number 148 | November 2011

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, Romania, 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

←

On cover:
ESA astronaut André Kuipers, 53, from Amsterdam, will be the first Dutchman to make two spaceflights. He flew on the 11-day Delta mission to the ISS in April 2004, and in December he will begin the PromISSe mission, the fourth European long-duration stay on the orbital outpost

bulletin
number 148 | November 2011

The *ESA Bulletin* is an ESA Communications production.

Published by:
ESA Communication Department

ESTEC, PO Box 299
2200 AG Noordwijk
The Netherlands
Tel: +31 71 565 3408

Email: contactesa@esa.int

Editor
Carl Walker

Designer
Giada Gasperoni (Taua),
Emiliana Colucci

Organisation
www.esa.int/credits

The *ESA Bulletin* is published by the European Space Agency. Individual articles may be reprinted provided the credit line reads ‘Reprinted from *ESA Bulletin*’, plus date of issue. Reprinted signed articles must bear the authors’ names.

ESA and the ESA logo are trademarks of the European Space Agency. Images copyright ESA unless stated otherwise. Permission to reproduce or distribute material identified as copyright of a third party must be obtained from the copyright owner concerned.

Copyright © 2011
European Space Agency
ISSN 0376-4265 | e-ISSN 1608-4713

→ contents


02


14


22


32


42


52

→ THE PROMISE OF SPACE

André Kuipers' PromISSe mission

Martin Zell and Nadjejda Vicente
Directorate of Human Spaceflight and Operations, ESTEC, Noordwijk, The Netherlands

Volker Damann and Hans Bolender
Directorate of Human Spaceflight and Operations, EAC, Cologne, Germany

↑

André Kuipers looks at Earth through a window on the ISS during his Delta mission in 2004

↑

The launch of Soyuz TMA-4 from Kazakhstan starting André's first spaceflight in 2004

Almost eight years have passed since André Kuipers' 11-day Delta mission. Now a fully operational International Space Station is awaiting him, this time for a much longer stay.

The roar of the rocket and the exhilaration of weightlessness are nothing new to André. In 2004, he was launched on a Soyuz for a visiting flight to the ISS, when the Station had only four main modules and two resident crewmembers. Today, there is a permanent, international six-astronaut crew on board an almost fully assembled ISS. With the Station's lifetime extended to 2020, André's presence in the orbital outpost inaugurates a new decade of best practical use.

André is set to be launched from the Baikonur Cosmodrome, in Kazakhstan, on a Soyuz spacecraft as Flight Engineer for Expeditions 30 and 31, together with Russian Soyuz commander Oleg Kononenko and NASA astronaut Don Pettit. They will remain in space for 148 days, nearly five months.

Named 'PromISSe', this is the first long-duration mission for a European astronaut following the end of the US Space Shuttle programme with the last flight of Shuttle *Atlantis* in July. During his stay in orbit, André will receive ESA's third Automated Transfer Vehicle, ATV *Edoardo Amaldi*, currently the largest vehicle for servicing the ISS.

In training again

The last two and half years have seen him follow a tailored training regime, flying between Houston, Moscow, Tsukuba in Japan, Montreal in Canada and the European Astronaut Centre (EAC) in Cologne, Germany.

→ The crew

Oleg Kononenko

Commander

Born June 1964, in Chardzhou, Turkmen SSR
Married, one son, one daughter
Mechanical engineer
Previous flight: Soyuz TMA-12

→ Flight patch for Soyuz TMA-03M (Spaceview/Roscosmos) and the patch for Expedition 30 (NASA)

↘ The patch for Expedition 31, which starts in March 2012, when NASA astronaut Joe Acaba and Russian cosmonauts Gennadi Padalka and Sergei Revin join André and his crew (NASA/International partners/Spaceview)

A dedicated blog launched last summer became a good way to track him during the final stages of his training on Earth. "Roughly half of my training has taken place in Star City, so every time I come to Russia it feels a bit like coming back home," he said in his diary.

"More than 50 people have been taking care of André's training programme during these 30 months, always trying to integrate the demands of the ISS partners, ESA and his own interests," says Hans Bolender, Head of the Astronaut Training Division at EAC. Every detail of his schedule has been carefully studied.

Simulations helped André to get ready for space, and his role as Soyuz Flight Engineer requires a large amount of 'flying hours' in the Russian spacecraft. "I have to assist the commander Oleg Kononenko from the left seat when approaching the ISS. I really enjoy manoeuvring the →

André Kuipers
Flight Engineer 1

Born October 1958, Amsterdam, the Netherlands
Married, three daughters and a son
Medical doctor
Previous flight: Soyuz TMA-4

Donald Pettit
Flight Engineer 2

Born April 1955, Silverton, Oregon, USA
Married, two sons
Chemical engineer
Previous flights: STS-113 (Expedition 6), STS-126

→ The path to the stars

André Kuipers' ambition to be an astronaut began early in life, but it wasn't until he became a medical doctor that he saw a way to combine his professional career with his interest in space exploration. Inspired by the idea of helping mankind to travel further in space, his research into human adaptation to space led him to the European Space Agency.

During his medical studies, André worked in the Vestibular Department of the Academic Medical Centre in Amsterdam, where he was involved in research on the equilibrium system. Then, as an officer of the Royal Netherlands Air Force Medical Corps, he studied accidents and incidents caused by spatial disorientation of pilots of high-performance aircraft.

↑

André Kuipers tests the SUIT tactile vest in the TNO rotating chair in November 2003 (TNO)

In 1989, he worked for the Research and Development department of the Netherlands Aerospace Medical Centre in Soesterberg. He was involved in research in, among other things, 'Space Adaptation Syndrome', blood pressure and cerebral blood flow in centrifuge tests and in weightless conditions in aircraft.

By 1991, André had become involved in the preparation, coordination and ground control of physiological experiments developed by ESA for space missions. In particular, he was Project Scientist for Anthrorack, a human physiology facility that flew on the Spacelab D-2 mission in 1993, and for two payloads that flew on the Mir space station during the six-month Euromir '95 mission.

In July 1999, André joined the European Astronaut Corps and was assigned to ESTEC in the Netherlands, continuing his work for the Microgravity Payloads Division. He also continued to support the ESA parabolic flight campaigns, participating in these flights as an experiment operator, technician, test subject and flight surgeon.

Until he was selected for his first flight, André supported a research programme in the physiological adaptation to weightlessness in humans. He coordinated the European experiments on lung function and blood pressure regulation, using ESA's specially developed apparatus, the Advanced Respiratory Monitoring System, which was launched on the Space Shuttle mission STS-107.

↓ ↘

André has been involved in space-related medical research since 1991 at ESA's technical establishment ESTEC in the Netherlands, including parabolic flight activities (right)

In 2002, André completed ESA's Basic Training Programme, and became eligible for assignment to a mission. He was chosen as backup for Pedro Duque on the Soyuz TMA-3 mission to the ISS, which took place in October 2003. He served as 'Crew Interface Coordinator' at the Russian Control Centre (TsUP) for this flight, which covered Expeditions 7 and 8.

André's first taste of space came on 19 April 2004, when he flew on Soyuz TMA-4 to the ISS with Gennadi Padalka from Russia and Mike Fincke from the USA. Since his first spaceflight, André has worked on ESA payload development, parabolic flight campaigns, healthcare spin-offs, as well as to ground support for missions of other ESA astronauts. He also qualified as a Eurocom, the crew communicator role at the Columbus Control Centre near Munich, Germany.

In 2007, André trained as backup for ESA astronaut Frank De Winne on Europe's second long-duration flight to the ISS, meaning that at some point he could be assigned to his own long-duration flight. The chance to fly again came in 2009, when he was finally assigned to make the fourth European long stay on the ISS and the first Dutchman to make two spaceflights.

↑

From top left, André training in 2003 for his return flight with the Expedition 8 crew, Mike Foale and Alexander Kaleri; with Mike Foale eating Dutch cheese for breakfast; working with the Microgravity Science Glovebox on the ISS

→

EVA training with Frank De Winne at Houston in 2007 (NASA)

↑

André will fly in the left seat (top of picture) of the three-person Soyuz capsule, traditionally assigned to European astronauts serving as Flight Engineer

→ capsule and docking smoothly to the Station. Even though I know it is just a simulation, there is lots of action. My heart beats faster and I feel my adrenaline rising," André said.

André has already been in the left seat of a Soyuz for his shorter flight in 2004, so he is undergoing what it is known as an 'experienced training flow'. "Now he has a much better operational understanding of what is really important for their daily life on board the ISS," explains Hans Bolender, who sees André calm and confident as the countdown approaches.

