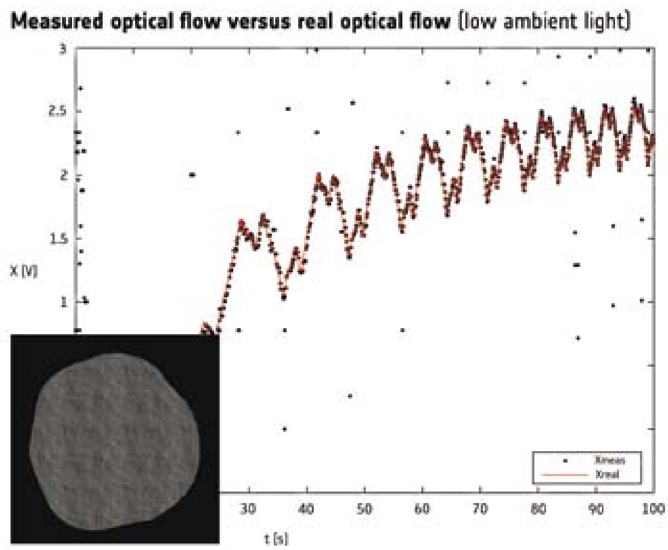
We have been working on elementary motion detectors, a simple neuromorphic neural circuit able to measure directly the optical flow inspired by insects. Insects rely on elementary motion detectors at a behavioural level to guide their flight and landing. For example, honey bees land on flat surfaces using only a small part of the roughly 950 000 neurons at their disposal by simply keeping the ventral optical flow constant.

We needed to answer two questions:
Can such detectors be used in the illumination conditions you would experience while landing on the Moon, on Mars or on an Earth co-orbiting asteroid?

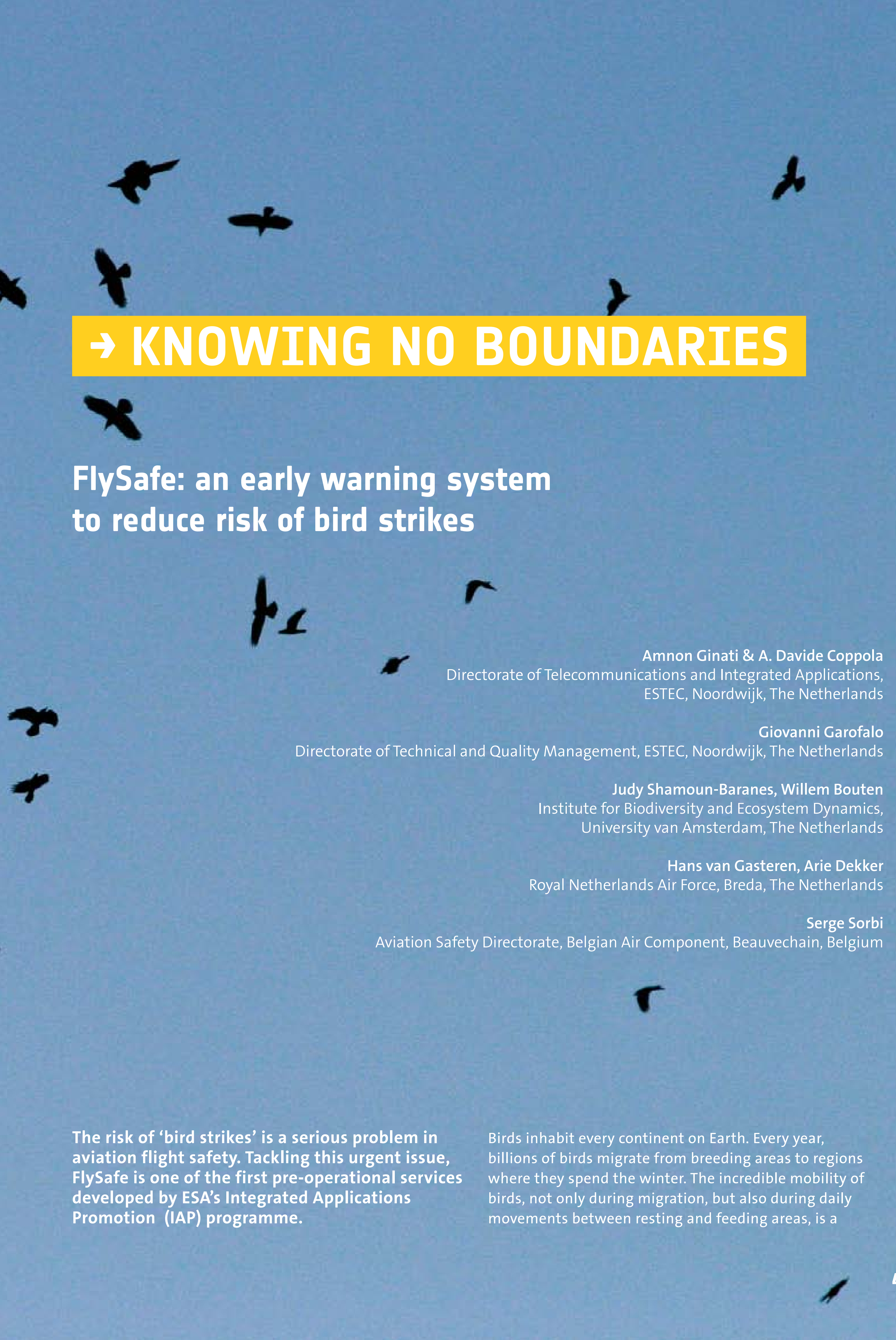
Is the principle of constant optical flow landing, evolved in nature for insect flight, convenient at some level also for guiding the landing of a spacecraft (i.e. a system equipped with reaction propulsion and designed to make efficient use of its mass)?

In collaboration with ETH/UZH in Zürich and the Université de la Méditerranée in Marseille, the team used artificial though realistic images of planetary surfaces to characterise the elementary motion detector performances during simulated landings on the Moon, on Mars and on virtual asteroids. Results show a very good and extremely uniform performance of the optical flow sensor with respect to lightning conditions. The results obtained served as the basis for the development of fully automated autopilots and navigation algorithms for both guidance and navigation during a planetary landing based on these detectors.

In parallel, we used the mathematical theory of optimal processes to compare the control structure of constant optical flow planetary descents with the structure of the optimal control of normal descents. The results show how constant optical flow descents, while able to closely approximate minimum-time optimal trajectories, fail to do so for maximal final mass trajectories, introducing a propellant mass penalty (evaluated at around 5–10% for 'high-gate/low-gate' Apollo-like descents) that need to be traded off with the expected hardware and software simplification offered by such a bio-inspired architecture.



↑ Example of the performance of one of the elementary motion detectors studied (from the group at the Université de la Méditerranée in Marseille) during a fast spiral descent on a virtual asteroid (lower left corner) under critical lighting conditions as simulated using the software PANGU. Light direction is assumed for simplicity to be always at zenith. The total avionics payload of the sensor would have a mass of less than 10 g and consume less than 1W of power.



→ KNOWING NO BOUNDARIES

FlySafe: an early warning system to reduce risk of bird strikes

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The risk of 'bird strikes' is a serious problem in aviation flight safety. Tackling this urgent issue, FlySafe is one of the first pre-operational services developed by ESA's Integrated Applications Promotion (IAP) programme.

Birds inhabit every continent on Earth. Every year, billions of birds migrate from breeding areas to regions where they spend the winter. The incredible mobility of birds, not only during migration, but also during daily movements between resting and feeding areas, is a fantastic expression of the connectivity and complexity of our global environment.

Birds can serve as an excellent flagship for habitat and species conservation, as a tool for education and as a source of inspiration to humankind. Birds show us the importance and requirements needed for a global approach to biosphere preservation and coexistence between humans and nature.

Many people are becoming more interested in bird movements, for example in relation to the spread of disease, conservation, ecology, education, urban planning, meteorology and even the operation of wind turbines and oil platforms.

But one of the most important issues is the threat that birds pose to flight safety: collisions of birds with aircraft, or 'bird strikes', can cause very serious and sometimes devastating accidents with severe consequences in both human and economic terms.

Bird strikes

Collisions between birds and aircraft are very common, with most bird strikes fortunately resulting in little or no damage to an aircraft. However, depending on the specific circumstances (such as the speed of the aircraft, the point of impact, the mass of the bird, the number of birds and the type of aircraft) some bird strikes result in the total destruction of the aircraft and the loss of human lives.

One bird strike that captured the attention of millions of people was the crash landing of the US Airways plane in the Hudson River, New York, in January 2009, after geese were ingested into the engines. Although the Airbus 320 was destroyed, luckily everyone survived the crash.

Bird strikes can occur en route, or locally in and around airfields. These local bird strikes occur in critical phases of flight, i.e. the few minutes after take-off or before landing, and so they are the cause of the majority of major mishaps.

Commercial airliners are in most danger from local bird strikes because at anywhere over 10 km from an airport, these aircraft are generally flying too high for birds. In contrast, military aircraft en route are usually flying very fast and very low, at 'bird rich' altitudes, so these bird strikes very often result in serious damage to the aircraft.

Birds know no boundaries

Understanding bird movement is no easy task. Several technological and traditional techniques are used to

↑ Every year, billions of birds migrate from breeding areas to regions where they spend the winter, some travelling more than 10 000 km track bird movements and understand the relationship between patterns in space and time and the environment. These techniques include, for example, space-based systems, ground-based military radars, mobile radar units and weather radars, infrared cameras, genetic and chemical markers, bird tagging (or 'ringing') and traditional visual observations.

However, these sources of data are often collected sporadically, at a limited number of locations or for a small number of species, and therefore can rarely be used to solve problems on an international scale.

Because bird migration is not a local phenomenon, it follows that information about bird movements on a global scale is fundamental for understanding migration and modelling their behaviour. This issue can be addressed by using space and ground-based technologies that bring together bird migration information on various geographical and time scales.

Added value of space

ESA's Integrated Applications Promotion (IAP) programme is stimulating and promoting European and international projects that result in user-driven services for European citizens on

→ Bird strike facts

UK – At least **110 serious bird strikes** suffered by military aircraft (from earliest records to **2004**), resulting in aircraft that were either destroyed, damaged beyond repair or involved human fatalities

Worldwide – **47 fatal accidents** in civil aviation have been recorded, with 88 aircraft destroyed and **243 people killed** (**1912–2004**)

USA – **7000 per year in 2005**, the number of wildlife strikes (mammals and birds) to civil aircraft, quadrupled since **1990**

USA – **$97.9 million per year**, the minimum direct and associated costs of bird strikes to civil aviation recorded by the Federal Aviation Association. If this figure is corrected for estimated **unreported** strikes, it could **exceed $489.9 million annually**

Worldwide – **$1.2 billion**, the conservative estimate for the annual cost of bird strikes due to damage and delays of commercial aircraft

These are highlights of reported national bird-strike statistics, although actual numbers are probably higher because in most countries bird-strike reporting is not yet obligatory.

↑ US Airways flight 1549 ended in the Hudson River after geese were ingested into the engines (**www.birdradar.com**)

← Remains of a Belgian C-130 aircraft that crashed in July 1996 at Eindhoven Air Base in the Netherlands due to a multiple bird strike with starlings and lapwings. 34 people were killed and 7 people were seriously injured (RNLAF).

regional, national and international levels. IAP activities are carried out in partnership with stakeholders and user communities (see http://iap.esa.int).

The key feature of these new applications is the added value of space, which not only makes them possible, but also gives a long-term sustainability to the resulting services. Space technologies, such as Earth observation, satellite navigation, satellite telecommunications or human spaceflight, whether taken alone or in combination with terrestrial systems, play a major and sometimes unique role in providing such solutions.

IAP is already active in diverse fields, ranging from energy grid management to aircraft safety, developing novel solutions and services that were previously unimaginable. Integrated applications are thus already benefiting European industrial competitiveness, while serving the needs of European society and global communities.

Because 'birds know no boundaries', ESA used the global space capability of its IAP programme to launch the 'FlySafe' demonstration project. Initiated in July 2007, ESA established a fruitful partnership between the air forces of the Netherlands, Belgium, Germany and France to develop a bird warning system to improve flight safety in northwest Europe.

FlySafe would combine the necessary and available space and ground-based systems, and the scientific research and technological applications from various user communities, to provide a sustainable service for the observation of large-scale bird migration.

In 2009, following a successful demonstration phase, Dutch and Belgian air forces proposed the creation of an operational service, to be hosted by the Royal Netherlands Meteorological Institute (KNMI), which is currently taking over this service. FlySafe is now being rolled out as an operational bird warning forecast service, providing enhanced real-time forecasts and 'nowcasts' – meaning the prediction of very near-future situations.

The bird warning centre is the first successful operational service initiated by ESA's IAP programme. FlySafe services are now being used by a variety of customers, including air forces, airlines, airports, agriculturalists and oil platforms.

IAP and the problem of bird migration

Through several international workshops and brainstorming sessions with experts (from academia, research institutes, nature conservation organisations, military and civil aviation authorities as well as health and agricultural organisations), the IAP team found that user groups needed data on bird movements at different resolutions, efficient access to bird-related and environmental data, integrated analysis results and finally a transfer of knowledge from migration ecologists to the other user groups.

They found four main themes related to bird migration: flight safety, human health, migration ecology and conservation and education. Based on the high impact that birds have on flight safety, both on routes and near airports, safety for military aviation was selected as the key subject of the project. Moreover, military aviation authorities acknowledged the need for improvements to current systems, closer cooperation between users and the setting up of a core 'cross-border' community.

FlySafe in detail

Current 'state of the art'

Around the world some air forces and civil airports practise various degrees of bird-strike reduction, which can roughly be divided into local and en route risk reduction activities. Locally, the populations of birds on airfields can be controlled or manipulated to some extent. However, this is impossible en route, therefore, to reduce the risk of bird strikes along aircraft routes, birds must be avoided.