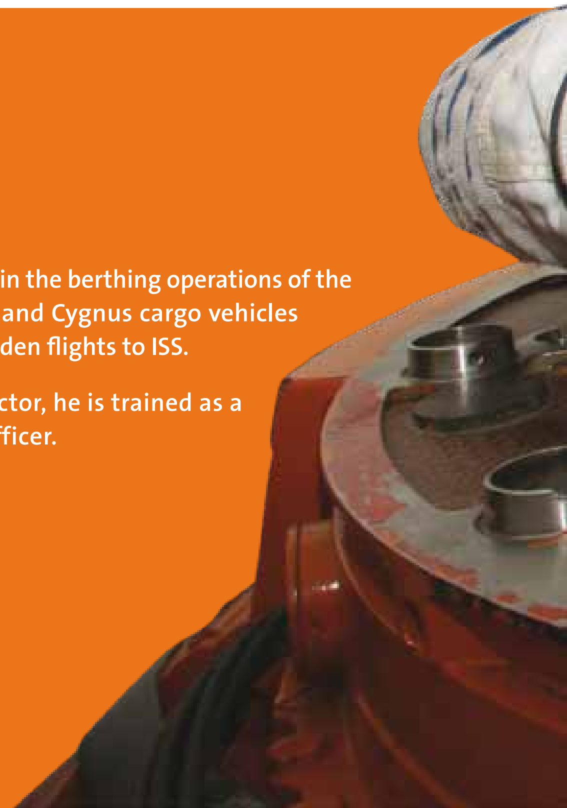
The 53-year-old astronaut has proved to be a great team player, with a high interest in robotic activities and human physiology research. His Russian language skills have improved significantly and he communicates easily with his cosmonaut colleagues. "This is something quite critical in case of an emergency on the Soyuz, where miscommunication or language barriers can endanger their lives," points out Bolender.

André's advanced training level enables him to face all kinds of emergency situations, prolonged isolation and psychological stress. Specialised trainers are teaching him critical launch and landing procedures on the Soyuz, as well as how to handle depressurisation, fire or toxic spills on board. This kind of training starts on the ground, but continues with the rest of the crew even after they board the Station.

Other non-life-threatening issues can have a big effect as well. If computers crash, it can lead to a major loss of data, communications or even experiments. In these cases, the ESA mission directors Claudio Sollazzo (Exp. 30) and Berti Meisinger (Exp. 31) are always in the front line at the Columbus Control Centre (COL-CC), at the German Aerospace Center (DLR) facility in Oberpfaffenhofen, near Munich, Germany.

→ André's tasks in space

- Participate in a substantial scientific programme, being trained for over 50 experiments for both ESA and ISS partners.
- Prime operator for the ATV *Edoardo Amaldi* rendezvous and docking.
- Support complex robotic operations, he is trained in the Space Station Remote Manipulator System (the Station's principal robotic arm).
- Closely involved in the berthing operations of the visiting Dragon and Cygnus cargo vehicles during their maiden flights to ISS.
- As a medical doctor, he is trained as a crew medical officer.



↑

André is fully trained to perform a possible Extravehicular Activity (EVA). This means that, if needed, he could perform a spacewalk outside the ISS

"Luckily, so far we have only had false alarms on the International Space Station. Fire and depressurisation alarms were activated in the past due to faulty equipment," recalls Berti Meisinger. When it happens, the whole Station needs to be reconfigured and the astronauts have to be alerted. In extreme cases, they are told to take shelter in the Russian Soyuz spacecraft.

"Our task on Earth is to allow the astronaut to do his job properly. Whenever there is a European astronaut on board, ESA has high expectations. We work to make sure that André can support all the ISS and Columbus activities required during his mission," explains Claudio Sollazzo. "We lay out his tasks day by day, I would even say almost hour by hour. However, it is a very dynamic process," he adds.

Is there a doctor on board?

André is not only trained for critical decision-making: he also knows how to run all the experiments, and he is proficient in the operations of every single system and payload related to the PromISSe mission.

"André needs to know how the first aid kits on the ISS and Soyuz work, where he can find certain medications and what medical procedures he should follow, usually different from what he learnt during his medical career," says Volker Damann, Head of the Crew Medical Support Office at EAC.

↓

Training includes launch and landing procedures on the Soyuz, as well as how to handle depressurisation, fire or toxic spills on board

The 'doctor in the house' will provide continuous feedback about his own health and the medical experiments where he is a test subject. He will often take samples of his blood, check his heart beat and monitor his eyes.

"I like looking inside my body. The data I collect can bring valuable information to the scientists on the ground, so we can learn more about the effects of weightlessness on the human body. And maybe my research will help in preparation for a future mission to Mars," says André.

A whole team of fitness experts, physiotherapists, sport scientists and nutritionists takes care of the astronaut's health. "The closer we get to the mission, the more intense his fitness programme is. You can compare us with a football team: we have a coach, a physiotherapist, a psychologist, etc. And we really try to tailor his fitness programme on a very individual basis," says Volker Damann.

Once in space, André will be subjected to weightlessness where, unlike on Earth, he will have to exercise two hours a day to avoid a significant bone and muscle loss, as well as maintain general fitness. The mechanisms behind these detrimental crew health effects are complex and partially still unknown, so his research on the ISS will significantly add to this knowledge.

Promising science

The transition from ISS assembly to full operations gives a boost to scientific research. With less time spent on ISS assembly tasks, it is expected that in the months to come significantly more crew time will be available for scientific experiments activities. This means that the PromISSe mission comes at an opportune moment, and André will be able to perform an extensive scientific programme for the benefit of life on Earth.

During his mission he will conduct around 35 ESA experiments covering a range of disciplines: human research, fluid physics, materials science, radiation research, biology and technology demonstrations. Being part of the ISS crew, André is also trained for around 20 experiments of the other ISS partners. The experiments look at the effects of microgravity and long-duration stays in space on the human body, and will benefit from André's background as a medical doctor.

Most of the scientific experiments will be carried out in Europe's Columbus laboratory, a world-class research platform with a multitude of facilities designed for different scientific disciplines. André will celebrate the fourth anniversary of this European laboratory module while in orbit. The whole of the scientific programme of European, US and Japanese teams will require the use of almost 30 different research facilities in the various ISS laboratories. Throughout André's stay on the ISS, the different cargo vehicles arriving will bring him new experiment instrumentation. The scientific programme does not rely solely on one vehicle, but sees a spread of uploaded equipment in time to allow for gradual execution of the scientific objectives.

André will be continuing some experiments that have already started in previous expeditions, but he will also start up some new exciting investigations. He will be the first subject in a new experiment that looks at the energy requirements and measurements of the energy balance for long-duration space missions.

↓

Apart from studying the effects of weightlessness on the human body, André has to keep up general physiological fitness

→ Mission name and logo

André's mission is called 'PromISSe', a name reflecting the great expectations placed on the future of human spaceflight and exploration. Following the trend of four previous European missions, 'ISS' is included in the name.

Ideas for the mission name were invited from the public by ESA in an online competition. The winner, 61-year-old Wim Holwerda from the Netherlands, believes that his winning proposal 'symbolises the promise that space exploration poses to the future of our planet and humankind, as well as the role that Europe can play in it'.

Mr Holwerda worked out an acronym from the word 'promISSe': Programme for Research in Orbit Maximising the Inspiration from Space Station for Europe, which shares three powerful messages with ESA – the crucial role of scientific research, a greater use of the ISS and the inspirational value of ESA space programmes.

The mission logo features the ISS orbiting Earth, accompanied by three icons and six stars. The name 'PromISSe' crowns a circular band of blue with orange edges. The 'ISS' part of the name is also in orange to highlight the Dutch participation in the mission. The centre of the logo shows a world free of national borders, with the silhouette of the ISS shown circling Earth, moving from the night to the day and about to fly over Europe.

The icons on the left represent the mission's three main elements: science, technology and education. The globe represents a knowledge-based society focused on our planet, the electronic circuit denotes technology and the conical laboratory flask denotes scientific research. The six stars represent the crewmembers, the six months that André will stay in space and, because the stars are similar to those on the EU flag, the European character.

↑

André and Oleg Kononenko in training for ATV rendezvous and docking operations at EAC, Cologne

André will also start the ESA contribution to the Meteron project, established by the partner space agencies to validate technologies targeted for future human and robotic operations.

Among other experiments related to human exploration of space are countermeasures for bone loss, the study of headaches in space and mapping radiation inside the ISS. Other experiments will see completion during the PromISSe mission, such as the SOLO experiment looking at the effect of sodium intake on the body and on bone metabolism, and the PASSAGES neuroscience experiment.

Traffic at the ISS

As Flight Engineer, André has several assignments, ranging from systems to payload operations. He will be the prime crewmember for the rendezvous and docking operations of ESA's third Automated Transfer Vehicle.

→ Ruimteschip Aarde

Ruimteschip Aarde (Spaceship Earth) is a project of the Netherlands Space Office, Amsterdam's NEMO science centre and Noordwijk's Space Expo museum working together with ESA and the World Wildlife Fund. During his stay in orbit, André will have a unique view of 'Spaceship Earth'. From the spectacular vantage point provided by Cupola, he will have the chance to observe both the beauty and fragility of our planet. Together with André, students will learn about life, biodiversity and climate change on Earth. As an ambassador of the World Wildlife Fund, he will also be exploring better ways to take care of the equilibrium between Earth and its inhabitants.

In March 2012, ATV *Edoardo Amaldi* is scheduled to be launched from ESA's Spaceport in Kourou, French Guiana. With its own flight control avionics and propulsion systems, Europe's most complex spacecraft has a high level of autonomy allowing it to navigate on its own and control its own rendezvous.

André and his crewmate Oleg Kononenko will monitor the ATV as it approaches the ISS. "They are well trained to intervene in case of any 'off-nominal' situation with ATV, or with the ISS, which could prevent it from docking with the Station. The rendezvous and docking manoeuvre requires a complex set of skills and very efficient communication between the two crewmembers. The astronauts are very excited about it. Their proficiency training with the ATV simulator will continue throughout the last days of their flight preparation in Baikonur. The simulator will also be used on the ISS to refresh their skills shortly before ATV arrives at the Station," said Hans Bolender.

The European vessel is not only a vital ferry for supplies, but also performs ISS attitude control and regular orbital reboosts, providing occasional manoeuvres to avoid collisions with space debris. While attached to the ISS, the ATV's thrusters will be used to raise the orbit of the complex. With ATV, Europe is contributing in kind towards its share of the Station's operational costs. The third ATV will deliver almost 7 tonnes of cargo, including around 3 tonnes of propellant.

André will also be closely involved in berthing the new Dragon (SpaceX) and Cygnus (Orbital Sciences) cargo vehicles as part of NASA's commercial resupply programme.

Looking at 'Spaceship Earth'

For nearly five months, André will be able to look back at our planet. Space is one of the most exciting platforms from which primary and secondary pupils can learn, and with André's help, European children will be able to participate in scientific activities. They will strengthen their knowledge of science, technology, engineering and mathematics, as well as study more about the requirements for life on Earth.

Science lessons will be sent from space to classrooms across Europe with in-orbit demonstrations of curriculum-based experiments dubbed 'Take Your Classroom into Space'. Because André is also an advocate for health and human wellbeing, he will encourage the new generation of space explorers to stay fit by following the second education initiative Mission-X: Train Like an Astronaut.

↑

André helps schoolchildren in Noordwijk with a project about space

He is eager to share his many experiences, the sights and sounds of life flying at 350 km above our heads. We will be able to watch a weightless André in 3D thanks to a high-definition 3D video camera for recording and live streaming of his daily life on the ISS.

Our special European correspondent will stay in touch with the ground not only through his own blog, but also via the Twitter, ESA YouTube and Flickr channels. Following the latest social media trends, André has already started 'tweeting' on Earth and he will continue to do so from orbit.

In his 1968 book, *The Promise of Space*, Arthur C. Clarke wrote: "Every age has its dreams, its symbols of romance. Past generations were moved by the graceful power of the great windjammer, by the distant whistle of locomotives pounding through the night. Our grandchildren will likewise have their inspiration – among the stars. They will be able to look up at the night sky and watch the stately procession of the Ports of Earth – the strange new harbours where the ships of space make their planetfalls and their departures."

This is happening now – we can look up at the night sky and see the stately procession of the ISS, our Port of Earth, where today's 'ships of space' arrive and depart. Through André's PromISSe mission, and of those next in line to fly, the inspiration of the stars continues to be strong, and each mission will mark another giant stride towards fulfilling the promise that awaits us. ■

Dawn of the age of Galileo – VS01, the first Soyuz flight from Europe's Spaceport in French Guiana, ready on the launch pad on 15 October

→ GLOBAL COUNTDOWN TO GALILEO

Javier Benedicto
Directorate of the Galileo Programme and Navigation-related Activities

Sean Blair
Communications Department, ESTEC, Noordwijk, The Netherlands

The first Galileo satellites were launched on 21 October – and Europe's own satellite navigation system is on its way to becoming a reality.

ESA has already flown two test missions, GIOVE-A and -B in 2005 and 2008, respectively – which served to claim radio frequencies set aside for the Galileo system, evaluate its planned orbital environment and demonstrate key technologies – but the recent satellites are the first true operational Galileo satellites in orbit.

Starting to place the system's 'space segment' in orbit represents a significant step forward, but it is only a single step in a long-term, multi-faceted effort. The satellites are the orbital 'tip' of a very large 'iceberg', an elaborate ground system essential to begin putting Galileo to work.

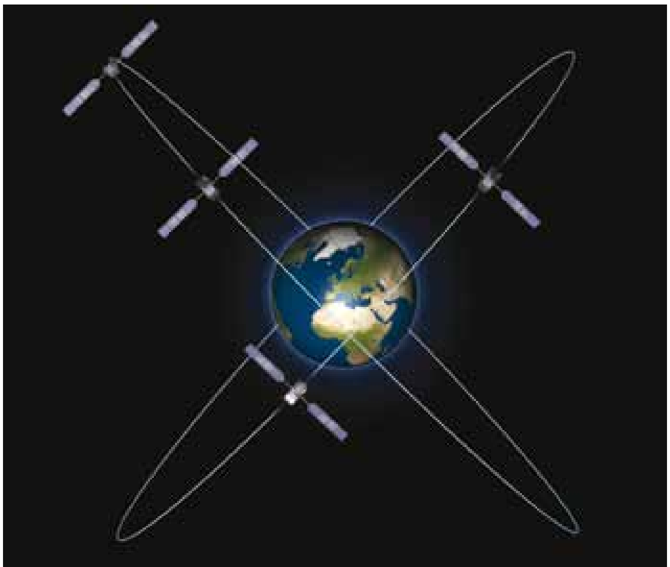
esa

← Galileo Protoflight Model and Flight Models during assembly and testing at Thales Alenia Space, Rome, May 2011

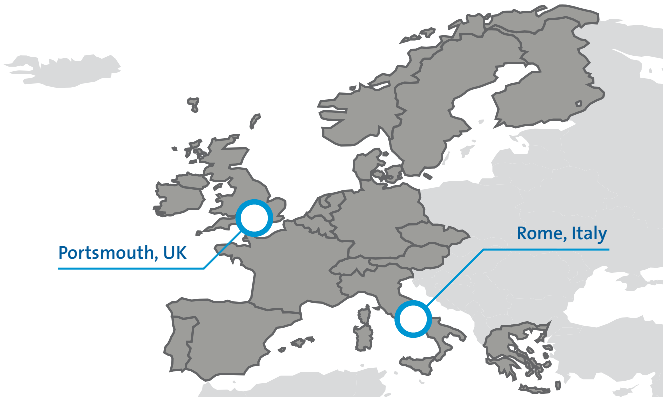
Creating Galileo IOV

The four Galileo In-Orbit Validation (IOV) satellites play a dual role, serving as testbeds for the next satellites due to follow them into orbit while also functioning as integral elements of the operational 30-satellite Galileo system – each satellite designed for a full 12-year lifespan providing navigation services to users worldwide.

Construction of the Galileo IOV satellites was overseen by EADS Astrium Germany, with EADS Astrium UK providing much of the payload and Thales Alenia Space in Italy responsible for satellite building, integration and testing. The four satellites are known as the Protoflight Model (PFM) and Flight Models 2, 3 and 4 (FM2, 3, 4). The former two are the first satellites to fly in space.



↑ The four Galileo satellites in their orbits



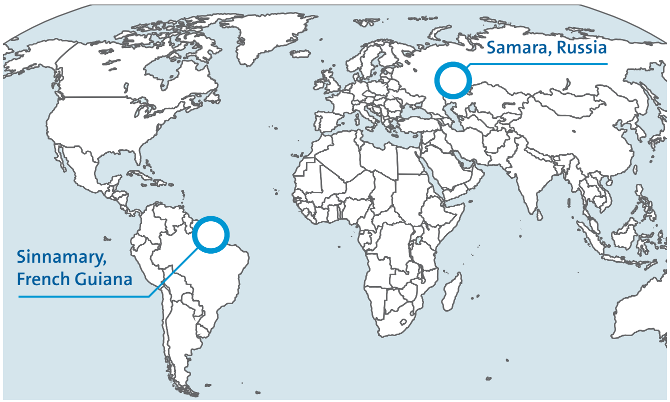
Each 700-kg satellite combines a powerful L-band antenna with a pair of passive hydrogen maser atomic clocks, the most accurate clock ever flown for satellite navigation: based on technology developed by ESA over more than a decade and a half, they are able to maintain an accuracy of one second per three million years. A pair of rubidium atomic clocks provides a technologically independent back-up, with an accuracy of three seconds per million years.

Satellite navigation is only possible by the highly precise measurement of time – with the time it takes for a signal to reach a receiver turned into a 'pseudo range estimate' of distance. The speed of light is 30 cm per nanosecond, and there are 1000 million nanoseconds in a second, so in practice even Galileo's onboard clocks are not accurate enough by themselves but need synchronisation with even more precise atomic clocks on the ground.

This linkage is enabled through Galileo's C-band antenna. Separate S-band antennas are used for downlinking satellite telemetry and uplinking telecommands, as well as receiving, processing and transmitting range measurements used to monitor satellite altitude – monitoring the satellites' precise orbits is as essential as keeping their clocks on time.

Soyuz from French Guiana

The first two Galileo satellites were flown to Europe's Spaceport in French Guiana on separate Antonov An-124 flights on 7 and 14 September. They are the first payloads to be flown on Russia's Soyuz rocket from its new launch site at Sinnamary, about 13 km northwest of the Kourou site used for Ariane 5 launches.



← One of the Antonov An-124 flights arrives in Kourou

→ Assembly of the three-stage Soyuz ST-B launcher begins in September at Europe's Spaceport

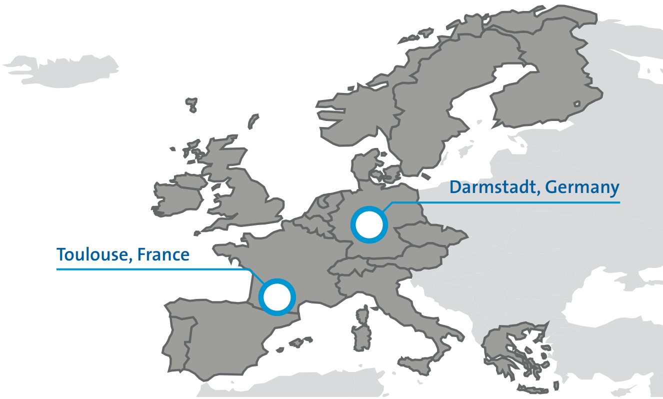
This was a historic occasion: the first Soyuz launch from a spaceport other than Baikonur in Kazakhstan or Plesetsk in Russia. The three-stage Soyuz launcher is the workhorse of the Russian space programme, in continuous production since the 1960s. Built in Samara, Russia, Soyuz has made more than 1700 manned and unmanned flights. It is designed to extremely high reliability levels for its use in manned missions – today it supports operations of the International Space Station.