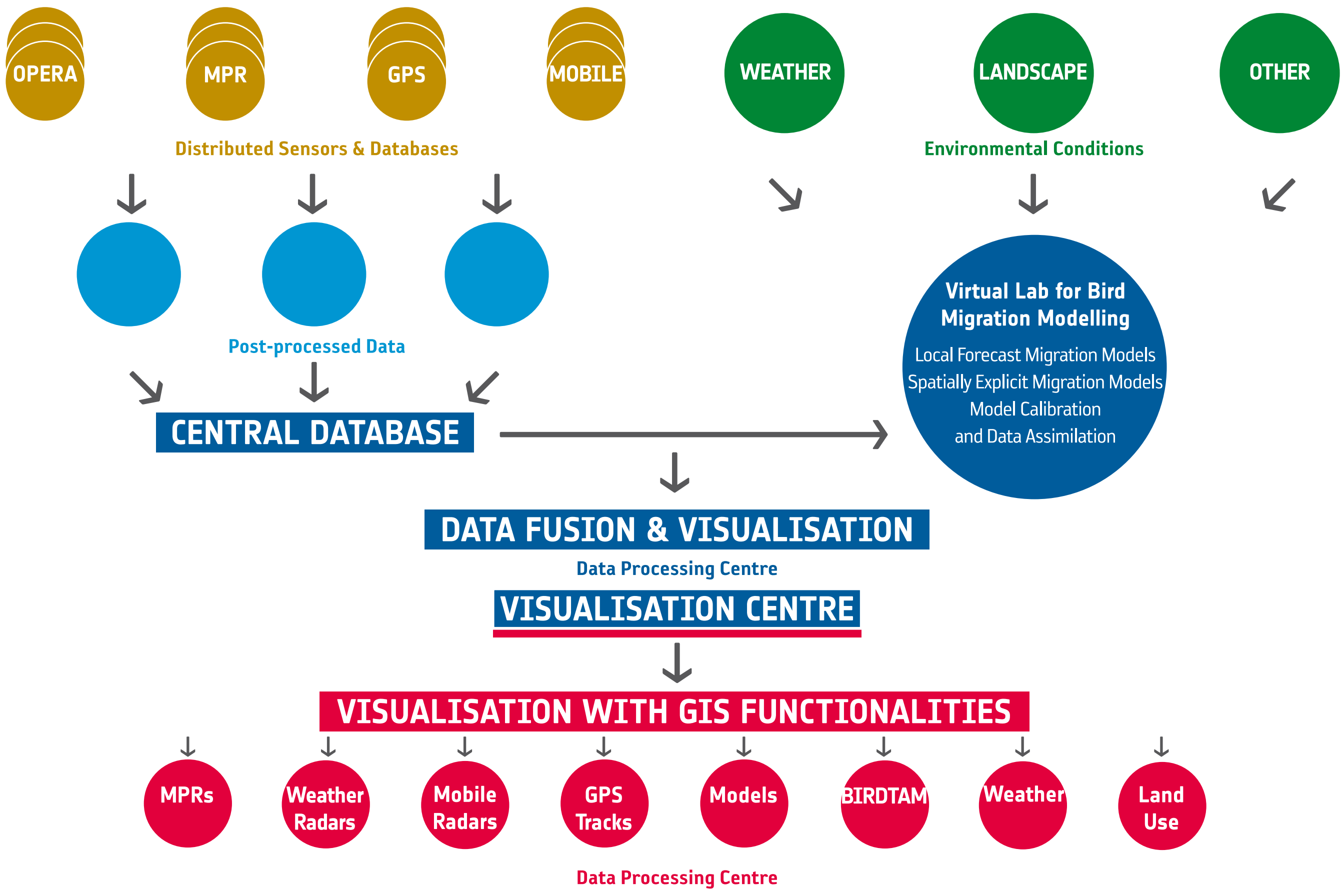
In Europe, a few air forces have recognised this problem and are promoting national activities focusing on ground-based technology, but these still miss the true global dimension of migration. In its risk reduction, the Royal Netherlands Air Force uses, for example, military radars to monitor bird densities in the air in near real-time, computer models that predict migration and techniques to identify bird remains after bird strikes. Nevertheless, these activities are spatially restricted and require further improvement.

Many European air forces have no bird risk reduction programme at all, so a systematic coverage of bird movements in space and time, interoperability between existing systems and standardisation of signal interpretation are completely missing.

How is 'space' used in FlySafe?

FlySafe incorporates data coming from several sensors to monitor bird movements, such as long-range military surveillance radars, short-range local radar systems, meteorological radars in the OPERA network (Operational Programme for the Exchange of Weather Radar Information) and tracking of individual birds from space. These data sources are complementary to a large extent.

Satellite telecommunications are being used for data transfer in areas where terrestrial infrastructure is unavailable, as well as for tracking individual birds (GPS tags).



↑ The information flow within the FlySafe system

Environmental information is essential when modelling bird migration, so information on meteorological conditions from the European Centre for Medium-range Weather Forecasts (ECMWF) and land cover maps from Earth observation satellites are used to support the interpreting and modelling of bird behaviour and bird migration dynamics.

Data from all the sensors used in FlySafe, including individually tracked birds, ECMWF and landscape data are now stored in a central database. This is the first time that such a large amount of data from different space and terrestrial sensors – including surveillance radars from several countries – has been stored together in one database. The database contains tens of millions of radar tracks. A new web service, 'BirdView', was developed to access this information directly from remote locations and interactively view multiple layers of FlySafe data.

New computer models have been developed to provide bird migration information at various scales. Landscape and land use data from Earth observation satellites as well as ECMWF data are used in these models to simulate the migration patterns of some key bird species over Europe and Africa.

Global tracking of birds from the GPS/Argos system is used to increase the knowledge about bird behaviour and interaction with the environment (Global Positioning System (GPS) tracking devices can transmit data via Argos, a satellite-based communications system that has been in use since 1978).

Regional computer models are predicting the intensity of bird migration over Belgium and the Netherlands. Hourly bird migration intensity forecasts are generated over the next 72 hours by an ensemble forecast of 50 models. These models use hourly updated weather variables forecasted by ECWMF.

FlySafe achievements

To meet FlySafe's objective of reducing the risk of bird strikes, the following issues needed to be addressed:

- federation and coordination of the users and their requirements;
- BIRDTAM standardisation;
- interoperability;
- increased efficiency of operational systems;
- calibration and validation of current sensors;
- development of forecast models to fill gaps caused by lack of real time information.

← Flight paths of gulls tracked from space during FlySafe between June 2007 and January 2008

For the first time since BIRDTAMs were introduced, the four participating air forces are working towards producing internationally coordinated BIRDTAMs.

To use meteorological radar data to track bird migration, simultaneous measurements were conducted between the Swiss Ornithological Institute's bird detection radar, three weather radars in the Netherlands, Belgium and France and two long-range military surveillance radars in the Netherlands and Belgium. These measurements were used to develop algorithms to extract vertical profiles of bird movements from wind profile data that were demonstrated and validated during the activity.

To improve the understanding of the daily and seasonal flight patterns of key bird species, and to test if bird movements around an air force training area are detectable by the medium-powered military radar in northern Holland, the movements of individual birds were tracked in real time.

Fascinating patterns of individual behaviour are already emerging from this study of tagged migrating gulls in the Netherlands. Fourteen lesser black-backed gulls and nine herring gulls trapped at a breeding colony in Vlieland, were tracked from space with GPS/Argos tags. The data show that these birds regularly cross a military training area at low altitudes. All of the lesser black-backed gulls were migrating, mostly to southern Spain (with some via the UK) whereas the herring gulls remained within the Netherlands.

A pre-operational FlySafe system, developed as a web-based service (http://public.flysafe.sara.nl/bambas/index.php) during the project, is now in use by the Belgian and Dutch air forces.

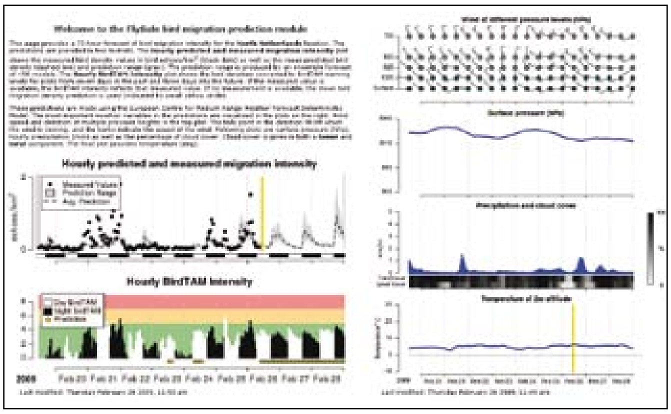
Short-term bird migration density predictions for the evening are announced during the course of the day for night flying. These announcements are treated as 'reliable' BIRDTAM predictions by both air forces with the same consequences for warnings and restrictions as a normal BIRDTAM.

Significantly, BIRDTAM predictions in the range of 5–8 (warnings and restrictions) can result in flight cancellations or even cancellation of all scheduled night flying activities for that specific evening. Thanks to the BIRDTAM predictions, air forces are now able to improve their training programme and avoid last-minute cancellations of, for example, night flight training exercises, which are expensive to prepare.

The Belgian and Dutch air forces have acknowledged the positive results of FlySafe, and have already demonstrated the potential of such approaches to reduce the risk of bird strikes. According to the Belgian Air Component, "FlySafe has already considerably improved the Belgian air force's mission operations, resulting in better flight planning, leading to relevant operational cost savings."

Follow-on for civil aviation

Following the bird strike accident on the Hudson River, in 2009, and inspired by the successful demonstration of FlySafe bird migration pre-operational services, a number of civil aviation authorities from Netherlands, UK, Belgium, Switzerland, Portugal and Germany have expressed their interest in the FlySafe project, enquiring with ESA as to whether FlySafe could be tailored to civil aviation purposes.



↑ The FlySafe web site, http://public.flysafe.sara.nl/bambas/index.php

Based on this user community request, ESA's IAP has initiated 'Bird Strike Risk Reduction for Civil Aviation', a feasibility study to assess the technical as well as the economic and regulatory viability of bird-strike risk reduction services for civil aviation.

The study is being supported by London Heathrow, Amsterdam Schiphol and Manchester Airports. It is also being supervised by the Bird Strike Risk Reduction Advisory Board, comprising representatives and experts from KLM/Air France, the Dutch Airline Pilot Association, Lisbon Airport, the Dutch Civil Airports Association, BAA, the UK Civil Aviation Authority, the Dutch Ministry of Transport, Public Works and Water Management, the UK Food and Environment Research Agency and the Royal Netherlands Air Force.

Future perspectives

The service capabilities demonstrated through FlySafe could pave the way for new developments to serve wider geographic areas and user communities (such as 'GoogleBird'). Many different communities need more comprehensive, easily accessible and interpretable information about bird distribution and movements at different scales and their interaction with the environment.

An essential foundation of a successful bird migration early warning system is the transfer of knowledge from the scientific community to the users, in areas such as flight safety, epidemiology and conservation. Therefore a platform is needed for technological improvements and trans-disciplinary communication and cooperation. Sustainable services could

> **"Imagine a sustainable system, where the tools and information developed and gathered for one purpose are used by many others, serving broad human interests such as public safety, health, science, energy, agriculture, education, conservation and quality of life. That is the vision demonstrated by FlySafe."**

← Almost a serious bird strike: a British Airways Boeing 757 aircraft about to land, apparently through a flock of birds. However, this amazing photo captures an optical illusion, the plane landed safely and no birds were harmed. They were actually some distance away from the aircraft (Adam Samu)

combine various existing bird migration measurement systems, tracking of individual birds from space and ground-based systems, improvement and enhancement of existing technologies, modelling tools, improved access to environmental data and diverse web services.

In flight safety alone, the possibilities for expansion could include all European air forces and those interested in operationally addressing bird hazards to flight safety. Following an invitation from 27 air forces, the FlySafe initiative was presented to the Air Force Flight Safety Committee (Europe), AFFSC(E) and received warm appreciation and several expressions of interest, confirmed by the AFFSCE's recent interest in establishing a dedicated FlySafe sub-committee. AFFSC(E) consists of flight safety representatives from several European air forces as well as the South African Air Force, Canadian forces and European-based elements of the US Air Force.

Civil aviation is a huge community that includes many stakeholders, including airlines, pilots, airports, air traffic control, government and EU transport. In some areas, efforts to reduce bird hazards remain minimal and localised. A coordinated and concerted effort between these various stakeholders is needed in order to make a significant advance in tackling bird hazards to civil aviation in airport vicinities. ESA is well positioned to stimulate and facilitate this task, but these communities are advised to prepare for and look at the sustainability of such a service by using the example of the Belgian and Dutch air forces.

There are numerous groups that need services to study, mitigate and prevent the spread of bird-carried diseases, such as 'bird 'flu' (avian influenza). These diseases can pose a major threat to human health and the world economy, either by directly affecting humans or by affecting our food sources. The World Bank estimates that a human influenza pandemic caused by a virus mutated from avian 'flu could cost the global economy US $800 billion per year.

The spread of bird-carried diseases and parasites may also have direct effects on global biodiversity through the decimation of large populations of birds. However, the true role of migratory birds is unclear, particularly due to the lack of sufficient information needed at large and local scales. International agencies such as the World Health Organization (WHO), the Food and Agriculture Organization (FAO), Wetlands International, the World Organisation for Animal Health (OIE) and the Convention on the Conservation of Migratory Species (CMS) have already shown interest in a potential FlySafe follow-up initiative.

Improvements in the collection, dissemination and interpretation of data are also expected in the near future. For example, it is expected that information on bird movements at population level can be collected from over 150 weather radars in Europe through the OPERA network within a few years.

The successful operational outcome of the FlySafe project has proved that ESA's IAP can play a fascinating role in bringing together user interests and communities. IAP uses a 'win-win' approach that promotes the added value of 'space' in a fair and unbiased way, and supports the development of sustainable space-based services for the benefit of society.

Acknowledgments

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Special thanks to the substantial support of ESA Joint Communication Board (JCB) delegates M. Wagner and S. Bogaerts (BE), G. Nieuwpoort and B. Meijvogel (The NL). The user communities express their gratitude to ESA's Director General Jean-Jacques Dordain, his support and confidence was needed to make the FlySafe project a reality.

→ NEWS IN BRIEF

Liftoff of V195, the 51st Ariane 5 flight on 26 June 2010, from Europe's Spaceport in French Guiana, on its mission to place the Arabsat-5A telecommunications satellite and the multi-mission COMS satellite into their planned transfer orbits

Space pioneer passes away

↑ George van Reeth (1924–2010)

George Pieter van Reeth passed away on 29 August, shortly before his 86th birthday. He had spent 27 years with ESA and its predecessor organisations ESRO and ELDO. He was a key player in the genesis and setting up of ESA itself, and was a force of stability and continuity throughout his long period of service to the European space endeavour.

Born on 29 August 1924 in Herselt, Belgium, he studied civil engineering and then law at the Catholic University of Louvain, obtaining a doctorate in law in 1952. He practised as an attorney at the bar in Antwerp from 1953 until 1962, when he became a legal expert in the NATO Starfighter Monitoring Office in Koblenz, tasked with negotiating and managing contracts for the purchase of electronic equipment.

In 1964, he joined ESRO to organise the Contracts Service at ESTEC, in the Netherlands, which had only just begun to operate. He introduced new forms of contract, and in particular, he adapted incentive contracts and project control methods as practised in the US to the specific European environment. He was instrumental in defining and implementing an industrial policy modified for the requirements of ESRO and later ESA. He played an important role in setting up the European industrial consortia that were, at that time, among the first European joint ventures to be set up in a high-technology field.

In 1972, he became Administrative Director of ELDO and then Acting Secretary General. Entrusted with all formalities relating to the winding down of the organisation, he secured the smooth integration into ESA of ELDO staff formerly involved in the Europa programmes.

He was intensively involved in the drafting of the ESA Convention, which led to the creation of a single agency in 1975. That same year he was appointed ESA's first Director of Administration in Paris. One of his first challenges was to select, and refurbish, the building for the future agency headquarters.

The new organisation needed new procedures for the execution of ESA's activities, in particular the implementation of the optional programmes, which covered legal, contractual and financial aspects. It was under his leadership that these procedures were successfully put in place and approved by Member States. In the 1980s, he encouraged the introduction of substantial changes in Human Resources, including the merit recognition system, negotiation procedures and the Young Graduate Trainee scheme.

In addition to his overall responsibility for the finance, personnel, legal and procurement services, he was involved in all aspects of the European space policy and major decision points such as Ministerial Council meetings.
George also played an important role in the negotiations with NASA for the launch of ESRO's first scientific satellites, which served as a model for the future and in the discussions towards the end of 1969 when the US invited Europe to take part in the post-Apollo programmes, among them Spacelab. Together with Reinhard Loosch (DE), he defended the interests of Europe in the negotiations on the Space Station. He was also a strong supporter of Ariane, and played a leading role in the negotiations on the creation of Arianespace and on the 'rules of the road' for launch service providers.

He was a strong believer in Education and Space History and supported many initiatives in those areas. It was appropriate, therefore, that when he retired from ESA in 1991, he became the first President of the International Space University (ISU). He also served as President of the International Astronautical Federation (IAF) from 1988 to 1990.