As a medium-class launcher, bringing Soyuz to French Guiana complements Ariane and Vega to enhance the flexibility and competitiveness of Europe's launcher family. French Guiana is much closer to the equator, so each launch will benefit from Earth's spin, increasing the maximum payload into geostationary transfer orbit from 1.7 tonnes to 3 tonnes.

Arianespace operates upgraded Soyuz-ST launchers from French Guiana, along with a more powerful Soyuz ST-B variant. It is this configuration, plus a reignitable Fregat-MT upper stage, that was used to launch the Galileo satellites into their final 23 222 km high orbits. The two satellites were cradled side by side in a dispenser that released them sideways into orbit.

These first Galileo satellites are due to be followed into orbit by a second pair next year. Their two Soyuz ST-B launchers arrived in French Guiana in June.

↑ The ‘Upper Composite’, comprising the Fregat upper stage, the Galileo satellites and fairing, put on top of the Soyuz launcher, completing the very first Soyuz vehicle on its launch pad at Europe’s Spaceport

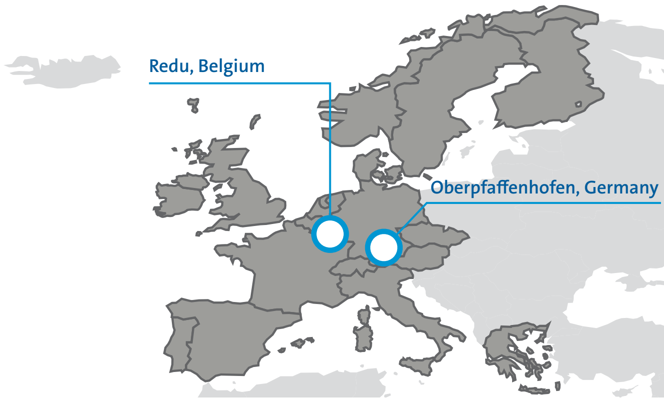


After launch

Immediately after the satellites were launched, their Launch and Early Operations Phase (LEOP) began with crucial activities such as the separation of the satellites from their Fregat-MT upper stage and the deployment of their solar arrays, proceeding into the gradual activation of platform systems.

The LEOP for the first launch was run from the Toulouse Control Centre, operated by a joint team from ESA’s European Space Operations Centre in Darmstadt, Germany, and the French space agency CNES. The same team will handle the subsequent LEOPs, 50% of which will be run from the ESOC Control Centre and 50% from the Toulouse Centre.

Once LEOP was completed, the satellites were handed over to the Galileo Control Centre at Oberpfaffenhofen near Munich, Germany, on 3 November, with navigation payload testing becoming the responsibility of ESA’s ground station at Redu in Belgium for the In-Orbit Test (IOT) campaign.



In-orbit testing

The IOT campaign will assess the performance of the satellites’ navigation payloads.

ESA’s Redu ground station has been equipped for the IOT campaign with specialised antennas for receiving and uplinking signals. Redu and Oberpfaffenhofen are constantly linked for the duration of the IOT so Redu can receive quasi-real-time telemetry and other supporting information.

↑ First two Galileo IOV satellites in orbit

Once released from their launcher, the Galileo satellites entered an orbit with a 14-hour period, making them visible from Redu for only limited periods each day, typically ranging from nine to three hours, so activities are carefully scheduled.

The IOT ground station is equipped with an L-band receive-only antenna to receive satellite navigation signals, a C-band transmit antenna to send navigation messages to the satellite payload and a UHF antenna for transmitting simulated search and rescue signals to the satellite.

The IOT campaign is measuring the accuracy and stability of the satellites' onboard clocks, as well as assessing the quality of the navigation signals. The results gathered will set a benchmark throughout the satellites' operational lives and provide a reference for the entire Galileo constellation.

The Redu station has already carried out a similar campaign for ESA's Galileo test satellite GIOVE-B, and will perform similar activities for further Galileo satellites, as well as being reactivated as needed for follow-up payload measurements or anomaly investigations.

← The two Galileo satellites being ejected from Fregat upper stage

Galileo control centres

There is lot more to Galileo than just its satellites in space. A worldwide ground network is essential to ensure the continued reliability of the time and positioning information embedded within the signals from orbit. The Galileo ground segment is one of the most complicated developments undertaken by Europe, having to achieve strict levels of performance, security and safety.

Satellite navigation relies on the receiver deriving the time and point in space from which a signal was transmitted to an extremely high level of accuracy. This information is embedded within the satellite signal itself. But the satellite's onboard atomic clocks can still drift – and a just a billionth of a second clock error corresponds to a 30 cm increase in error.

So a network of ground stations continuously checks each satellite's clock against the Galileo System Time (GST). Accurate to 28 billionths of a second, GST is generated by the Precise Timing Facility at the Galileo Control Centre in Fucino, Italy, which is in turn cross-checked for alignment to the International Coordinated Universal Time by a group of European timing laboratories.

Satellite orbits drift as well, nudged by the gravitational tug of Earth's slight equatorial bulge and by the Moon and Sun. Even the slight but continuous push of sunlight itself can affect satellites in their orbital paths. So the ground stations placed around the world to pick up Galileo signals perform 'radio-ranging' in reverse on the satellites transmitting them, to pinpoint their current position and identify any orbital drift.

The information on the satellites' clock performance and positions is gathered so that a corrective message can be uplinked to the satellites for rebroadcast to users in the satellite signals themselves. Closing the loop in this way means that optimal performance can be maintained over time. The quality and reliability of each individual Galileo signal is also checked.

→ Making the future: Galileo's partners

The definition phase and development and In-Orbit Validation of the Galileo programme were carried out by ESA and co-funded by ESA with the European Commission (EC). The EC is managing and fully funding the follow-up Full Operational Capability phase, with ESA delegated to act as design and procurement agent on the EC's behalf.

This worldwide network has two interconnected centres. Galileo's Ground Mission Segment (GMS) is tasked with overseeing Galileo's navigation services, providing cutting-edge navigation performance at high speed around the clock, processing data from a worldwide network of

→ Antennas at the Galileo Control Centre in Fucino, Italy

← Galileo Telemetry, Tracking and Command station at Esrange Space Centre, Kiruna, Sweden (SSC)

stations. GMS incorporates two million lines of software code, 500 internal functions, 400 messages and 600 signals circulating through 14 different elements.

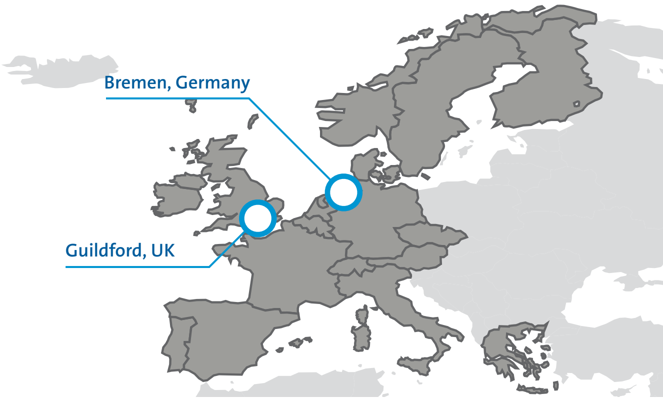
Meanwhile Galileo's Ground Control Segment (GCS) monitors and controls the Galileo satellite constellation, including 'housekeeping' the attitude, orbit and power levels of each individual satellite.

During the IOV phase, Galileo's GMS is based at Fucino, operated by Telespazio. The GCS is based at the Oberpfaffenhofen Control Centre, run by the Gesellschaft für Raumfahrtanwendungen (GfR) mbH, a subsidiary of the German Aerospace Center.

During the IOV phase, these two centres have distinct roles, but in future they will host equivalent facilities, working together as 'hot backups' with realtime data synchronisation. In the event of the loss of one centre, the other will be able to continue operations in a seamless way.

These two centres are at the heart of a global network of sensor stations – providing coverage for clock synchronisation and orbit measurements – and uplink stations to uplink navigation and integrity correction messages for rebroadcast by the satellite payloads.

Two Telemetry, Tracking and Command stations at Kiruna in Sweden and Kourou in French Guiana relay uplink commands to the satellites themselves. A secure Data Dissemination Network interconnects all Galileo ground facilities.



Galileo's next phase

The first four satellites are fully representative of the others that will follow them into orbit. Fourteen more will combine with these to provide the 'Initial Operational Capability' by the middle of the decade, which will then lead into the next phase, the final 30-satellite 'Full Operational Capability'.