For more than a quarter of the 20th century, his impressive stature, allied to a strong and refined character, a renowned competence and close connections with all those who mattered at that time in the sector, enabled successive Directors General and Member State delegations to take with confidence those audacious decisions that shaped the fate of Europe in space. Those who had the privilege of working with George will remember him as an exceptional personality, a great asset to ESA and to the space sector.

Next step to the moon

ESA's lunar lander mission to land in the mountainous and heavily cratered terrain of the lunar south pole, possibly in 2018, took a significant step forward in September when a further study contract was signed with EADS Astrium in Berlin, Germany.

↑ Artist's impression of ESA's Lunar Lander concept

The south polar region of the Moon may be a prime location for future human explorers because it offers almost continuous sunlight for power and potential access to vital resources such as water ice.

The start of this 'Phase-B1' study is an important milestone because now, after the preliminary planning and feasibility studies, the mission's design will be continued under the leadership of EADS Astrium Bremen and some of the key technologies, such as propulsion and navigation, will be developed and tested for the first time.

To reach the surface safely, the lander must precisely navigate its way to a mountain peak or crater rim, carefully avoiding boulders and steep slopes before gently setting down to take some of the most spectacular views in the Solar System.

The Moon is a favoured target for the human exploration missions outlined in the 'Global Exploration Strategy' by 14 space agencies around the world. This strategy supports international space exploration and calls for further studies of the Moon and Mars – places where humans will one day live and work.

The aim of ESA's proposed precursor mission is to probe the unknown moonscape and test new technology to prepare for future human landings.

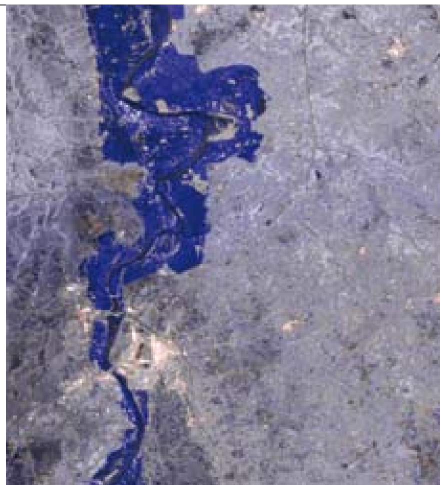
The study contract will provide the basis for the final design of the mission and lander, which will be presented to ESA's Ministerial Council meeting in 2012 for full approval.

Earth observation aids Pakistan

Devastating around a third of the country, the floods in Pakistan have affected up to an estimated 20 million people. To support humanitarian relief, data from a range of Earth observation satellites have been used to generate essential maps of the flooded areas

These floods are arguably the worst in living memory, leaving many hundreds dead and millions homeless or marooned as villages and infrastructure have washed away. The latest satellite imagery is being used to show how far the flood waters have spread, enabling rescue teams on the ground to identify the best way to access those stranded and in need. This is especially important because this year's floods have affected such a vast area.

Typically, maps are created using radar imagery such as that acquired by ESA's Envisat Advanced Synthetic Aperture Radar 'ASAR', which can see through cloud and darkness, as well as from optical instruments.



↑ This image shows a 100×500 km strip of the flood area in Pakistan, seen by Envisat in August with inundated regions in blue

Journey to the 'Red Planet'

Mars500 is the first full-length simulated mission to Mars and, on 15 September, the crew celebrated their first 105 days in isolation since the hatch to their Mars 'spacecraft' was closed.

Six international crewmembers are sealed in a spacecraft mock-up, housed in Russia's Institute for Biomedical Problems (IBMP) near Moscow, for a 520-day simulated mission to Mars that began on 3 June. With only 550 m³ of space inside, this simulator doubles as an interplanetary spaceship, a Mars lander and a martian landscape.

The crew are experiencing a mission that is as close as possible to a real space voyage to Mars without leaving Earth. Living and working like astronauts, eating special food and exercising in the same way as crews do on the International Space Station, are Diego Urbina (Italian/Colombian, 27) and Romain Charles (French, 31), both selected by ESA, with Russians Sukhrob Kamolov (32), Alexei Sitev (38), Alexander Smoleyevski (33) and Wang Yue (26) from China.

Their mission is to 'fly to Mars' in 240 days, 'land on and explore Mars' for a month and 'return to Earth' in 250 days, using their imitation interplanetary spacecraft, lander and martian surface. The study, in other words, recreates the exact timeline that a real mission to Mars would require. The 'departure' from Earth's orbit took place on 14 June and the 'landing' on Mars is planned for 10 February 2011. The entire 'mission' should last 520 days, with the crew expected to 'land' back on Earth on 5 November.

While onboard, the crew must manage to use the food and equipment stored in the facility. Only electricity, water and some air are fed into the compartments from outside.

In addition to testing many novel technologies, such as telemedicine equipment that may have applications for remote areas on Earth, Mars500 is an extreme test of human endurance. Staying almost 18 months inside the metal containers will be hard for the crew, even after their training by astronauts and submariners. In one of his online mission diaries, Charles Romain said, "I have received a lot of advice from experts to help me cope with the isolation. I really appreciate and understand them now. The main advice that I heard from everyone is: stay busy, be careful with your health and keep a normal day/night schedule."

↑ Romain, Yue, Diego and Alexander preparing an EEG recording, a measurement of electrical activity along the scalp produced by the firing of neurons in the brain

The crew will no doubt have their ups and downs during the long mission, and these psychological changes are a key part of the experiment. They divide their weekdays equally between work, free time and rest, with the weekends usually free. Because a closed environment with restricted space can quickly lead to a poor physical condition, the crew exercise up to two hours a day, and monitor their condition on a regular basis. The latter consists of blood and urine analysis, blood pressure measurements and other simple medical checks.

The crew have roughly 100 experiments to perform during this isolation study on behalf of the scientists involved in Mars500. One of the experiments

"Is there a doctor on the plane?"

→ Key information about passenger health can be transmitted via satellite to a dedicated response centre

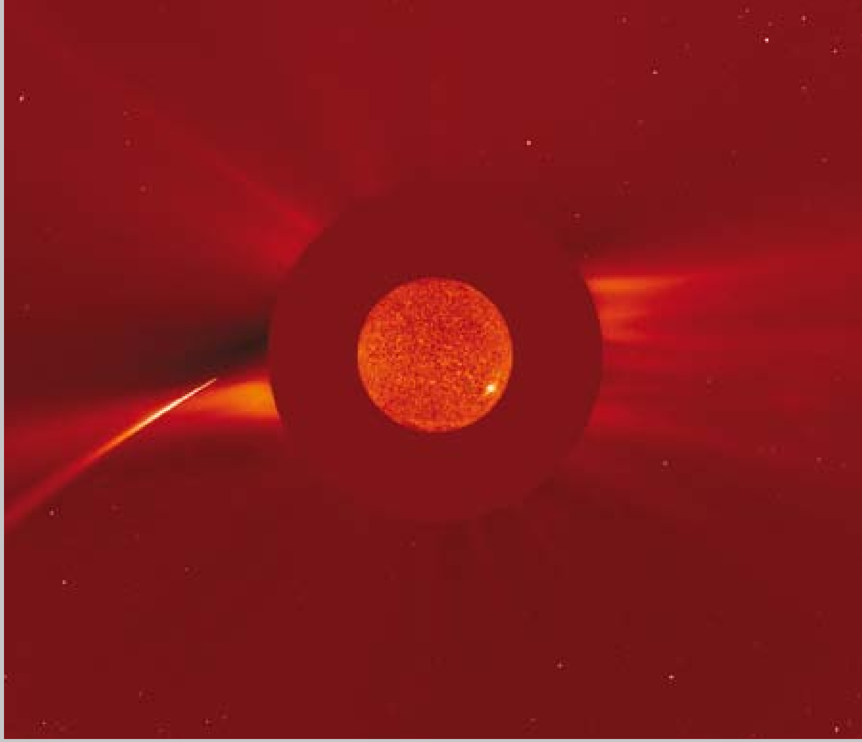
This request over aircraft speakers is the traditional response to a potential onboard medical emergency. But now the availability of expert medical advice can be guaranteed every time.

Etihad Airways, national carrier of the United Arab Emirates, is the latest airline to install the ESA-derived Tempus IC telemedicine system on its long-haul flights. ESA supported involves, for example, 'electro-encephalography' (EEG) to assess whether exercise can be used as a countermeasure to psycho-physiological deconditioning during long-term confinement.

For this experiment, EEG and cognitive tests are made before and after exercise, to see how exercise can help the crew cope with the psychological problems of isolation. Finally, the crew have been trained to operate the control systems of their 'spacecraft', also carrying out any maintenance tasks to subsystems or other as required.

Mars500 is an important part of Europe's pathway to exploration. Paving the way for human exploration activities in space, such as future missions to the Moon and Mars, is one of the main aims of ESA's Directorate of Human Spaceflight. ESA has a long tradition of conducting research on the physiological and psychological aspects of spaceflight.

Ultimately, the purpose of the Mars500 study is to gather data, knowledge and experience in order to prepare for a real mission to Mars. It will help to determine key psychological and physiological effects of being in such an enclosed environment for an extended period of time. Making sure that astronauts are prepared mentally and physically for the demands of long-duration exploration missions is imperative to a mission's success.



SOHO's 2000th comet

Take part in a history-making comet-discovering mission, by predicting the date and time SOHO's 2000th comet will appear.

Even though SOHO's primary target is the Sun, its LASCO coronagraph instrument has become the most prolific comet discoverer in history.

Since LASCO began observations in January 1996, it has observed over 1900 comets. The majority of these comets belong to the Kreutz group of sungrazing comets. The 'Kreutz Sungrazers' are a family of comets characterised by orbits taking them extremely close to the Sun at perihelion. They are believed to be fragments of one large comet that broke up several centuries ago and are named after the German astronomer Heinrich Kreutz, who first demonstrated that they were related.

To celebrate this outstanding achievement of SOHO/LASCO, we invite you to predict the 2000th SOHO comet - and win a prize! Enter the SOHO 2000th Comet Contest at **http://soho.esac.esa.int/comet2000**

the development of the technology in collaboration with the UK manufacturer RDT. Already in service with numerous airlines, the briefcase-sized Tempus IC telemedicine system puts non-medical cabin crew in contact with ground-based experts during in-flight medical emergencies.

Key information about a passenger's health can be quickly transmitted via satellite to a dedicated response centre. The same vital signs which are measured routinely in a hospital emergency room, including blood pressure and sugar levels, temperature and heart rate, are captured to a clinical level of quality. At the same time, the crew can also talk with the medical specialists and send them both still and moving pictures of the situation.

Imagine a long-haul flight passenger complaining of acute shoulder pain: they may just have strained his muscles lifting too much luggage – or they could be experiencing a heart attack. With the rise of larger aircraft and lower air fares, the number of people of all ages travelling by air is increasing," explained Graham Murphy, CEO of RDT.

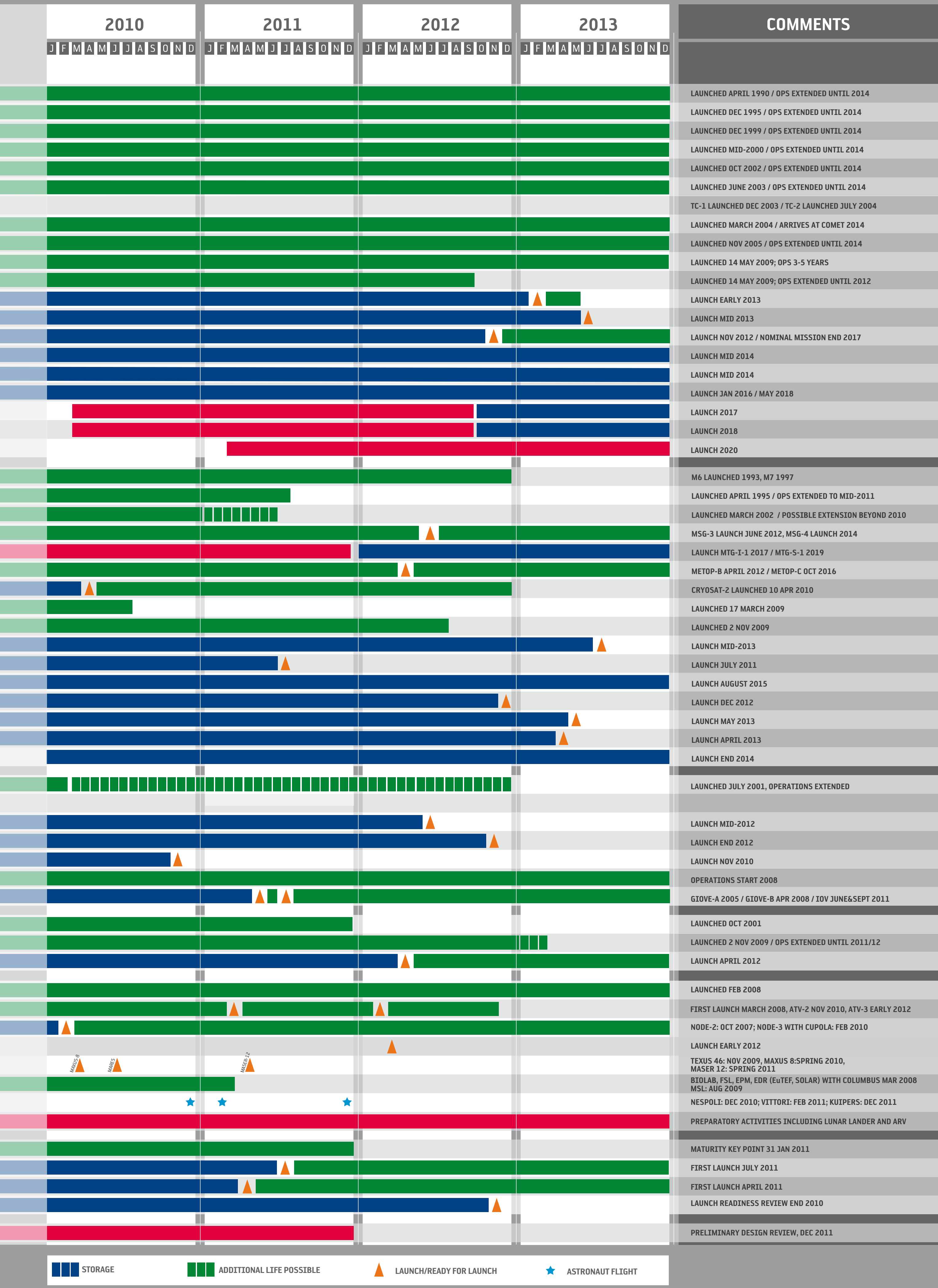
"As a result, the probability of a medical emergency occurring in flight has risen, and the pilot will often divert the flight to the nearest airport where medical attention can be provided. In simple terms, better diagnosis directly benefits the airline and its passengers."