The next 14 Galileo satellites are taking shape: the platforms and overall integration are the responsibility of OHB in Bremen, Germany, while their payloads are being constructed by Surrey Satellite Technology Ltd, based in Guildford, UK. When the 18 Galileo satellites are in orbit, they will provide initial services to users, with the full range of Galileo services from the complete 30-strong constellation scheduled by the end of the decade. ■

Sean Blair is an EJR-Quartz writer for ESA

Proba-1 remains in orbit, all its technology goals long since accomplished but still fully functional and its imaging services in steady demand

→ AUTONOMY IN ACTION

Ten years of Proba-1

Sean Blair
Communication Department, ESTEC, Noordwijk, The Netherlands

There are times when photographers have to move their cameras: when trying to resolve objects in rapid motion for instance, or capturing a subject from a variety of angles. So it is with ESA's Proba-1 microsatellite, whose main camera is still going strong after a decade in orbit.

At less than a cubic metre in volume, Proba-1's modest size lends it great agility and unique abilities that have seen its data used by a total of 446 Principal Investigator teams worldwide, and its camera, the Compact High Resolution Imaging Spectrometer (CHRIS), has acquired upwards of 15 560 science images of more than 3250 separate sites around the globe.

"To date Proba-1 remains the most agile and stable satellite platform in its range," explains Frank Preud'homme, Commercial Director of QinetiQ Space Belgium, the company serving as ESA's prime contractor for the development of the mission (previously known as Verhaert Design and Development).

"These attributes are a prerequisite for high-performance remote sensing missions. For Proba-1 – and the other Proba missions that have followed – the approach that has been taken has been to develop small satellites according to ESA quality standards but with specific implementation guidelines worked out between QinetiQ Space and ESA, making the platform ideally suited for operational missions at affordable costs where reliability is an important parameter."

ESA acquires, processes and distributes Proba-1 data as part of its 'Third Party Mission' data portfolio (together with international partner missions such as NASA's Landsat satellites, the Japanese ALOS satellite, the French Spot satellites or the UK-built Disaster Monitoring Constellation).

For the majority of Earth-observing missions, image acquisition is simply a matter of opening a viewing aperture, but Proba-1 is very different. A technology demonstration satellite turned Earth observation mission, the satellite's platform and payload effectively work as one. Spinning reaction wheels guided by a star tracker can roll the satellite off to 25° off-nadir in the across-track directions and 55° in the along-track direction.

To begin with, this allows Proba-1 to compensate for the effective satellite speed over Earth's surface of 7.5 km per second. This 'forward motion compensation' boosts its overall integration time per image, giving CHRIS an imaging performance and signal-to-noise equivalent to that of an instrument with an aperture area five times larger. Across-track tilts also increase the frequency with which the satellite is able to revisit areas of interest to less than a week.

Seeing all the angles

In addition, Proba-1 can acquire different views of the same target at up to five different viewing angles: at ±55°/±36°, as well as the standard nadir view. It is this capacity in particular that has proved invaluable to many scientists investigating the 'Bi-Reflectance Distribution Function' (BRDF) of vegetation and other land cover features – meaning how the light they reflect changes with shifts in illumination or view angle.

"Say you're looking at a sunflower on the ground," explains Mike Cutter of Surrey Satellite Technology Ltd's Optical Payloads Group (formerly the Sira Space Group), which developed CHRIS and processes the data on behalf of ESA's ESRIN centre.

"You'll see a different mix of colours depending on where you're standing, as well as the growing season and time of day: the yellow canopy, green stalk and leaves, brown soil, sun glint or shadows. The same is true when observing from orbit. Quantifying this BRDF offers a way of giving much more accurate classification of vegetation and canopy covers, such as the tree species within forests."

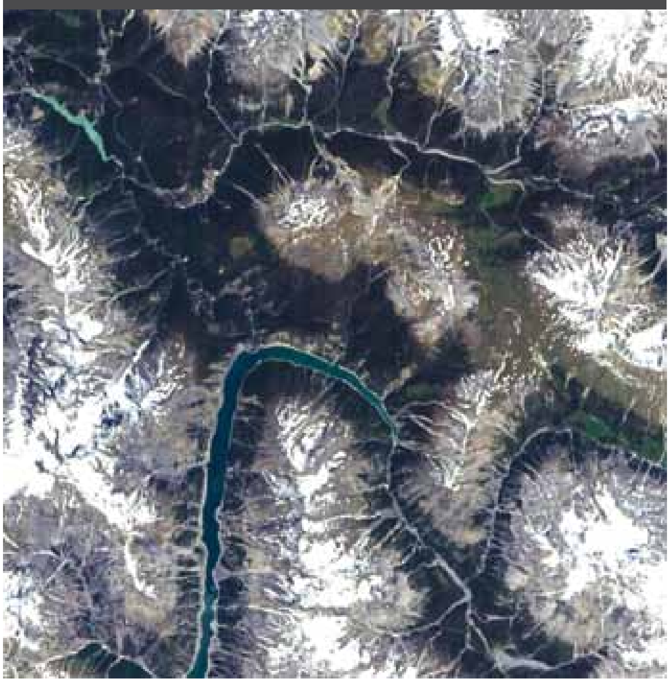
Beyond the sprightliness of its host platform, the hyperspectral CHRIS imager is well-suited to such a task in its own right, its design enabling users to fine-tune its settings as desired. Each 17 m sampled 13 sq. km image is viewed in a total of 18 visible and near-infrared spectral bands at once. Alternatively, the swath can be reduced by half, to 6.5 sq. km, to observe 34 spectral bands at a time, or 62 spectral bands observed if the spatial sampling is increased to 34 m.

A worldwide community of users

Researcher David Goodenough of Natural Resources Canada has found that CHRIS multi-angle observations of Canadian forests and associated land cover reduced his classification errors by more than half. Teams in Switzerland, Germany and Australia meanwhile have been using CHRIS observations to classify the leaf angle and therefore maturity of maize, wheat and cotton crops respectively (the angle of the leaves increases as the structure of the growing crops change, the stems and heads coming to dominate). A Peking University project has done the same for seasonal observations of wheat, cotton and apple orchards in the Hengshui area of China's Hebei Province.

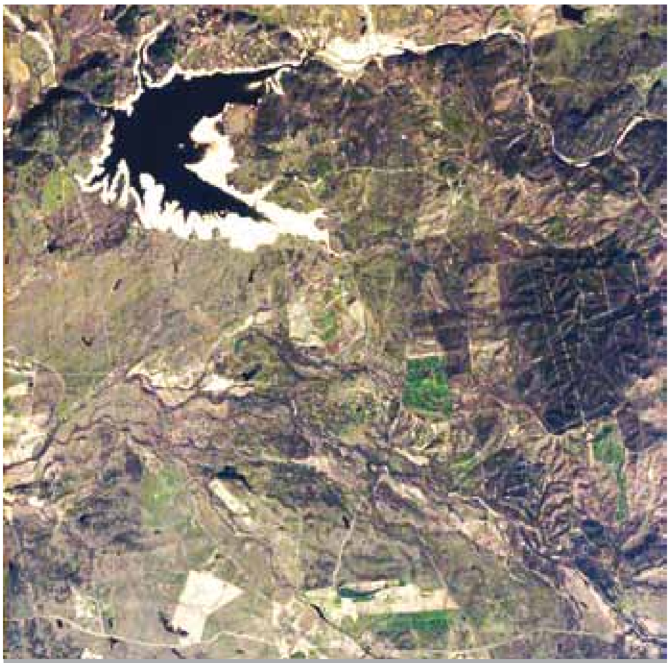
Other CHRIS users within the land cover field concentrate on spectral data alone – multi-angular views not being relevant. Bettina Weber of the University of Kaiserlautern in Germany has employed CHRIS imagery to measure the coverage and estimate the biomass of lichens and biological soil crusts

↓ CHRIS view of Swiss National Park, Switzerland



in the Namibian Desert. Such crusts play an important ecological role, anchoring soil in place, so their loss over time can flag up erosion patterns.

CHRIS data has also found favour in combination with other, lower spatial and spectral resolution imagers, such as NASA's Moderate Resolution Imaging Spectroradiometer or the Medium Resolution Imaging Spectrometer on ESA's Envisat satellite. "It can give extra detail of a local section of a larger satellite image acquired at lower spatial resolution, which is often useful," adds Mike Cutter.



↑ ↓ CHRIS views of the Rosarito Reservoir in Spain

CHRIS over water, and imaging the air

This is true on land, but especially so over water. A community of users are using CHRIS to sample water quality, its multispectral imagery serving to derive standardised parameters such as chlorophyll content, total suspended soils and dissolved organic matter within inland water bodies such as the Rosarito Reservoir and Aracena Dam in Spain – research of growing significance due to the European Commission's Water Framework and Drinking Water Directives.

Proba-1 acquired a notable image of the 2010 Gulf of Mexico oil spill and has also been used to study spills within Venezuela's Lake Maracaibo, one of the most ancient, oil-rich (and hence polluted) water bodies in the world. In Germany CHRIS data has been harnessed to assess the ecological condition of abandoned open-cast mining areas, identifying impacts on vegetation, sediments and water – iron oxide tailings can not only turn water brown but also acidic. Similar techniques can be used within coastal waters, with one survey of chlorophyll and suspended particles performed off Ostend in Belgium.

↑ CHRIS view of Rupel and Schelde rivers in Belgium

But CHRIS is also being used to survey the bathymetry of coastal waters as well as their contents: Ray Merton of the University of New South Wales in Australia has developed an innovative algorithm to estimate the shallowness of coastal waters by identifying the shifting frequency of waves as they approach the coast or underlying reefs, employing the fact that the wave's spatial frequency increases as the water gets shallower. This technique can be used in highly sedimented water without needing to rely on the optical visibility through the water as typically used in bathymetry.

↓ Konakri, Guinea, seen by Proba-1's CHRIS instrument in 2002

CHRIS is also usable for atmospheric aerosol monitoring, its higher resolution offering enhanced insight into highly polluted regions. A team led by Janet Nichol at the University Polytechnic of Hong Kong adapted an algorithm originally developed by MODIS to retrieve aerosol optical thickness (AOT) over Hong Kong, with results checked against by Sun photometer and lidar measurements, as well as air quality data gathered by ground stations. They estimated an error of around 6%, compared to up to 20% from comparable MODIS data products – the entire sampling area of 11 x 11 km being only slightly larger than a single MODIS AOT pixel.

↑ Proba image of Victoria Harbour in Hong Kong

Versatile by design

The versatility that has attracted devoted users around the world was inherent from Proba-1's very start. Its name stands for 'Project for Onboard Autonomy'. "The aim of the project, supported in particular by the Belgian Federal Science Policy Office through ESA's General Support Technology Programme, was to demonstrate as many new technologies as possible on a single platform, the resulting small satellite being able to operate itself with minimum ground control," explains Frederic Teston of ESA's In-Orbit Demonstration Programme.

Onboard innovations included what were then novel gallium arsenide solar cells, one of the first lithium ion batteries – now the longest operating such item – in low-Earth orbit, and attitude and orbit determination using only star trackers and GPS sensors, doing without the then-standard standard Earth or Sun sensors or gyros (GPS timings are also used to synchronise operations).

Navigation and attitude control software was generated through 'autocoding' to cut costs – essentially applying code to write code – with Proba-1's overseen by an ERC32 computer, a space version of a standard commercial processor, subsequently employed on projects including ESA's Automated Transfer Vehicle, the Columbus laboratory module on the International Space Station, the European Robotic Arm and the forthcoming Sentinel satellites that support Europe's Global Monitoring for Environment and Security initiative.

As part of Proba-1's technology goals, all software components in the central computer or embedded within other subsystems can be reprogrammed in flight. The satellite itself does as much work as possible: CHRIS users only have to submit the latitude, longitude and altitude of their intended target and the onboard computer navigates to the correct location, tilts, shoots and delivers the scene.

Steering by the stars

During normal operations, Proba-1's attitude is provided with the star tracker viewing two star fields, and the orbit calculated autonomously from GPS data. Knowing the orbit and attitude allows the satellite to deduce the direction of all user-selected Earthbound targets.

Attitude is controlled using a set of four reaction wheels mounted in a tetrahedral configuration – set one spinning and the satellite spins in the opposing direction, yielding a pointing accuracy of one arc minute (one sixtieth of a degree). Momentum built up in the wheels is dumped via magnetotorquers – electromagnets that interact with Earth's magnetic field – that are also used to align the satellite in the event of it entering 'safe mode'. The satellite has no fuel, further reducing its mass and avoiding any 'sloshing' effects that might interfere with fine pointing.

Proba-1 payloads

As this autonomous technology demonstrator underwent development, led for ESA by what is now QinetiQ Space Belgium (then Verhaert Design and Development), payloads were sought. "There were several candidates, however CHRIS found favour because it had particularly challenging requirements, so offered a good demonstration of Proba-1's onboard autonomy," recalls Mike Cutter.

CHRIS was the largest of five payloads. A second, smaller imager, the High Resolution Camera (HRC) developed by Belgian company OIP Sensor Systems provides monochrome 5–10 m resolution images across an approximately 25 sq. km field of view.

And with Proba-1's approximately 600 km polar orbit taking it through the polar 'horns' of Earth's radiation belts, it also carries two radiation monitors: the Standard Radiation Monitor (one of a family of monitors flown on various ESA missions, building up radiation maps across the inner Solar System) and a smaller Miniaturised Radiation Monitor. Finally, a space-debris detector, the Debris In-Orbit Evaluator, was also flown – another version of this detector was later attached to the ISS.

A decade in orbit

Proba-1 was designed to be compatible with several launchers, including Ariane 5, to help find a cheaper 'piggyback' launch opportunity (launch costs can amount to a considerable proportion of a mission's final price tag), finally riding to orbit on 22 October 2001 on an Indian Polar Satellite Launch Vehicle (PSLV), from the launch station at Shriharikota, a small island about 100 km from Madras.

Proba-1 remains in orbit, all its technology goals long since accomplished but still fully functional and its imaging services in steady demand. Funded by ESA's Earth Observation Programme since 2004, the scientific data exploitation is overseen from ESA's Earth observation centre in ESRIN. CHRIS acquires an average of three sets of five multi-angle images daily, with the HRC high-resolution black-and-white camera also returning a steady stream of imagery.

The satellite is commanded from ESA's Redu ground station in Belgium with a dedicated 2.4 m antenna, with Kiruna in Sweden serving as an additional data downlink. The onboard autonomy and the ground-segment automation elements allow the control of satellite passes with no operator attendance. This approach proved to be very successful in terms of operational efficiency and has been reiterated for the coming Proba satellites.

The user segment operations of Proba-1 are spread across ESA's Member States, overseen by the ESRIN team. A company called RSAC Ltd (UK) compiles a schedule of upcoming CHRIS targets based on Principal Investigator (PI) requests gathered by ESRIN. This process is guided by NORAD 'two-line elements' feeding an orbital model compiled every fortnight by Jeff Settle and his colleagues at the University of Reading, forecasting which sites will be visible per given day, along with a 48-hour cloud prediction product (initially provided by the UK Met Office but lately by weather.com).

→ Proba-1

Spacecraft mass	94 kg
Instrument mass	25 kg
Technology payload mass	30 kg
Shape	60 x 60 x 80 cm box-shaped aluminium honeycomb structure
Launch date	22 October 2001
Launch site	Sriharikota, India
Launcher	Antrix/ISRO PSLV-C3
Orbit	LEO Sun-synchronous
Orbital parameters	681 x 561 km

→ Disaster monitoring

North Sentinel Island in the Indian Ocean – seen here in this 2005 CHRIS image – was one of the more obscure victims of the 2004 Asian tsunami, with geological uplift leading to formerly submerged coral reefs rising above the waves. The shift represented a big environmental change for the island's inhabitants, the Sentinelese, one of the last uncontacted indigenous human tribes on Earth.

The image shows how CHRIS images can be employed for detailed disaster monitoring, one of more than 500 acquired to date on behalf of the International Charter 'Space and Major Disasters', an agreement between global space agencies under which satellite imagery is supplied freely to emergency responders on a best-effort basis.

The resulting target coordinates are then transferred to Redu by SSTL together with the payload configuration for the specific PI requested spectral and spatial observation conditions. The acquired image data is then processed to Level 1b by SSTL and delivered to ESRIN for downlink by the PIs.

There are currently a total of 42 262 CHRIS data sets available for scientific users in the ESRIN data archive, each set comprising between one and five images of the same target. The archive also contains more than 13 000 HRC images.

Effects of time

The only noticeable ageing effect experienced by the satellite comes from a combination of cumulative radiation damage and higher seasonal temperatures (counter-intuitively for us in the Northern hemisphere, Earth comes closest to the Sun in January, leading to an effective 10% increase in solar flux). After 10 years in orbit (and a design life of only two years) Proba-1's star tracker shows sensitivity to the resulting change in temperature.

There are ways to overcome the effect, such as reorienting the satellite between imaging acquisitions to decrease the solar flux reaching the star tracker. But still, CHRIS has been forced into taking 'winter holidays' these last few years.

Time is gradually running out for Proba-1 in another way, nothing to do with its design but resulting from stern laws of orbital mechanics. Like most Earth observation missions, Proba-1 was placed into a Sun-synchronous orbit, meaning it keeps pace with the Sun so that it crosses the equator northward at a fixed local time, helping to keep lighting conditions constant for comparing images.

At launch, this local time was 10:30 a.m., the orbit chosen so it would advance up to 10:46 within the first three years and then gradually drift back earlier. "This gave us very good local times for about eight years," adds Frederic. "Bear in mind that the original mission lifetime was set at two years originally. It's becoming more of a problem as we get past 9:00 a.m., and there will come a point it simply gets too dark."

Orbital geometry aside, having sufficient funds to support missions that considerably exceed their nominal lifetime is always a challenge. "We are happy that through the past eight years our national delegations have supported

← Proba-2

→ Proba-3

us in extending the mission and thus enabling the variety of applications to expand further every year," says Bianca Hoersch, the Proba-1 Mission Manager.

"The funding from Third Party Missions and the current Earth Observation Envelope Programmes has ensured the mission operations until the end of 2012. It would be great to have CHRIS around even longer until national hyperspectral instruments such as the Italian PRISMA or the German EnMap missions become available, currently foreseen for 2013."

The Proba family

The success of Proba-1 has inspired a family of follow-on technology demonstrator missions, aimed at providing more frequent flight opportunities to new European technologies. Proba-2 has been in orbit since November 2009, carrying 17 technology demonstrations and four science payloads focused on the Sun and space weather.