→ PROGRAMMES IN PROGRESS

Status at end of September 2010

Parts of Europe and Africa seen at night from the Cupola on the International Space Station, 400 km above Earth on 28 October. The view looks northward over Sicily and the 'boot' of Italy, with the Adriatic Sea and Greece on the right and Tunisia partially visible on the left


2006
2007
2008
2009
J F M A M J J A S O N D
SCIENCE & ROBOTIC EXPLORATION PROGRAMME
HUBBLE
SOHO
XMM-NEWTON
CLUSTER
INTEGRAL
MARS EXPRESS
DOUBLE STAR
ROSETTA
VENUS EXPRESS
HERSCHEL
PLANCK
LISA PATHFINDER
MICROSCOPE
GAIA
JWST
BEPICOLOMBO
EXOMARS
COSMIC VISION M1
COSMIC VISION M2
COSMIC VISION L1
EARTH OBSERVATION PROGRAMME
METEOSAT-6/7
ERS-2
ENVISAT
MSG
MTG
METOP
CRYOSAT
GOCE
SMOS
ADM-AEOLUS
SWARM
EARTHCARE
SENTINEL-1
SENTINEL-2
SENTINEL-3
SENTINEL-5 PRECURSOR
TELECOMMS/NAVIGATION PROGRAMMES
ARTEMIS
ALPHABUS
ALPHASAT
SMALL GEO SAT.
HYLAS
GNSS-1/EGNOS
GALILEO
TECH. PROG.
PROBA-1
PROBA-2
PROBA-V
HUMAN SPACEFLIGHT PROGRAMME
COLUMBUS
ATV
NODE-2 / NODE-3 / CUPOLA
ERA
EMIR/ELIPS
FOTON-M3
TEXUS-44
TEXUS-45
MASER-11
TEXUS-46
MFC
ASTRONAUT FLIGHT
TRANSPORTATION & HUMAN EXPLORATION
LAUNCHER PROGRAMME
ARIANE 5 POST-ECA / DEVELOPMENT STEP 1
VEGA
SOYUZ AT CSG
IXV
SSA
PREPARATORY PROGRAMME
DEFINITION PHASE
MAIN DEVELOPMENT PHASE
OPERATIONS


2010
2011
2012
2013
J F M A M J J A S O N D
COMMENTS
LAUNCHED APRIL 1990 / OPS EXTENDED UNTIL 2014
LAUNCHED DEC 1995 / OPS EXTENDED UNTIL 2014
LAUNCHED DEC 1999 / OPS EXTENDED UNTIL 2014
LAUNCHED MID-2000 / OPS EXTENDED UNTIL 2014
LAUNCHED OCT 2002 / OPS EXTENDED UNTIL 2014
LAUNCHED JUNE 2003 / OPS EXTENDED UNTIL 2014
TC-1 LAUNCHED DEC 2003 / TC-2 LAUNCHED JULY 2004
LAUNCHED MARCH 2004 / ARRIVES AT COMET 2014
LAUNCHED NOV 2005 / OPS EXTENDED UNTIL 2014
LAUNCHED 14 MAY 2009; OPS 3-5 YEARS
LAUNCHED 14 MAY 2009; OPS EXTENDED UNTIL 2012
LAUNCH EARLY 2013
LAUNCH MID 2013
LAUNCH NOV 2012 / NOMINAL MISSION END 2017
LAUNCH MID 2014
LAUNCH MID 2014
LAUNCH JAN 2016 / MAY 2018
LAUNCH 2017
LAUNCH 2018
LAUNCH 2020
M6 LAUNCHED 1993, M7 1997
LAUNCHED APRIL 1995 / OPS EXTENDED TO MID-2011
LAUNCHED MARCH 2002 / POSSIBLE EXTENSION BEYOND 2010
MSG-3 LAUNCH JUNE 2012, MSG-4 LAUNCH 2014
LAUNCH MTG-I-1 2017 / MTG-S-1 2019
METOP-B APRIL 2012 / METOP-C OCT 2016
CRYOSAT-2 LAUNCHED 10 APR 2010
LAUNCHED 17 MARCH 2009
LAUNCHED 2 NOV 2009
LAUNCH MID-2013
LAUNCH JULY 2011
LAUNCH AUGUST 2015
LAUNCH DEC 2012
LAUNCH MAY 2013
LAUNCH APRIL 2013
LAUNCH END 2014
LAUNCHED JULY 2001, OPERATIONS EXTENDED
LAUNCH MID-2012
LAUNCH END 2012
LAUNCH NOV 2010
OPERATIONS START 2008
GIOVE-A 2005 / GIOVE-B APR 2008 / IOV JUNE&SEPT 2011
LAUNCHED OCT 2001
LAUNCHED 2 NOV 2009 / OPS EXTENDED UNTIL 2011/12
LAUNCH APRIL 2012
LAUNCHED FEB 2008
FIRST LAUNCH MARCH 2008, ATV-2 NOV 2010, ATV-3 EARLY 2012
NODE-2: OCT 2007; NODE-3 WITH CUPOLA: FEB 2010
LAUNCH EARLY 2012
MAXUS-8
MARES
MASER-12
TEXUS 46: NOV 2009, MAXUS 8:SPRING 2010,
MASER 12: SPRING 2011
BIOLAB, FSL, EPM, EDR (EuTEF, SOLAR) WITH COLUMBUS MAR 2008
MSL: AUG 2009
NESPOLI: DEC 2010; VITTORI: FEB 2011; KUIPERS: DEC 2011
PREPARATORY ACTIVITIES INCLUDING LUNAR LANDER AND ARV
MATURITY KEY POINT 31 JAN 2011
FIRST LAUNCH JULY 2011
FIRST LAUNCH APRIL 2011
LAUNCH READINESS REVIEW END 2010
PRELIMINARY DESIGN REVIEW, DEC 2011
STORAGE
ADDITIONAL LIFE POSSIBLE
LAUNCH/READY FOR LAUNCH
ASTRONAUT FLIGHT

KEY TO ACRONYMS

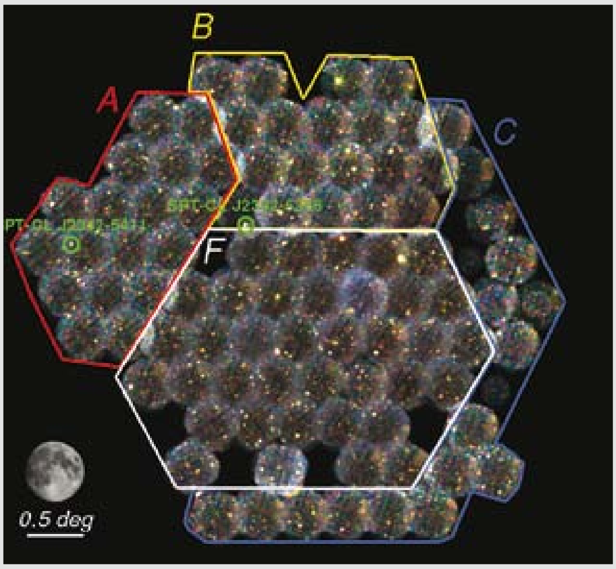
AM	Avionics Model	MoU	Memorandum of Understanding
AO	Announcement of Opportunity	PDR	Preliminary Design Review
AU	Astronomical Unit	PRR	Preliminary Requirement Review
CDR	Critical Design Review	QM	Qualification Model
CSG	Centre Spatial Guyanais	SM	Structural Model
ELM	Electrical Model	SRR	System Requirement Review
EM	Engineering Model	STM	Structural/Thermal Model
EQM	Electrical Qualification Model	TM	Thermal Model
FAR	Flight Acceptance Review		
FM	Flight Model		
ITT	Invitation to Tender		

→ XMM-NEWTON

ESA's X-ray observatory XMM-Newton has discovered two massive galaxy clusters, confirming a previous detection obtained through observations of the 'Sunyaev-Zel'dovich effect', the 'shadow' they cast on the Cosmic Microwave Background. The discovery is the first result obtained using a novel 'mosaic' observing mode introduced recently on XMM-Newton.

The new observing mode allows large areas of the sky, much larger than the field of view of the cameras on the spacecraft, to be surveyed in a very efficient way. This is achieved with a single calibration measurement, performed at the beginning of the observing series and taking up to one hour, which is then applied to all adjacent fields that are subsequently observed. This is much cheaper in terms of observing time than the previous mode, in which the calibration measurements were performed for each field individually, taking up to one hour for each observation.

This new mode can be applied to observations of several astrophysical environments (for example galaxy clusters, supernova remnants, crowded fields) which require large areas of the sky to be surveyed with exposure times from a few minutes to a couple of hours.



This XMM-Newton image, showing more than 100 galaxy clusters, was obtained using the new mosaic observing mode. The survey targeted a patch of the sky about 70 times the area of a full Moon (the size of the Moon is shown for comparison). The green circles mark the positions of two new massive galaxy clusters. This false-colour image was constructed from the X-ray intensities in 3 bands: 0.3–0.5 keV (red), 0.5–2.0 keV (blue) and 2.0–4.5 keV (green), respectively. Regions A, B and C mark the three large fields covered by new mosaic mode observations. Region F identifies the deeper core of the survey

→ CLUSTER

The Cluster spacecraft will begin a very long eclipse season this autumn, from October through to July 2011. During the next few months, Cluster will move back to the dayside magnetosphere to target the solar wind with a tetrahedral configuration at scales of around 5000 km.

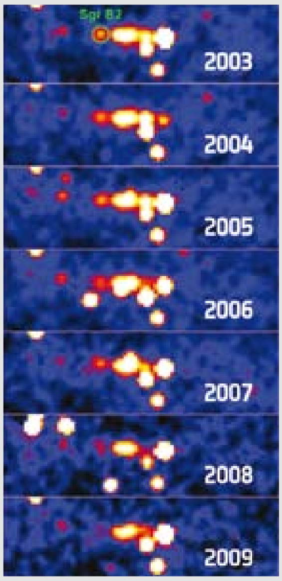
The Cluster Active Archive (CAA) continues its growth, approaching 1100 users. The 12th Cross Calibration meeting will be held in Toulouse at the end of October. The cross-calibration activity is a cornerstone of the CAA and provides momentum to ensure the highest quality data is provided by the CAA.

Cluster celebrated its 10th anniversary during the summer. The last ten years have seen a wealth of scientific output, which continues with strength and quality, recently passing 1300 refereed publications.

→ INTEGRAL

Integral operations continue smoothly with the spacecraft, instruments and ground segment all performing normally. The next SPI annealing will take place from 10–28 October.

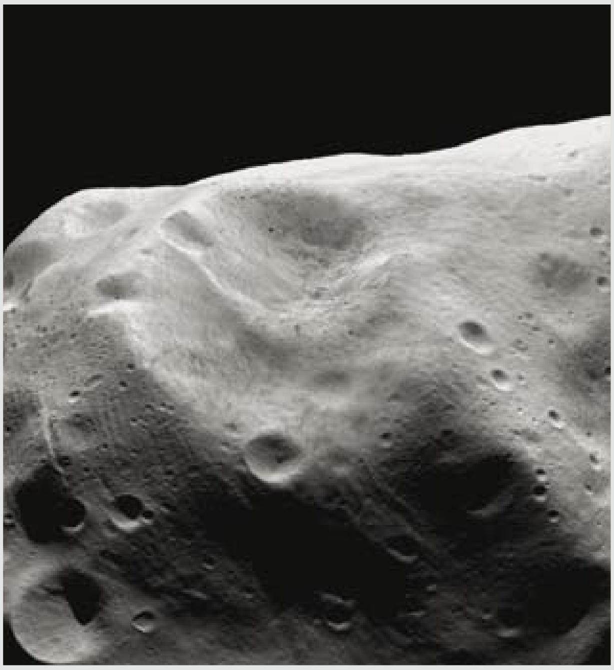
Recent Integral results established that the behaviour of the supermassive black hole Sgr A* resembles that of a Low Luminosity Active Galactic Nucleus and it might become brighter again in the future. Hard X-rays from the giant molecular cloud Sgr B2 are best interpreted as scattering of radiation emitted by Sgr A*. Integral discovered that its fading non-thermal emission likely traces the end of the past activity of Sgr A* about 100 years ago. Along with XMM-Newton measurements of the Fe K-line variability from other clouds of this region (G. Ponti et al., ApJ 714, 732, 2010), this discovery allowed both the strength and duration of this past activity to be determined.



Integral/IBIS 20–60 keV views of the Galactic Centre from 2003 to 2009. Most of the sources are X-ray binary stars and display strong time variability. The green circle corresponds to the position of the molecular cloud Sgr B2. The associated hard X-ray source, IGR J17475-2822, shows a clear decline in flux during the seven years of monitoring (R. Terrier et al., ApJ 719, 143, 2010)

→ ROSETTA

After the successful flyby of asteroid (21) Lutetia, the data analysis continues. Results reported at various conferences confirm that an excellent scientific outcome has been achieved. Images from the OSIRIS cameras reveal that the surface of the asteroid is covered by a 'regolith', a layer of loose dust, soil and rocks similar to that discovered on other planetary surfaces and the Moon, estimated to be at least 600 metres thick. In the younger, hence more recently resurfaced regions, there are craters which are completely buried by this regolith blanket. The thick regolith influences the thermal behaviour of the asteroid. Measurements by the MIRO instrument show that the thermal inertia values are consistent with values of regolith powder observed on the Moon.



The surface of asteroid (21) Lutetia as seen by Rosetta (ESA/ MPS/ OSIRIS team)

Geomorphological investigations have already led to the identification of a great number of distinct geological features on (21) Lutetia, such as boulders, scarps, ridges, faults and grooves. Pit-chains and landslides have also been found. From the analysis of the radio science experiment it was possible to determine the mass of the asteroid and, together with the volume obtained from the OSIRIS images, the density of (21) Lutetia was found to be about 3.4 g/cm^3.

→ VENUS EXPRESS

A new model of the density of the atmosphere of Venus in the altitude range 100–250 km has been constructed, based on new measurements by Venus Express. These measurements show that the density is up to 60% less than that predicted by the previous best model. These measurements have been carried out with the new 'torque measurement' technique developed recently by the Venus Express team.

Performed at altitudes below 200 km, this technique involves flying with one solar panel turned fully to the flight direction and the other panel edge-on, so that molecules of the thin upper atmosphere create a torque on the spacecraft for about three minutes around the lowest altitude. This method is very sensitive and allows a full trace of the density of the atmosphere to be measured every time the spacecraft comes near the pericentre.

Artist impression of Venus Express, flying with one solar panel turned to fully to the flight direction and the other panel edge -on, in the thin upper atmosphere of Venus

The reason for the lower-than-expected density is not fully understood, but it is likely to be a result of how the model was constructed, using data from earlier missions that measured primarily in the equatorial region. The present low solar activity may also play a role. In October, Venus Express will reach its lowest-ever altitude above the surface of Venus: 165 km! This will provide even more and better opportunities for additional density measurements in this unexplored but important region of the venusian atmosphere.

The Japanese Venus Climate Orbiter, Akatsuki, was launched on 21 May. It is due to arrive in orbit around Venus on 7 December. Joint operations between Akatsuki and Venus Express will start in January 2011 and will cover a large number of different cases, including simultaneous observations at different scales, differential radio science observations, long-term chained tracking of cloud patterns, spectral versus large-scale imaging observations and cross-calibration. Several of these observations will also be coordinated with observers at a number of the world's leading ground-based observing facilities.

An elongated crater on Mars, as seen by the High-Resolution Stereo Camera on ESA's Mars Express in July 2009. This feature, about 75 km long, is in a region north-west of the Hellas impact basin and south of the Huygens crater, approximately at 21°S, 55°E. Its oval shape is most likely due to a meteoritic body hitting the surface of Mars at a very shallow angle. This false colour image results from merging a high-resolution nadir image with a lower-resolution three-colour image and has a resolution of 16 m per pixel.

→ HERSCHEL

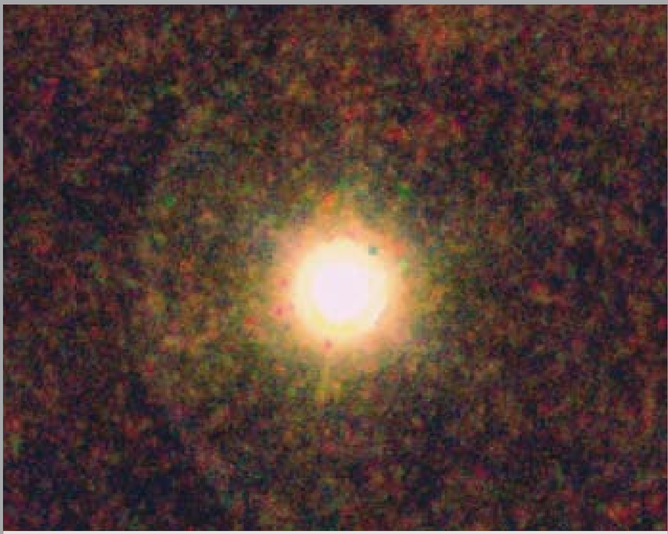
Herschel passed the mission 500-day mark some time ago, and is performing routine science observations with its three instruments: PACS, SPIRE and HIFI. All Herschel data are archived in the Herschel Science Archive and a bulk reprocessing of all available data started recently (about eight days of data can be reprocessed every day, so this will take roughly two months to complete).

The first in-flight call to the worldwide astronomical community for open time observing proposals was issued by the Herschel Science Centre on 20 May with submission deadline on 22 July. The 576 proposals received, collectively written by about 2400 astronomers, are currently being evaluated by the Herschel Observing Time Allocation Committee.

In addition to the 'Herschel First Results' symposium held on 4–7 May at ESTEC, special invited talks and Herschel special sessions have featured prominently in several other major symposia, acknowledging the importance of Herschel scientific results already achieved. The *Astronomy & Astrophysics* 'Herschel Special Issue' was published (July–August 2010) containing 152 papers, followed by the *Astronomy & Astrophysics* 'HIFI Special Feature' (September 2010) with an additional 50 papers.

The first scientific result based on Herschel to be published in *Nature* (Decin et al. 467, 64, September 2010) was the detection of warm water vapour around the evolved carbon star IRC+10216 (CW Leo). Cold water vapour, speculated as originating from evaporation of comet-like bodies, had been detected surprisingly around this aging star earlier in a single spectral line.

The Herschel observations using PACS and SPIRE detected 61 lines, some indicating a temperature of around 1000K, placing them very close to the stellar photosphere. The presence of this hot water cannot be explained by the original hypothesis. The new explanation involves a 'clumpy' structure of the circumstellar matter, enabling



Combined Herschel PACS and SPIRE image of the evolved carbon star IRC +10216. Blue represents PACS 160 µm data, while green and red are SPIRE 250 and 350 µm data. In this image, the stellar wind can be studied around the star with the interaction with the interstellar medium. The incomplete arc on the left of the image is a bow-shock formed at the interface between the two (ESA/PACS/SPIRE/MESS)

a fraction of the interstellar ultraviolet radiation field to penetrate all the way down to where the water is not only observed, but actually formed. The ultraviolet radiation is the critical ingredient in the chain leading to the formation of the hot water detected by Herschel.

→ PLANCK

Planck has essentially completed two full surveys of the whole sky so far. The LFI and the HFI Data Processing Centre (DPC) are exchanging data regularly for cross-calibration and joint processing. The data processing pipelines in each of the two DPCs are working routinely from end to end. Constant improvements are being incorporated regularly into the pipelines to account for and correct subtle systematic effects as these become understood.

The Early Release Compact Source Catalogue (ERCSC) is currently being generated by the two DPCs. It will be delivered to ESA on 1 December and released to the public on 11 January 2011. This first data delivery by the Planck consortia will undergo a formal review in early November. The first Planck public conference, 'The millimetre and sub-millimetre sky in the Planck mission era' is being organised, taking place in Paris, Cité des Sciences, 10–14 January 2011 (**www.planck2011.fr**). The ERCSC will be released during this conference, together with a number of scientific articles on non-cosmological topics.

→ COROT

The CNES/ESA COROT satellite is operating normally. It has been 'slewed' (turned) toward its 'winter' targets in the constellation of Monoceros, where a detailed asteroseismological study is planned of a bright solar analogue, an M-dwarf star, hot A and B-type stars, as well as a number of giant stars. This is in addition to the search for exoplanets in yet another field.

COROT has now discovered about 20 transiting exoplanets orbiting solar-type stars and the following-up process is ongoing with another 60–70 candidates. The discovered planets and their host stars are being studied in detail by the exoplanet research community. The first asteroseismic discovery of a magnetic activity cycle in a Sun-like star was reported recently.

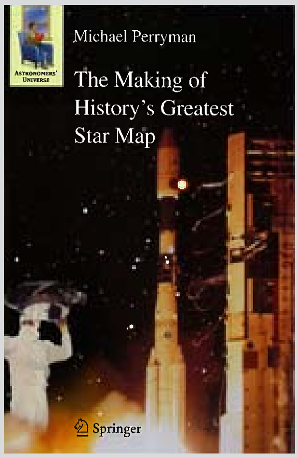
→ GAIA

The folding optics structure, which will later accommodate part of the Gaia optics, has been glued on the 'torus' (optical bench). Six of the ten FM mirrors have been delivered and the other two are expected in October. A major achievement was the delivery of the first large primary mirror. All flight CCDs have been delivered and the coupling tests with front-end electronics are taking place.

Integration of the Focal Plane SM was completed and it has been shipped to Intespace where it will be subjected to the mechanical tests. The SM contains a full

Hipparcos achievements book

ESA's Hipparcos mission was pivotal in mapping our galaxy, the Milky Way. After a devastating blow soon after launch, Hipparcos was ultimately a stunning triumph. Now, a fascinating account by Michael Perryman, ESA's Hipparcos Project Scientist, takes us through the history of star maps, Europe's ground-breaking mission, its achievements and what comes next.



For more about *The Making of History's Greatest Star Map* (ISBN 978-3-642-11601-8, 275pp) see **www.springer.com**

One of Gaia's two primary mirrors during the final inspection (Sagem)

detection chain (one CCD and its electronics), therefore the electrical performances will also be verified after vibration. The first of seven Video Processing Unit FMs (the scientific onboard computer) was delivered. It contains the final version of the science software.
The characterisation test campaign of the micropropulsion thrusters at Onera was completed. Results showed a better-than-expected accuracy of the balance facility and good performances of the microthrusters.

The Service Module FM was delivered by Astrium Ltd (Stevenage) to Astrium SAS (Toulouse) with chemical propulsion and part of the micropropulsion hardware integrated. Integration of the electronics units has started. CDRs for all units and modules are closed. The collocation of the system CDR took place in Toulouse at the end of September. The CDR itself took place in October.

→ LISA PATHFINDER

After completion of the transfer-orbit thermal test, the LISA Pathfinder launch composite has been shipped back to Astrium Ltd (Stevenage). The Propulsion Module FM is stored until next use at the end of the year for the system mechanical test campaign preparation. This third system test (after the magnetic system test early this year and the transfer-orbit thermal test) will submit the flight configuration of the Propulsion and Science Modules to the qualification sine load environment, to prove system compatibility with the load induced by the Vega and Rockot launchers. The Science Module FM is now in final integration, with all the platform units integrated and the LISA Technology Package (LTP) payload electronic units being installed as they are made available. The LTP central core assembly, comprising the inertial sensors and the optical bench interferometer, will be replaced by a dummy mass for this test, which will be carried out at IABG facilities in 2011.

In the meantime, the functional verification of the spacecraft is progressing, at both Real-time Test Bench and Software Verification Facility levels, in order to prepare for the start of the first integration system test which will take place around November this year. A new version of the software has been delivered for platform operations, while the final version, which will include the payload operations and the Failure Detection, Isolation and Recovery (FDIR), will be available in spring next year in time for the on-station thermal vacuum test.

The micropropulsion system is progressing with the delivery of all three flight Power Control Units and Neutraliser units. The FEEP thruster will start the second lifetime test in October, to confirm the performance obtained in the first lifetime test two years ago. If successful, the formal qualification of the thruster will start, followed by the production of the flight units.

The US Disturbance Reduction System payload flight hardware was previously integrated on the Science Module. All suppliers of the electronics units for the European LISA Technology Package (LTP) have delivered their units to Astrium GmbH. The Optical Metrology Subsystem FM was tested at the Albert Einstein Institute in Hanover. After a test of the Caging Mechanism Assembly QM, the manufacturing of the FM parts started. However, a series of non-conformances has forced a halt to the FM integration and a review of the manufacturing methods and processes is being carried out. Owing to the delay of some LTP components, the launch of LISA Pathfinder cannot take place before early 2013.

Complete integrated NIRSpec flight instrument before cover integration

→ MICROSCOPE

The preparatory freefall drop tests of the T-SAGE sensor unit QM at ZARM have restarted after a required repair on the sensor after the first activities. The final qualification drop-test is planned for December this year.
The Phase-B1 of the micropropulsion system started at Thales Alenia Space in September. In parallel, CNES is performing the definition of the feed system and tanks. ESA began the procurement process in October.

At satellite level, CNES is performing a study to compare two solutions of installation of the propellant tanks (either internal or external to the lateral panels). CNES is reviewing the Picard star sensor performance to evaluate if a third optical head is required for Microscope.

MIRI instrument ready for vibration test

→ JAMES WEBB SPACE TELESCOPE

Significant technical progress has been achieved on the NASA side. All the primary mirror segments have completed their initial polishing. Twelve mirror segments are in final polishing to eliminate the deformation measured during the cryo-testing. The Integrated Science Instrument Module FM has undergone cryo-stability testing and cryo-proof load testing is ongoing. The correlation of the thermal tests of the hot/cold transition region is completed and test correlation of the 1/3 Sun shade test model is ongoing. All Deep Space Network (DSN) 32 m antennas have been upgraded to support the Ka-band link. In summary, 75% of the flight mass is in manufacturing, integration or test.

All NIRSpec instrument flight subassemblies have been delivered and integrated, including the NASA micro-shutter assembly and the detector system. The Mandatory Inspection Point before cover closure was successful and the next step is the vibration test at the end of October.

The flight spare detector chips have been selected and the build- up of a flight spare detector is ongoing. The flight detector performance remains a concern and a possible exchange with the flight spare will be considered after completion of the flight spare detector characterisation. All MIRI instrument flight subassemblies, with the exception of the detector system from JPL, have been already delivered and integrated. Dummy-mass detectors have been integrated and the formal instrument acceptance test campaign has started. The vibration test is ongoing and the first axis has been passed. The flight detector will be delivered at the end of 2010 and will be integrated before the cryo-acceptance test.

BepiColombo MMO Thermal Model in the Large Space Simulator at ESTEC

MPO Structural Thermal Model in static load test

→ BEPICOLOMBO

The manufacture of the STMs is at an advanced stage. The MMO Sunshield (MOSIF) TM structure is ready for painting and delivery, in time for the 10 Solar Constant test together with the MMO planned before Christmas. The MPO structure completed the static load test, demonstrating better stiffness than analysed. The MTM structure manufacturing is proceeding and its CDR completed. While the high-temperature Multi-Layer Insulation (MLI) for the MOSIF is expected for the thermal test, the MLI delivery for the MPO and MTM is likely to be late due to the complex manufacturing process. Vibration tests on the MLI confirmed the generation of debris from the Nextel outer-blanket layer. Because no alternative material for large spacecraft surfaces in the high-temperature Mercury environment will be available in time, local design changes to reduce application of Nextel and to protect sensitive payload apertures are being investigated.

Manufacturing of spacecraft EQM equipment is well under way but, in order to meet the demanding schedule, the model philosophy for some equipment was adapted. System-level work on the Engineering Test Bench is starting with the integration of the Onboard Computer and the Solid-state Mass Memory. Power analysis, renewed after optimisation of the solar cell layout, shows a slight improvement of benefit to the payload operations. The neutraliser anomaly of the electric propulsion system can be resolved with single neutraliser operation in 'spot mode', which avoids noise and lifetime impact. Design changes were initiated and a twin engine test-firing was begun to demonstrate correct operation of a single neutraliser. The pre-shipment review of the MPO payload STM was completed, meaning 6 out of 11 instruments are ready to be delivered. In addition, one EM instrument pre-shipment review was completed. The remaining delivery dates for the instrument models are in line with the corresponding system-level integration and test campaigns.

The MMO TM arrived at ESTEC on 15 September for its first test at 10 Solar Constants in the Large Space Simulator. The spacecraft was prepared by Japanese engineers from JAXA and NEC, and the test progressed as planned. The MMO equipment and subsystem-level CDR is ongoing. The procurement of the flight launch adapter with Arianespace, to be used in 2011 in the spacecraft STM campaign, was initiated. Launch is planned in the Mercury launch opportunity in mid-2014.

→ EXOMARS

The ExoMars programme was consolidated with final agreement with the prime contractor in August for the second extension of the Phase-B2 (Phase B2X2). Schedule and technology-critical procurement began for Advance C/D slice 2 which runs in parallel to Phase B2X2 activities until 31 March 2011. The next milestone of Phase B2X2 is the System PDR planned for October to December. The planning for this major review was agreed with the Inspector General's office and, as part of the international cooperation with NASA, participation of NASA Jet Propulsion Laboratory (JPL) is expected with top-level NASA managers as board members

An area east of Moscow, Russia, with smoke plumes from burning peat fields and forest fires visible in this Envisat image, taken on 29 July. The city itself is seen in the bottom left corner. The smoke plumes are several hundred kilometres long

with ESA department heads. An industrial day was organised by the prime contractor, Thales Alenia Space Italy, in Turin in September and a large turn-out by European industry attests to the interest that ExoMars has generated in industry.

Five instruments were selected for the ExoMars Trace Gas Orbiter after the Announcement of Opportunity. Four of the instruments are funded by NASA, while the fifth is a European instrument led by Belgium. Meetings were held between ESA and NASA to establish the basic parameters of the instrument management, and to confirm the NASA provision of a Ka-band telecommunications package in the Orbiter. A first meeting was held at Kennedy Space Center to discuss the potential launcher for the ExoMars 2016 mission, NASA JPL as procuring agent and launch authorities. The Entry, Descent and Landing Module Demonstrator design advanced, with an Announcement of Opportunity for Surface Science Sensors expected in late 2010.

For the 2018 mission, discussions continue to establish the NASA architecture while ESA is trying to maintain the investments associated with the existing Rover design by keeping the boundaries of the present design. However, some Rover Module modifications are necessary for the new physical layout of the 2018 mission, as well as to incorporate Participating State instruments. This has resulted in a risk of mass increase with respect to the 300 kg limit agreed with NASA. The Rover Vehicle contractor (ASU) must reduce the risk of mass growth. Development of the ESA Rover is progressing towards shipment to NASA JPL for their integration operations in 2016.

→ ERS-2

Originally designed to monitor Earth for just three years, ERS-2 is still in orbit and going strong after 15 years of delivering essential data. Beside the ATSR-2 failure of February 2008 (having delivered sea-surface temperature data to a precision of 0.1K), all instruments are performing to specifications. The platform still has more than 50% of fuel still available and the mission is also very well supported by the global ground station network, providing near-real-time data to the operational meteorological community and science data to the spacecraft operators at ESOC.