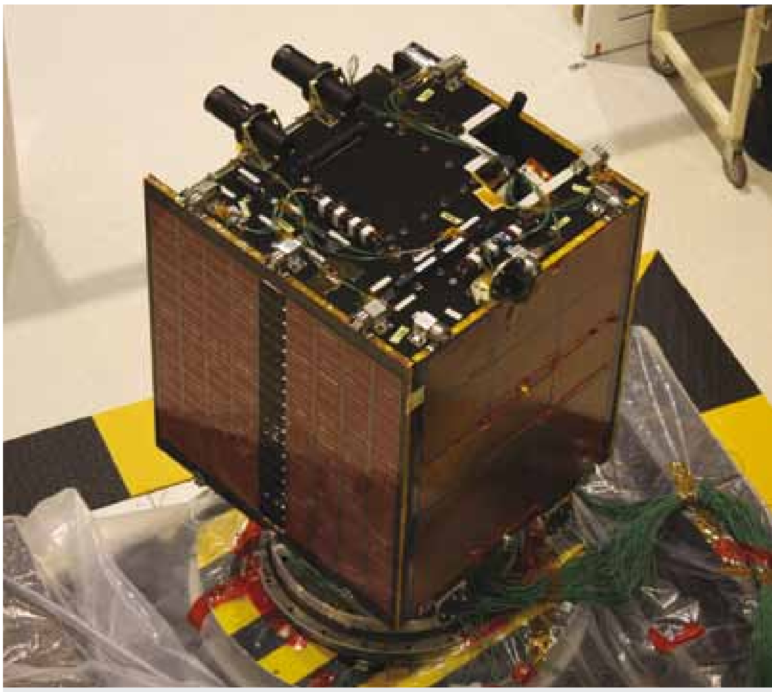
Proba-V is due for launch next year, providing daily maps of global vegetation cover in order to ensure data continuity between the end of the 'Vegetation' series of sensors flown on France's Spot-4 and -5 satellites and the launch of a compatible sensor on ESA's Sentinel-3.

Its novel technologies include a compact telescope and short-wave infrared detectors, the first X-band gallium nitride transmitter, as well as an energetic particle monitor and an experimental automatic dependent surveillance-broadcast receiver, used for aircraft tracking.

Also under study is Proba-3, a double satellite mission to demonstrate close formation-flying techniques, with one satellite casting the other in an artificial solar eclipse to reveal hidden features of the inner solar corona.

All the other Proba missions to come follow the first one's example, incorporating demanding science payloads to serve as the best possible demonstration of the experimental technologies integrated aboard. If the results are good enough then the scientific end users will come – challenging Proba's engineers to do their very best to make it happen. ■

Sean Blair is an EJR-Quartz writer for ESA



↑ Proba-V Structural and Thermal Model during testing in Toulouse, France, in 2010 (Intespace)

↑ A mosaic of four black and white images taken by Proba-1's High Resolution Camera in September 2011, showing massed camper vans and tents gathered for the desert-based Burning Man festival at Black Rock, Nevada, USA

→ Proba-1: lessons learned

The Proba-1 experience has proved remarkably successful in demonstrating the potential of small satellites in space, first, for flight-testing new technologies and going on to serve scientific end-users.

Small satellites – their mass measured in the tens of kilograms, rather than tonnes – take months instead of years to develop and are much cheaper and simpler to build and launch. In the case of Proba-1, it succeeded in its aim of being launched within two years of the start of its Phase-B design study phase.

Spending less money per mission means a somewhat increased level of risk becomes acceptable, and experimental systems that the (understandably) risk-averse mission manager of a full-sized satellite might flinch at can find a berth in space.

This opens up new opportunities for European companies to prove novel technology in space. In-orbit demonstration is the last step on the technology development ladder: flight heritage is essential for market acceptance.

The satellite itself represented an experiment – Proba-1's name also derived from the Latin word *probare* – 'to test', or 'to try'. Autonomy was seen as a highly desirable attribute for future missions, but also it tends to drive up development costs and threaten, in the worst case, the loss of control of the satellite. But this mission was small enough to take the risk.

Autonomy also required more complex onboard software – which meant a lot of time taken to write it, at least traditionally. Autocoding reduced the time taken to compile and validate Proba-1's flight software by a factor of nearly two.

The project proceeded in other novel ways for ESA: mission control system development became an integral part of the overall mission programme, along with associated operations. Development occurred incrementally, with progressive validation taking place throughout activities ranging from software development, spacecraft integration and system testing to in-orbit operations.

For ESA's industrial partners, the experience proved an extremely valuable one. For what was then Verhaert Design and Development, Proba-1 provided the opportunity for them to oversee a high-profile space project by themselves, rather than work on a subcontracted slice of another company's work.

"Proba-1 was a milestone in developing our prime contractor capabilities. Despite prime contractorship of other important large projects, it was Proba-1 that marked QinetiQ Space as a small system integrator," comments Frank Preud'homme, Commercial Director of QinetiQ Space.

"This allowed QinetiQ Space to acquire larger projects in turn, and to attract motivated young engineers to further develop these capabilities. New young engineers were trained on the Proba projects. And once Proba-1 was adopted by ESA's Earth Observation Directorate for operations, providing high-quality images daily, the opportunity was opened up for us to show interested customers the advantage of the automated operations concept, further enhanced by the advances made in the follow-up Proba missions."

The Optical Payload Group of Surrey Satellite Technology Ltd (SSTL) recount a similar experience: "Our staff became extremely enthusiastic about having full control of a satellite instrument, rather than supplying subsystems to prime contractors and it helped give consideration to the approach to take when developing low-cost missions," said Mike Cutter of SSTL.

"CHRIS helped put us on the map as a small satellite instrument supplier. It also helped to build up our relationship with SSTL, which led to the joint bid for the NigeriaSat-2 Very High Resolution Imager and the subsequent acquisition of the Sira Space Group by SSTL. NigeriaSat-2 was launched in August 2011 and is providing 2.5 m imagery. Expertise and heritage in payload development for small satellites can also drive new business opportunities, as seen by the recent award to SSTL to build the 1 m resolution spacecraft under contract to its subsidiary, DMC International Imaging Ltd."

↑ The Pyramids of Giza in Egypt, taken by Proba-1's High Resolution Camera in March 2004. The three main pyramids stand on the edge of Greater Cairo at the verge of the desert

↑ Uluru, also known as Ayers Rock, in Australia as taken in April 2004 by the High Resolution Camera on Proba

↑ Proba-1 took this image of Liberty Island and Ellis Island, New York, from 600 km altitude in 2006. Liberty State Park is to the left, and New Jersey is at the top left. Manhattan is top right, and Governor's Island is bottom right

Alphasat, the first satellite using the new European high-power Alphabus telecommunications platform, will carry four hosted payloads, called Technology Demonstration Payloads

→ HITCHING A RIDE TO ORBIT

The 'hosted payloads' concept

Andreas Mauroschat, Stephane Lascar, Rudolf Halm, Francois Garat, Kevin Goodey, Xavier Lobao and Fabrice Joly
Directorate of Telecommunications and Integrated Applications, ESTEC, Noordwijk, The Netherlands

As a cost-effective way to deploy new services, validate new technologies, give them 'flight heritage' in space and introduce them in the commercial market, the concept of 'hosted payloads' offers a win-win-win solution for operators, industry and public institutions alike.

New technologies developed for satellite communications are validated through simulation and extensive testing but, just as in everyday life, it's the experience that counts. ESA's Telecommunications Programme (ARTES) supports the research and development of new technologies and services to enhance and improve communications via satellite.

By working together with Europe's satcom industry, ESA has helped a fledgling business sector grow into a flourishing one. Through ARTES, ideas develop into projects; projects develop into products and products are developed up to space qualification.

But what happens then? It is up to industry to sell this new product, which can be hard to do if it has never actually been validated in space. Ground qualification is one thing; actual operation in orbit is another.

However, launching and operating a dedicated satellite to introduce a new satellite service or augment an existing one, or just to validate new satellite technologies would be too expensive. One solution that ESA has promoted over the last years is the 'hosted payload' concept. With hosted payloads, new technological advances can be demonstrated in orbit and additional satellite payloads can be operated in a win-win-win approach for operators, industry and public institutions like ESA.

Hosted payloads benefit from available capacity on commercial satellites to accommodate additional transponders, instruments, or other applications that have to be operated in space. Partners share the satellite platform. This arrangement takes less time and money to implement, allowing advances in satcom technologies and services and new businesses to grow. This concept has also been referred to as 'piggybacking', 'hitchhiking' or secondary payloads.

The satcom industry worldwide is launching commercial satellites every year. Euroconsult, a leading international consulting and analyst firm that has worked on several ARTES studies for ESA, has forecasted that 214 commercial communications satellites will be launched into a geostationary arc between 2010 and 2019.

According to Euroconsult, commercial satellite services outside geostationary orbit (GEO) will get a boost with a total of 200 satellites to be built and launched into medium and low Earth orbits during the next decade. Most of them will be communications satellites to replace the first low Earth orbit (LEO) generation operated by Iridium, Globalstar and Orbcomm.

↑ ESA has supported a number of hosted payloads over the years, including the AmerHis system on Amazonas 1 (Hispasat)

These numbers show there is indeed a 'way up' to validate new technologies if industry, operators and publicly funded research and development programmes, such as ESA's ARTES programme, work together. Hosted payloads can be used by government agencies seeking to have an orbital communications capability without having to pay the cost of building and launching an entire government-owned satellite.

Using a hosted payload on a commercial satellite can reduce both the expense and time required to get a communications system into space. For the satellite operator, the hosted payload is a way of increasing the benefit generated by one satellite, and to start the gradual introduction of a new service with a minimised risk.