Earlier this year, ERS-2 flew its third tandem observation campaign with Envisat, covering the same ground track with a 30-minute time difference. The difference of 35 MHz between the carrier frequencies of the two SAR systems was compensated for by changing slightly the plane of ERS-2, allowing interferometry between the satellites. The generation of accurate, low-relief digital elevation models and measurement of the speeds of fast-moving glaciers have been unique scientific achievements. This successful mission will reach its end of funding in 2011 and will then be ‘de-orbited’, becoming the first ESA mission to leave its orbit intentionally.

→ ENVISAT

The Envisat mission is proceeding satisfactorily, with stable instrument performances. To save onboard hydrazine in order to extend its lifetime, its orbital parameters will be modified:

no more orbit inclination maintenance, a new altitude and repeat cycle. All scientific and operational applications will be maintained after the orbit change, except SAR interferometry, which would require tight orbit inclination maintenance. The orbit change will start on 22 October and will require the suspension of data flow to Envisat users for about 10 days. An initial operations and mini-commissioning phase will follow in November/December.

Envisat continues to contribute to a better understanding of our planet, observing the second lowest Arctic sea-ice extent in September, as well as the birth of a new giant iceberg in Greenland seas (Petermann iceberg). Envisat also contributed to the observations of the forest fires in Russia and the flooding in Pakistan during August. ASAR data were provided very quickly and in large quantities for monitoring the large oil spill in the Gulf of Mexico.

→ GOCE

The first three gravity field models based on GOCE data were presented in a dedicated session at ESA's Living Planet Symposium, Bergen, in June and July. These models all confirm the excellent quality of the GOCE data, both in terms of gradiometry for the finer scales and in terms of satellite-to-satellite tracking for the coarser features of the Earth gravity field.

Based on these models, new estimates of the mean dynamic topography and, in particular, the mesoscale ocean circulation, have been derived. Both these results demonstrate that GOCE is on track to meet its highly challenging scientific objectives, especially for the precision of the equipotential surface determined by the Earth gravity field, the 'geoid'.

On 8 July, an anomaly occurred in the onboard computer and data handling system, which disrupted science operations for about two months. By late September, mission operations were fully resumed without loss of function. A proposal for extending the GOCE mission to the end of 2012 was submitted to ESA Member States.

→ SMOS

The commissioning phase was completed at the end of May. The end-of-commissioning review concluded that SMOS was in excellent shape, with all subsystems in space and on the ground functioning as planned. Operational scenarios and calibration strategies for the operations phase were defined. The one area of concern remained the radio-frequency interference over some parts of Europe, North America and Asia. The formal handover between development and operations teams took place in June. SMOS data products (all level 1 and a subset of level 2) are available for Principle Investigators through the ESA calibration and validation portal. The general release of the SMOS level 1 data products (brightness temperatures) took place in July. Level 2 data products i.d., soil moisture and ocean salinity, were released in September. The first results were presented at the Living Planet Symposium in June, to the great interest of the science community and much appreciation for their quality.

→ CRYOSAT

Commissioning is now nearing completion. Data are flowing to the calibration and validation teams following an upgrade to the ground processors in early July. Another update to resolve bugs discovered since July is planned. Because of the constraint of implementing and installing improvements to the operational system, the upgraded processor will not be available until the middle of November, after the end of commissioning.

At this point the processing of the Precise DORIS orbit will also be enabled, instead of the intermediate precision orbit used during the commissioning phase. This will introduce a delay in the distribution of products, since the precise orbit requires 30 days to generate. Users should start receiving products in December, these products being from data acquired in November.

→ ADM-AEOLUS

The satellite platform is temporarily out of storage, for the periodic reaction wheel maintenance. The new version of the application software is being loaded and a dry-run of the Integrated System Test will be carried out at avionics level. The equipment procurement for the In-orbit Cleaning Subsystem, implemented to provide the required oxygen flow for 'cleaning' the high-intensity laser optics, is ongoing and the first iteration of the subsystem development model is under test. The flight designs for sealing the laser and transmitter optics have been established.

The telescope FM is back in 'class 100' cleanroom storage at Astrium SAS (Toulouse) after having passed a vacuum test at Centre Spatiale de Liege. The test confirmed robustness against laser-induced contamination effects on the optical elements which cannot be protected by the oxygen gas flow.

Master oscillator vacuum testing of the first ALADIN laser transmitter FM at Selex-Galileo (Florence) confirmed adequate laser beam performance stability. Nevertheless, an in-depth review of the laser, involving independent laser experts, identified the need to make some substantial modifications to the current design in order to regain adequate performance margins for the three years of in-orbit operation. The most significant modification is a change of the operational principle, from 'burst' to 'continuous' mode. A requirement review was completed to define the associated requirements mode.

Stable and complete versions of the end-to-end simulator and ground payload data processing software are available, but they need to be upgraded to support the new continuous mode of the ALADIN instrument. These significant changes to the instrument design have delayed the planned launch date to mid-2013.

→ SWARM

Integration of the first satellite is complete, and this is now undergoing functional tests before shipment to the IABG test facility at Ottobrunn. The integration of the flight units on the second satellite is well advanced despite the delayed delivery of some instruments.

Back-up solutions have been put in place to safeguard the satellite FM1 and 2 delivery schedule because of the delivery delay of the Accelerometer (ACC), the Electrical Field instrument (EFI) and the Absolute Scalar magnetometer (ASM). The first EFI FM has been tested and calibrated and is now ready to be integrated with the second satellite. A magnetic characterisation/calibration campaign was organised at IABG with both the scalar and vector magnetometers.

A meeting with Eurockot and Khrunichev indicated the design and development of the complex adapter between the launcher and the three satellites is in progress as well as the procurement of the various elements of the rocket.

The ground segment development is well advanced, with operational and functional testing of the ground data processors planned to start soon. Regular check points and compatibility tests are organised between the satellite operations team and the satellite software team.

→ EARTHCARE

The prime contractor updated the EarthCARE system documentation and the spacecraft configuration drawings to accommodate the recent modifications imposed by the new and enlarged ATLID bi-static lidar concept. The main changes affect the structure height (support struts increased by 125 mm) and the power subsystem with an enlarged solar array and the addition of a third battery.

The implementation of ATLID Instrument PDR actions and recommendations is ongoing. The instrument structure and the thermal configuration have been modified to handle the new instrument envelope and larger mass, as well as the increased power dissipation. Performance analysis and subsystem allocation have led to an enlarged beam expander diameter (100 mm). The transmitter breadboard has been tested, using a master oscillator, pump-unit and harmonic stage, with results in line with allocated budgets. An optimisation process and series of sensitivity tests have started to give the required confidence in the present transmitter design. Laser-induced contamination tests provided encouraging results and complementary testing is being prepared in both pressurised and vacuum environments.

The programme schedule is being consolidated with the prime contractor. A significant delay in the launch is likely as a result of the reconfiguration of the lidar and associated changes.

The first Broad-Band Radiometer telescope assembly has been manufactured for alignment and performance testing. A representative mechanism model has been assembled and is presently undergoing high-speed rotation tests. The Multi-Spectral Imager (MSI) Manufacturing Review has been held and the production of the MSI Engineering Confidence Model has been released.

In Japan, the Cloud Profiling Radar EM antenna pattern tests have been completed and the data analysis is ongoing. In parallel, the SM production is nearing completion to prepare for the mechanical test campaign. Meanwhile, JAXA has approved the EarthCARE Cooperation Agreement.

→ METEOSAT

Meteosat-8/MSG-1

By the end of August, the satellite had completed eight years in orbit, still in good health with instruments performing normally. It continues to provide the Rapid Scan Service, complementing the full-disc mission of the operational Meteosat-9. The last north/south station- keeping manoeuvre was performed in October, after which the satellite inclination will drift at a rate of about 1 degree per year. Analysis has shown that the satellite can operate at least up to 6 degrees of inclination at full performance, so a minimum of six additional years of mission are possible (for a design life of seven years).

Meteosat-9/MSG-2

Meteosat-9 is Eumetsat's main operational satellite at 0° longitude, performing the full-disc mission (one image every 15 minutes on 12 spectral channels). Meteosat-8 serves as its back-up. Satellite and payload performances are excellent.

MSG-3

MSG-3 is in long-term storage in Thales Alenia Space Cannes. Negotiations with industry regarding destorage activities and launch campaign are concluded, satellite activities will start January 2011 for a launch mid-2012.

MSG-4

The new SEVIRI Drive Unit (DU) is under acceptance testing. Once the qualified DU is available, dismounting activities on the satellite will start. After reintegration of the DU and the SEVIRI instrument, the satellite will go through mechanical, acoustic and reference testing.

MTG

The Contract Proposal for the MTG Phase-B2/C/D was approved in June and in parallel the Eumetsat Programme Resolution was also unanimously agreed and opened for subscription. Final negotiations with the winning consortium, comprising Thales Alenia Space France, OHB Systems and Kayser Threde, are ongoing. Convergence on the technical, contractual and financial baseline design is required for the start of Phase-B2.

→ METOP

MetOp-A

The satellite is in good health, all instruments continue to perform excellently. The HRPT continue to be operated in restricted coverage area and Eumetsat discontinued the LRPT operation.

MetOp-B

The Payload Module 1 (PLM-1) for MetOp B passed the thermal vacuum test in July. Some instruments will now go for final calibration before launch. Service Module 1 (SVM-1) completed reference testing and will go into storage before the thermal vacuum test in July 2011. ESA, Eumetsat and Starsem started to review all documentation and preparation for the launch campaign, planned to start with transport to Baikonur in January 2012 for a launch on a Soyuz in April 2012.

MetOp-C

PLM-3 was taken out of storage in April and all instruments including the HRPT, AMSU-1 and MHS instruments were integrated and tested. In October, PLM-3 will go through functional tests before the shipment to Astrium SAS (Toulouse) in December. SVM-3 completed its functional tests and is being prepared for mating with PLM-3.

The satellite assembly, integration and test activities (PLM-3, SVM-3 and solar array) are planned for the end of 2010, ready for the vibration and acoustic tests in March 2011 at Intespace. MetOp-C is planned for launch in October 2016, but needs to be ready as a back-up for MetOp-B by mid-2013. The contract for the MetOp-C launch, on a Soyuz from Kourou, was signed between Eumetsat and Arianespace in September.

→ SENTINEL-1

The Sentinel-1 System CDR was completed in July. Together with the Thermal Control Subsystem CDR in September, all design reviews are complete. Authorisation to proceed with production of flight units (Phase-D) was given.

The instrument development is progressing with the Waveguide Radiator (Astrium GmbH) manufacturing process under control, with a reported yield of 95% in the critical plating process. The Electronic Front-End module (Thales Alenia Space Italy) manufacturing continues with the production of the EQM models and the dedicated Tile Amplifiers. The test campaigns for the mini-Tile STM and the Tile EQM are verifying the SAR antenna thermomechanical design and life test. The SAR Electronics (Astrium Ltd) EM test campaign is complete.

The Astrium cleanroom in Toulouse with both MetOp SVMs. In front, MetOp-C SVM-3 is under preparation for mating with the PLM and the solar array for the vibration and acoustic satellite acceptance tests. MetOp-B SVM-1 has finished the functional tests and will be prepared for an acceptance thermal vacuum test in 2011 (Astrium)

The consolidation of the Optical Communication Payload (OCP) interfaces is under way after the review of the OCP Interface Control Document by ESA, DLR and TESAT (OCP provider).

The new ITT for the procurement of Sentinel-1 launch services was issued, open to non-European launch service providers.

→ SENTINEL-2

After the low-level Instrument CDRs, the Multispectral Payload Instrument CDR will be completed by the end of October. The instrument EM performance characterisation is providing good results. The satellite System CDR will take place between October and December. These two major project reviews will concentrate on the result of EM test campaigns prior to releasing the plans to implement the instrument and satellite proto-flight programme of work. In the meantime, equipment EMs were delivered for integration, and QM and FM manufacturing has started.

The first satellite software version, implementing the satellite command and control functions, is being tested within a simulated environment. After this pre-validation, the software will be uploaded to a satellite testbed to complete its formal acceptance before its final release for Satellite Assembly Integration and Test.

The OCP framework agreement between ESA and DLR has been finalised, and the interfaces with Sentinel-2 are consolidated. The OCP FM is being manufactured.

Image quality activities conducted by CNES are proceeding, including development of the Ground Prototype Processor and the specification of the Image Quality Processor to support the Operational Processor development and preparation of the in-orbit commissioning phase. Selection of the Sentinel-2A launch service provider is expected to conclude in October.

→ SENTINEL-3

Phase-C/D detailed design activities are proceeding with most of the equipment CDRs completed. The first two Instrument CDRs (SRAL and MWR) have started, while the remaining Instrument and Satellite CDRs will follow in late 2010 and early 2011. At ground segment level, the Payload Data Ground Segment contractor was selected at the end of September. At space segment level, the industrial consortium is almost complete, with only three contracts to be placed out of 122.

At system level, activities concentrated on the flight software. Three versions have been defined to allow parallel software development and verification while fitting the needs of the satellite assembly, integration and testing (AIT). The first of these versions will be completed by the end of the year.

In parallel, the ground processor simulator development is proceeding, to be available around April 2011 for the optical simulators and January 2011 for the topography simulators.

In addition to the detailed design finalisation for the CDR, manufacturing and testing activities at unit level are proceeding with delivery and testing of several STMs and EMs. The SMU (On-Board Computer) EM was delivered to the prime contractor, allowing starting of the virtual EM testbed activities at satellite level, where all satellite avionics will be gradually integrated and validated, together with the flight software, before starting the AIT of the PFM satellite. A preliminary Payload Data Handling Unit EM was delivered to the platform contractor, where interface validation tests are being performed. Manufacture of FM items has already begun, including the satellite and SLSTR instrument structures, to keep on schedule.

At instrument level, the main problems have been related to the availability of 'Electronic, Electrical and Electromechanical' parts and components, due to bottlenecks with 'single-source' suppliers in Europe for these elements. Several EM/EQM activities are ongoing through the various instrument suppliers showing very satisfactory results.

The bidding period for the selection of the Sentinel-3 launcher services contractor closed in September and the proposals are being evaluated to place the contract by early 2011.

→ SENTINEL-5 PRECURSOR

Two parallel Sentinel-5 Precursor system and spacecraft Phase-A/B1 studies with Astrium Ltd (UK) and OHB started in June for one year. Interface definition meetings between both satellite prime contractors and Dutch Space ensure an efficient specification of the TROPOMI payload and platform interfaces. TROPOMI, jointly procured by ESA and the Netherlands, went through a design-to-cost exercise resulting in a rationalisation of the overall payload design and procurement plan. The procurements of the SWIR, the common ICU and UVN front end by Dutch Space, were delayed with new start dates expected in October. New adapted procurement items include a passive cooler, telescope support structure and electrical ground support equipment. The Phase-B design process should be completed by the end of 2010.

→ ALPHABUS/ALPHASAT

System and launch

The Alphabus Qualification Review is planned to be complete by the end of November. This review will confirm the qualification of the Service Module as a generic product line.

The results of the 'Shogun' shock testing campaign show that Alphabus complies with the Ariane 5 launch environment requirement. Using the measurements inside the spacecraft, the prime contractor team reassessed the qualification of each unit by comparing its qualification test at unit level to the level expected in flight. Launch of Alphasat on an Ariane 5 is scheduled for the second half of 2012.

Service Module (SM)

Activities on the SM integration are progressing: the electric propulsion system gas plate has been delivered to Toulouse and integrated on the SM, and the proof test, covering the xenon high-pressure part, was performed in the Astrium bunker facility. Thermal control and multi-layer insulation were installed on the SM. The battery modules have been mounted on the east/west SM walls and full battery level tests have started. The Closed Loop System (CLS) test equipment was delivered to Toulouse in September and will be connected to the spacecraft for the end-to-end system-level test campaign.

Remaining activities on the SM include: completion of the Chemical Propulsion System (last SM thruster integration and functional test), integration of PSR PFM, re-integration of refurbished star trackers, integration of fourth reaction wheel, final electrical and functional testing and testing of the electric propulsion Thruster Module Assembly (TMA)/SM interface before integration of the TMA in the Repeater Module. These activities should be complete by the end of the year for the SM to be ready for coupling with the Repeater Module.

Payload/Repeater Module

The Inmarsat extended L-band (XL) payload will support advanced geomobile communications and augment Inmarsat's Broadband Global Area Network service with its coverage centred over Africa and providing additional coverage to Europe, the Middle-East and parts of Asia.

On the Inmarsat operational payload, the majority of the EQM testing is complete and about 75% of the payload equipment is either already delivered or being shipped to Portsmouth for integration on North/South Half Repeater Module structures Despite the progress, significant challenges still remain in the development of the critical elements: the integrated processor and the calibration and frequency generator units. The Payload Repeater Module will be shipped to Astrium SAS (Toulouse) in December.

Technology Demonstration Payloads

Development of the Technology Demonstration Payloads (TDPs) is progressing with flight hardware being manufactured and tested. Each TDP development offers unique challenges but all are progressing towards embarkation on the Alphasat satellite.

Alphabus Service Module under final assembly in Toulouse (Astrium)

A new activity related to the ground segment of TDP5 is under preparation with Joanneum Research (Austria) in coordination with the Italian space agency, ASI, which is responsible for the TDP ground operations. It consists of the definition, selection, installation and operation of a high-performance Q/V-band ground station with tracking antenna at a fixed location in Graz.

Alphabus Extension

The Alphabus Extension will extend the power, mass and thermal rejection capabilities capability of the platform. The industrial proposal was received in July and evaluated by ESA and CNES and is currently under negotiation with the industrial contract to be placed before the end of the year.

Alphasat Ground and User Segment and Applications

The Ground and User Segment and Applications programme will exploit the enhanced performances of the Alphasat satellite. Its workplan contains a set of activities defined with Inmarsat for the exploitation of the global Inmarsat 4 satellite constellation as well as Alphasat.

These activities started in 2010 with Inmarsat, and include general Alphasat service and system requirement definition and preliminary design activities and the development of core functionalities for safety and emergency communication services for maritime, aeronautical and land-vehicular environments. Thrane & Thrane (Denmark) also began developing a generic BGAN user terminal

In French Guiana, the first Soyuz for launch from Europe's Spaceport has been assembled in the MIK building. The vehicle will then be transferred to the launch pad in the horizontal position on a rail-mounted erector system, seen left. At the pad, the erector will raise the Soyuz into the upright position for launch

platform supporting the upgraded capabilities of the BGAN system using the Alphasat satellite.
User communities will greatly benefit from the new applications or integrated solutions to be developed in the frame of ARTES 8, which will cover user needs by developing the mobile satellite communication solutions provided by Alphasat. An open ITT is planned for late 2010 covering Alphasat applications development.

→ ARIANE 5 POST-ECA

A major step was achieved in July with the conclusion of the Launch System Concept Review (LSCR).

Subcontractors are joining in Phase-1.1 and contracted development activities are being implemented. Phase-1 began after many 'Beginning of Activity Technical Committee' meetings, starting activities in the different domains. First meetings have been held with the prime contractors to start subsequent procurement activities.

On Vinci M3 a test with trip ring has taken place. The erosion of the Liquid Oxygen Turbo-Pump (TPO) dynamic seal package (DSP), which remains a critical element of the engine, is under steady observation. Design requirements for the hot-firing stage test bench are agreed and a first draft specification is available. The baseline scenario 'DSP erosion elementary tests at ULG' is confirmed.

The PDR of the PF52 is expected at the end of October. The documentation key point for the ECA demonstration flight PDR has taken place. No problems were identified, but development plan and cost files remain to be delivered.

As part of the upper-stage mass removal/performance improvement process, ideas were needed on a 400 kg gain and promising lightweight (lower rigidity) concepts are under evaluation with CASA on the VEB cone. Other performance recovery activities were initiated at system level, including ideas for load reductions. The LSCR identified insufficient performance margin, which has thus been restored.

→ VEGA/P80

On 7 September, ESA and Arianespace signed the work order for the production of the first Vega launcher, after qualification, as part of the Vega flexibility demonstration flights contract signed in December 2009. Arianespace and ELV (Avio Group) concluded a contract for five launch vehicles with a firm order on one.

Tests on two additional thrusters were completed in July. The Rafael thruster was confirmed as the baseline design for the qualification. The first part of the Launch System Ground Qualification Review was completed 8 July. Part 3 of the Ground Segment Integrated Tests was completed.

The new Soyuz launch facility at the Centre Spatial Guyana (CSG), Europe's Spaceport in French Guiana, with a view of the Soyuz launch platform from the flame pit. This five-level reinforced concrete structure houses mission equipment. The top two levels have 15 m-wide openings for the launch table and the erected Soyuz vehicle. Its upper area accommodates the pad infrastructure, including the service tower, the fuelling booms and the erector (ESA/CNES/Arianespace/Optique Video CSG)

→ SOYUZ AT CSG

The programme plan has been updated for the first Soyuz launch from CSG in April 2011.

Implementation of the 'Corps d'Etats Complémentaires' (CEC) activities on the Mobile Gantry on a three-shift basis, which started in June, has reached its full capacity with the start in July of the energy and air-conditioning activities as well as fluids activities. The 'Mobile Gantry in ZL' (launch zone) milestone is planned for October. Infrastructure and energy acceptance reviews of the launcher storage, extension of the kerosene storage area and extension of kerosene fuelling area were held on 30 July.

Test campaigns for the Soyuz Launch System qualification are complete (Fregat mock-up filling test, GAZ-1, BT Gaz 2, Liquid Nitrogen, BT LOX) and the integration of the upper composite mock-up started with its installation on the specific trailer (PFRCS) in September.

→ FUTURE LAUNCHERS PREPARATORY PROGRAMME

The consolidated contract with NGL Prime SpA was finalised and the rider to transfer the NGL Prime SpA responsibilities to Joint Propulsion Team and Thales Alenia Space Italy is under finalisation.

Intermediate eXperimental Vehicle (IXV)

On 15 September, the IXV Industrial Workshop took place as part of a yearly series envisaged up to the flight in 2013. The main objectives were to share the IXV technical and programmatic achievements, provide the opportunity for industry to show the hardware development activities already undertaken to support the detailed design solutions proposed, and discuss short- and long-term perspectives up to the mission and future applications.

Next Generation Launcher (NGL)

In July, a contract was signed with Astrium ST to cover system studies and technologies development as well as stage/system support for technology development. System activities are progressing, with a first milestone of two industrial workshops organised in September for the Upper Composite and Lower Composite respectively. These workshops allowed the identification of interesting technologies and subsystem architectures that could be traded and later injected into the design of the launch vehicles under consideration.

NGL Propulsion

The High Thrust Engine demonstrator received the name of SCORE-D, an acronym that stands for Stage Combustion Rocket Engine Demonstrator. At technology level, the test campaign of the SCENE Nozzle, performed on the P8 test bench, was completed in early September. Other test campaigns are in progress.

Work on upper-stage propulsion is progressing to plan, with PRR/SRRs held in September. The mission description and propulsion system requirements were devised and submitted, as well as possible layout concepts of the demonstrator.

NGL Technologies

The contract for the development of Cryogenic Upper Stage Technologies (CUST) was signed in June and the industrial activities are progressing with the completion of the SRR for all the technologies addressed. Furthermore, the PDR was held for the Propellant Management Device (PMD) experiment, to be flown on a Texus sounding rocket.

Materials and structures activities are now in place for the composite feed line, composite structures, composite cryogenic tanks and aluminium-lithium (Al-Li) cryogenic tanks. Engine thrust frame and fairing related technologies are under evaluation.

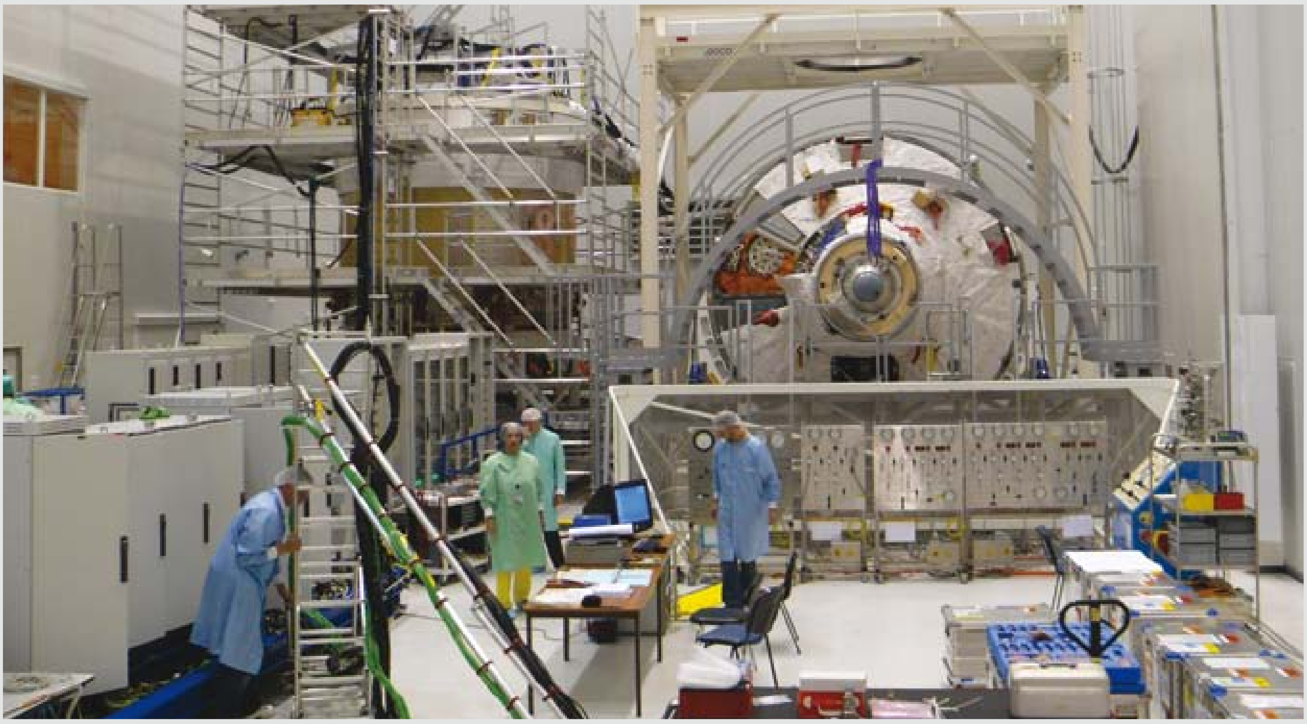
→ HUMAN SPACEFLIGHT

In the latest NASA Space Shuttle launch manifest, there are still two officially scheduled Shuttle flights remaining:

The Mars500 crew in September. Back row from left, Sukhrob Kamolov, Romain Charles, Diego Urbina, Yue Wang. Front row, Alexei Sitev and Alexander Smoleyevski

STS-133 (ULF-5), planned for November 2010, which will deliver the Permanent Multipurpose Module to the ISS; and STS-134 (ULF-6), now scheduled for 27 February 2011, carrying the Alpha Magnetic Spectrometer (AMS-02) and ESA astronaut Roberto Vittori (IT) on an ASI flight opportunity. STS-135 is a 'Launch on Need' (LON) flight, meaning the mission will only be flown if the rescue mission STS-335, designated to support STS-134, is not needed.

The Alpha Magnetic Spectrometer (AMS-02) was transferred from CERN (Geneva) by aircraft to Kennedy Space Center in August. Its final launch preparation activities at the Space Station



The mating of ATV *Johannes Kepler*'s Service Module and the Integrated Cargo Carrier took place at the end of October. Here, all the components are being prepared for mating in the S5C hall at Kourou, French Guiana

Processing Facility are on schedule for launch on STS-134. In September, an agreement was signed with the Dutch Ministry of Economic Affairs for the co-funding of the Erasmus User Support and Operations Centre (USOC) at ESTEC, Noordwijk, for a period of three years at €1.8 million.

On 15 September, the crew of the Mars500 520-day simulated mission to Mars, including the two ESA crewmembers Romain Charles and Diego Urbina, passed the 105-day record set by the crew of the precursor study in 2009. The next milestone will be a simulated 'landing' on Mars planned for 10 February 2011, with the return back on Earth expected in November 2011.

The Call for Ideas for 'Climate Change Studies from ISS' was evaluated with Earth Observation experts. Out of 45 proposals received, there were a significant number with high scientific relevance to the ISS as an observation platform, which would indicate that a full AO should be issued.

The peer review and feasibility assessment of the 12 proposals received for the new Concordia AO were completed and a dedicated results and selection proposal was endorsed in October.

Following the full certification of the Airbus A300 for partial-gravity flights, a dedicated AO was issued to the European science community in June to submit their proposals for experiments to be performed under partial gravity. ESA intends to organise a joint partial-gravity parabolic flight campaign with CNES and DLR, tentatively by mid-2011.

A first plenary session of the Human Spaceflight and Exploration Advisory Committee HESAC was held on 9 July at ESA Headquarters, in which ISS Utilisation and Exploration Scenarios, and the entry into force of the Lisbon Treaty, were among other agenda items.

AMS-02 begins the first stage of its voyage to the International Space Station, at Geneva airport, Switzerland (CERN)

The contract for the full development of the Atomic Clock Ensemble in Space (ACES) ISS payload was signed on 16 July by ESA with Astrium as prime contractor. The €35 million contract requires the ACES FM and the ground segment to be delivered by autumn 2013.

→ SPACE INFRASTRUCTURE DEVELOPMENT/ISS EXPLOITATION

The ATV *Johannes Kepler* launch date has been confirmed as 15 February 2011 with a docking window on 26 February. The ATV *Johannes Kepler* launch site operations have so far been performed on schedule. The delayed launch date will require putting ATV *Johannes Kepler* into a 'cocooning' configuration until the restart of the launch campaign in November.

The ATV *Edoardo Amaldi* 'ready for launch' date has slipped to the end of February 2012, due to the delay in the Equipped Avionics Bay (EAB-3) thermal vacuum test at Intespace. EAB-3 will be shipped to Toulouse on 18 October. ATV-4 system integration started in July and is on schedule.

→ UTILISATION

Implementation of the Increment 24 experiment programme was completed in September with the exchange of three ISS crew members. Increment 25/26 started subsequently and is expected to run until March 2011. It will encompass the largest part of the science programme planned for ESA astronaut Paolo Nespoli's (IT) mission, which commences in Increment 26 (Expedition 26).

External payloads

The SOLAR platform was in Sun-pointing mode and acquiring data until 20 July, when the Sun observation window closed. A new Sun observation window opened again on 3 September. Following the conclusion of the detailed technical feasibility study for on-orbit lifetime extension the science team will be able to continue gathering science data in a period of increasing solar activity up to 2013 and possibly beyond.

The Expose-R facility with nine exobiology experiments continues to function well and acquire scientific data. A tentative return of the sample trays is foreseen for late 2010 which allows for a scientifically beneficial 50% extension of the open space exposure period.

The Vessel Identification System (Automatic Identification System, AIS) is working well and is continuing to acquire data. The AIS will test the tracking of global maritime

↑ Astronaut candidates Alexander Gerst (left), Samantha Cristoforetti (centre) and Andreas Mogensen (right), during a Water Delivery System briefing with ATV instructor Liliana Ravagnolo at EAC in March.

traffic from space. Telemetry is received by the Norwegian User Support and Operations Centre (N-USOC) in Trondheim via ESA's Columbus Control Centre in Germany.

Life sciences

The latest ESA experiment in the European Modular Cultivation System in July, Genara-A, was carried to the ISS on STS-132 in May. The experiment was concluded on 23 July, and the culture chambers containing the samples from the experiment containers were put in the European-built MELFI-2 freezer (until their return on STS-33/ULF-5). Genara-A is studying plant (*Arabidopsis*) growth at molecular level in weightlessness.

The functional recovery activities for the Biolab facility are ongoing. The European Physiology Modules (EPM) facility in Columbus has been activated for the DOSIS (Dose Distribution inside the ISS) experiment. Data from DOSIS was sent back via the EPM facility on 25 August. DOSIS is progressing well with the instrument acquiring data using the active DOSTEL detector in the EPM, following removal and return of the passive dosimeters on STS-132. The passive detectors are undergoing detailed scientific analyses.

In the two weeks before 10 September, ESA's Sodium Loading in Microgravity (SOLO) experiment was completed with ISS astronauts Doug Wheelock and Shannon Walker as test subjects. The blood and urine samples were placed in one of the MELFI freezers. SOLO is studying salt retention in space and related physiological effects.

The Portable Pulmonary Function System (PPFS) is continuing to support ESA's ThermoLab experiment with NASA's Maximum Volume Oxygen (VO2 Max) experiment. ThermoLab uses the ESA-developed PPFS (combined with exercise) to investigate thermoregulatory and cardiovascular adaptations during rest and exercise in the course of long-term exposure to weightlessness.

ESA's Matroshka radiation phantom, which has been in the Japanese Kibo laboratory since 4 May, is continuously acquiring data about the radiation environment inside the ISS. Following agreements with JAXA and Roscosmos, the joint long-duration experiment run will be performed until HTV-2 arrives in 2011.

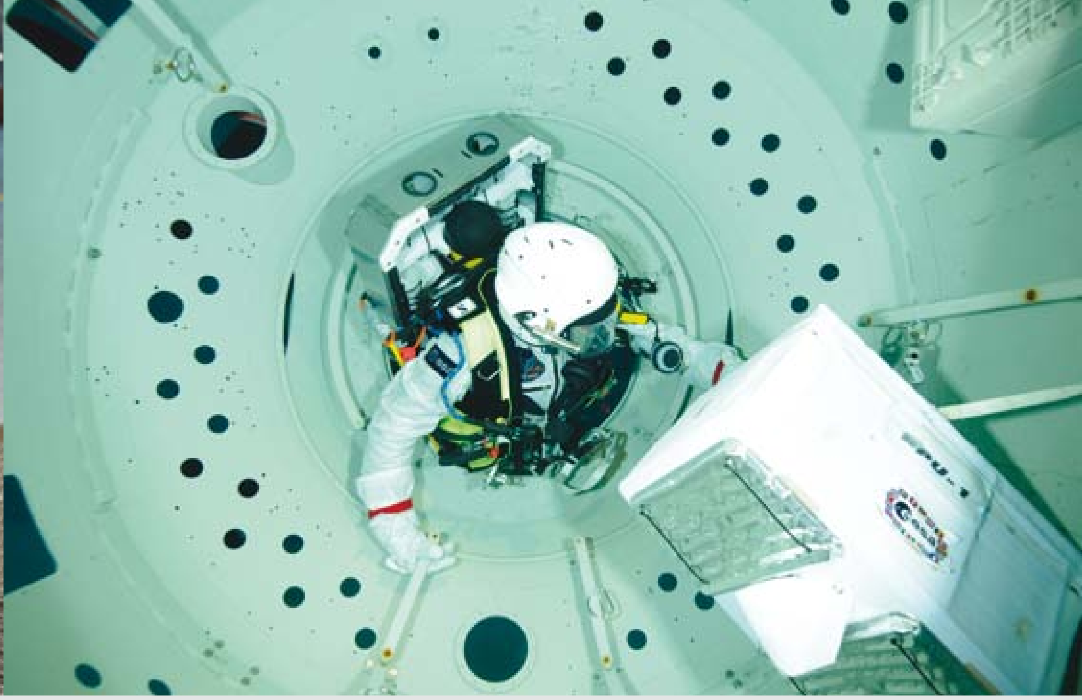
Materials and fluids research

Twelve of the CETSOL/MICAST experiment samples have been processed so far, and are now being analysed by science teams on the ground. CETSOL and MICAST are two complementary materials science projects, studying the formation of microstructures during the solidification of metallic alloys. US scientists and European science teams are performing joint experiments.

The next SODI experiments are Diffusion and Soret Coefficient measurements for improvement of crude oil recovery (DSC) and Crystallisation of Advanced Photonic Devices (Colloid). The Colloid cell assembly was sent to the ISS on Progress flight 39P on 10 September with the refurbished SODI control unit.

Technology research

The Erasmus Recording Binocular (ERB-2) commissioning checkout was completed by ISS astronaut Tracy Caldwell-Dyson on 10 September. ERB-2 is a 3D video camera that uses high-definition optics and advanced electronics to provide a vastly improved 3D effect for mapping the ISS.



↑↗ Astronaut candidate Samantha Cristoforetti being kitted out for Extravehicular Activity (EVA, or 'spacewalk') training by ESA instructor Herve Stevenin at the EAC Neutral Buoyancy Facility, Cologne, in June. Alexander Gerst (above) during EVA training

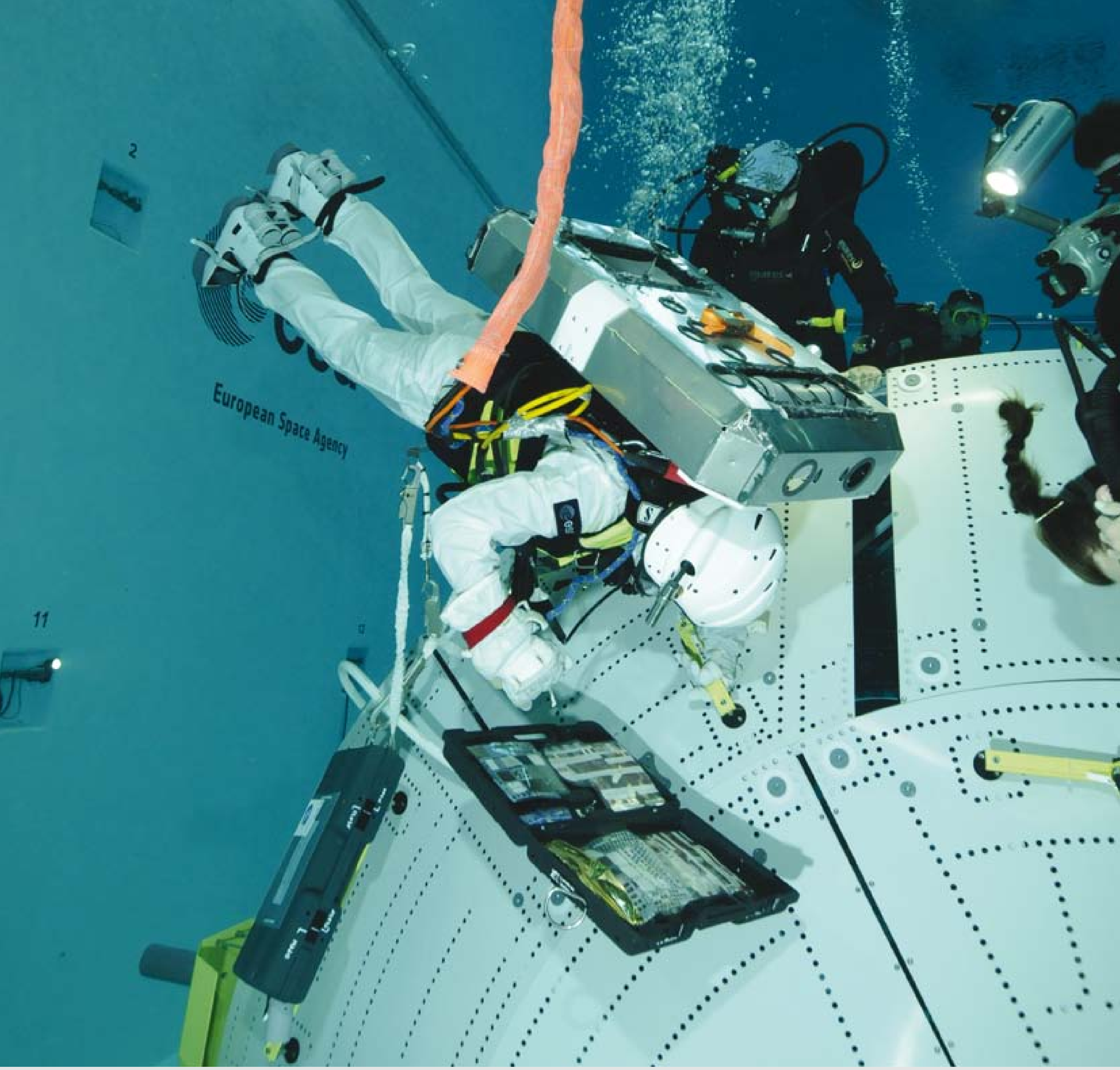
Non-ISS missions

The winter-over isolation campaign continued at Concordia, Antarctica, until November. A new ESA crewmember for the next campaign was selected and six new science proposals were chosen from the last AO. Two bed-rest studies are in progress, one at DLR (nutrition focus) and MEDES (with centrifuge and artificial gravity).

→ ASTRONAUTS

On 8 October, the name and logo for Paolo Nespoli's long-duration mission to the ISS (MagISStra) was announced at an Expedition 26/27 media day at Oberpfaffenhofen, Germany. A news conference with Nespoli live from Houston was also hosted via ESTEC in Noordwijk on 15 September.

Prime crew for Soyuz TMA-20, Expeditions 26 and 27, Catherine Coleman, Dmitri Kondratyev and Paolo Nespoli



Astronaut candidate Timothy Peake underwater during his EVA familiarisation course. This course teaches ESA astronauts the basic Extravehicular Activity (EVA, or 'spacewalk') concepts and skills, such as tethering to the International Space Station, the use of special EVA tools, communicating with an EVA crewmate and with the control room and how to keep full situational awareness in a complex and challenging environment

Crew training for ISS Expeditions 25 to 30 is progressing on schedule. Training continues for Nespoli and Roberto Vittori for their missions in December and February 2011 respectively. André Kuipers (NL) continues his mission training for Expedition 30/31 starting at the end of 2011.

Basic training for the new astronaut candidates is going well, with basic training completed in November this year. An event to mark this achievement will be held at EAC on 22 November.

→ CREW TRANSPORTATION AND HUMAN EXPLORATION

Advanced Reentry Vehicle (ARV)

The ARV Phase-A PRR took place in the summer and was concluded in September. While the ARV concept is being developed, the interface aspects and the mission requirements are being finalised. Discussions have taken place with ISS partners for a more-detailed assessment of the

ISS needs for 2016–20, to establish a Common Transportation Policy with the ISS international partners.

International Berthing Docking Mechanism (IBDM)

The Request for Quotation for the Advanced Tasks for the Development of the Enhanced Engineering Development Unit has been issued to Qinetiq (BE) and MDA (CA). Proposals received on 30 September are under evaluation. The closed-loop tests were performed by Qinetiq and MDA at INTA, Madrid, with the support of SENER (ES) between April to July.

The International Docking System Standard Working Group continues to work on the detailed configuration for the new system standard. The Fifth Technical Interchange Meeting was hosted by ESA in June. Progress was made for all the technical aspects of the docking standard interface, with the final definition to be finalised at the next meeting in October.

Expert

Phase-D of the test bed development is ongoing. The vehicle integration started at Thales Alenia Space Italy, Turin, to be ready for system tests in October. The Italian delegation confirmed its availability to provide funding needed to complete the project, already solicited by the other Participating States. Nevertheless a formal written commitment depends on the authorisation for launch, to be provided by the Russian Ministry of Defence. The contract for the development of the Descent and Landing System was signed by Thales Alenia Space Italy and SRC Makeyev. The signed contract schedule ensured that sufficient development margin is maintained for a launch in summer 2011.

Lunar Lander

Europe took a step closer to landing on the Moon with the signature of the Lunar Lander Phase-B1 contract in Berlin on 16 September. The contract will culminate in a Preliminary SRR in 2012, providing the basis for the final design of the mission and Lander. Subsequently, Canada announced its contribution to the Lunar Lander activities in the European Transportation and Human Exploration Preparatory Activities programme with €1.3 million (2008 economic conditions), and Participating States approved this contribution at the programme board meeting held in October.

Human Exploration Technology

Following the decision to proceed with the Advanced Closed Loop System (ACLS) Phase-C2, leading to a System PDR next year, the related Engineering Change Request has been sent to industry.

The Tender Evaluation Board for the MELiSSA Food Characterisation Phase-2 activity took place in July, but no firm decision was reached as yet. Meanwhile, the activities at the MELiSSA Pilot Plant in Barcelona are progressing to plan and the remaining Belgian funding has been submitted and approved.

International Architecture Development and Scenario Studies

Contracts for the Exploration Scenario Studies with EADS Astrium GmbH and Thales Alenia Space Italy as prime contractors were signed in August.

→ OUTREACH ACTIVITIES

The 'Future's Day' exibition at the Farnborough Air Show, UK, in July, featured education activities about nutrition and living on the ISS, with the help of ESA astronaut Jean François Clervoy. A short video about the AMS-02 ('Searching for the Missing Universe') was completed in 13 languages with exercises for high-school students.

→ SSA PREPARATORY PROGRAMME

ESA's Space Situational Awareness (SSA) system will enable Europe to autonomously predict, detect and assess the risk to life, property and satellites due to orbiting space objects, harmful space weather or near-Earth objects (NEOs). The SSA Preparatory Programme was approved at the Ministerial Council in November 2008. The programme started in January 2009, with 11 participating Member States. Luxembourg and Finland joined in May 2010.

The first half of the SSA Preparatory Programme (2009/10) was dedicated to system-level activities, i.e. the definition of appropriate governance, data policy and data security models; consolidation of customer requirements and system requirements; and, establishment of a top-level SSA architectural design, followed by the provision of an estimate for the total cost of the future SSA system. The detailed architectural design, originally foreseen to take place in 2010, has moved to 2011/12 due to a delay in SSA System Requirements activities.

In parallel to these activities, detailed assessments of national facilities across the three SSA Segments (Space Surveillance & Tracking, Space Weather, Near-Earth Objects) are being conducted together with participating Member States. This will allow existing assets to cooperate fully in the future SSA System. Based on currently operating tools, facilities and services of ESA and participating Member States, a subset of preliminary Precursor Services has been identified across the three domains. According to the progress of the corresponding industrial procurements, these will start operations in 2011. Finally, SSA governance and data policy aspects have undergone a reflection process through joint sessions with the EC, EU Council and the European Defence Agency. By autumn 2010, the SSA Core Team had been fully relocated to ESAC under the management of the Directorate of Operations and Infrastructure. Significant support to SSA is being delivered by specialist offices and teams from other ESA Directorates, including Technical & Quality Management and Science & Robotic Exploration.

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