→ Skyplex

Available today on Eutelsat's Hot Bird and W3A satellites, the Skyplex unit can receive bit-rate uplink signals in the range 350 Kbps to 6 Mbps. It then demodulates them for multiplexing into a single digital stream at 38 Mbps, which is then remodulated on board the satellite for broadcast.

Using a PC-based Skyplex multiplex adapter and an adapted DVB modulator combined with a small dish and medium power amplifier, a broadcaster can send a signal from anywhere in the coverage zone up to the Skyplex unit.

Since Skyplex enables DVB transmission direct-to-home, the broadcaster can decide whether to encrypt the uplink streams (with a choice of conditional access systems) or to simply leave them in the clear. With such influence over encryption, the broadcaster is able to closely define and manage the target audience.

Supporting the concept

Through ARTES, ESA has supported a number of hosted payloads over the years. These include the launch of the Skyplex processor on the Hot Bird 4 satellite, followed by AmerHis on Amazonas 1.

AmerHis has enabled Hispasat to provide high-performance interactive multimedia services on its four Ku-band coverage zones: North America, South America, Brazil and Europe.

The AmerHis payload works like a switchboard in space managed by a Network Control Centre on the ground, which is able to configure the payload, assign capacity and manage user traffic.

The AmerHis system allows for the development of new, more flexible, higher quality and higher transmission speed broadband services. By using a lattice network, the system allows for direct communication between small stations. Another important advance is the interconnectivity between the coverage beams. This allows the connection of one or more coverage zones using a single transmission, as well as the onboard merging of various signals into one, even if they come from different coverage zones. Both improvements can be applied to services such as video conferencing and corporate networks.

Both Skyplex and AmerHis projects were important pathfinders for the high-throughput satellite systems that are currently proposed to provide high-speed internet services, which are expected to become a major market for satellite communication in the coming years.

What ESA is doing today?

ESA recently sponsored a hosted payloads workshop where interest in this concept proved to be very high. A roundtable discussion, chaired by Magali Vaissiere, ESA's Director of Telecommunications and Integrated Applications, concluded that hosted payload opportunities with ESA should be further explored by setting up public–private partnerships embarking institutional payloads on commercial satellites. About 80 participants, including members of Europe's satcom industry, ESA national delegations, space agencies and institutions, attended the workshop, which focused on the four hosted payloads that will be launched on board Alphasat.

← Eutelsat's Hot Bird 4 satellite carried the Skyplex processor, also supported through ESA's ARTES programme

← At the Alphasat Hosted Payload Workshop in Lisbon in June, Magali Vaissiere, ESA Directorate of Telecommunications and Integrated Applications discusses hosted payload opportunities

Alphasat, developed in partnership with European operator Inmarsat, is the first satellite to be launched using the new European high-power Alphabus telecommunications platform developed by Astrium and Thales Alenia Space under an ESA/CNES cooperation programme. The flight of Alphasat is, in fact, a validation of Europe's new high power platform in orbit.

Alphabus completed qualification at the end of 2010 and is now available on the commercial market to accommodate missions needing up to 18 kW of payload power.

An extension contract to build a more powerful Alphabus was signed end of last year by EADS Astrium, Thales Alenia Space, ESA and CNES, to qualify Alphabus for the very high-power end of the communication satellite market. The new developments within the Alphabus Extension programme will extend the payload range up to 22 kW power, 2000 kg and 19 kW of maximum heat rejection. Features of the Alphabus Extension programme will be introduced in the Alphabus Product Line for satellite bids as soon as they become available, and as needed by satellite operators, as of 2012.

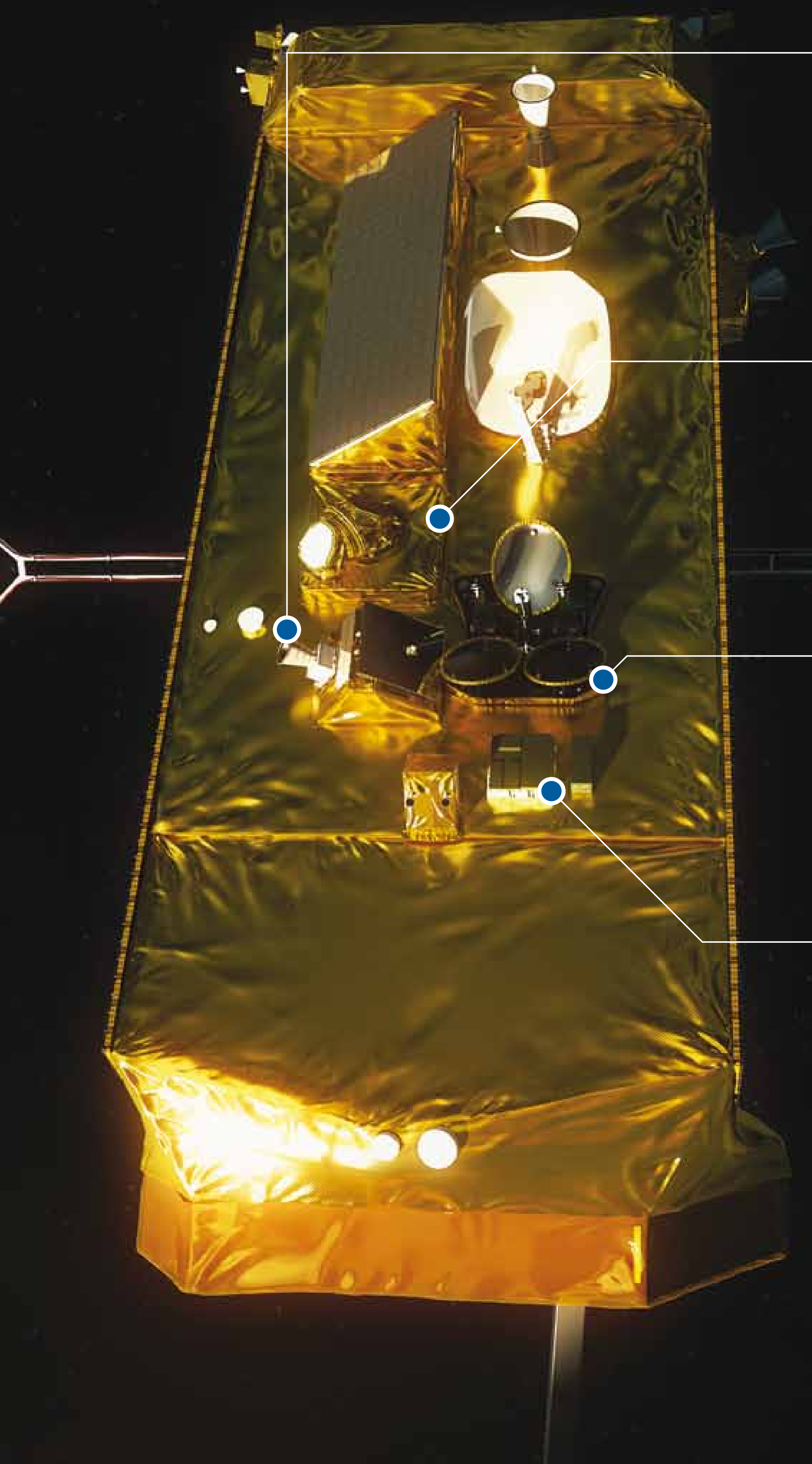
As a result, Alphabus provides unprecedented payload capacity to satellite operators, and therefore offers a great potential to embark hosted payloads. As a 'pathfinder', Alphasat was set up as a public–private partnership exploiting the large payload capacity of Alphabus and including a number of hosted payloads.

The hosted payloads to be flown on Alphasat are four technology demonstration payloads that were developed with the support of ESA or delivered as 'customer furnished instruments' (CFIs) by a national space agency. These new technologies that will be flown will advance European industry once they are validated in space. An open call to European industry was issued in 2005 to select the hosted payloads for development and flight on Alphasat. ESA ARTES funding allowed companies to assume risks in development that might otherwise not be taken.

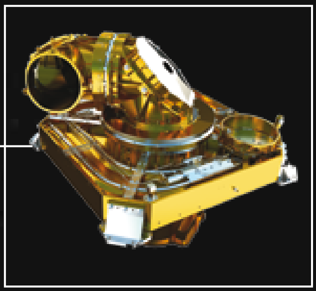
Technology demonstration payloads (TDPs)

The four TDPs that were selected are: TDP1, an Advanced Laser Communication Terminal to demonstrate LEO to GEO communication links; TDP5, Q/V-band propagation and communications experiment to assess the feasibility of these bands for future commercial applications; TDP6, an Advanced Star Tracker with active pixel detector; and TDP8, an environment effects facility to monitor the GEO radiation environment and its effects on electronic components and sensors.

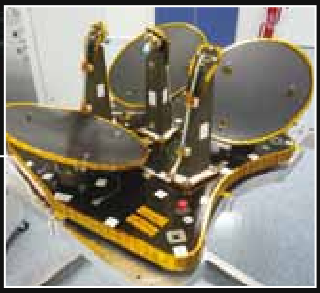
→ Alphasat Protoflight Model before acoustic testing, with Technology demonstration payloads visible (Astrium)



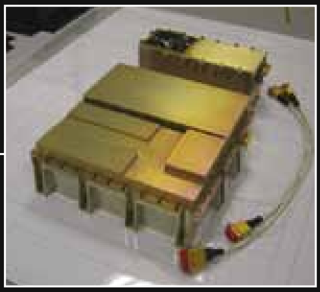
APS star tracker



Laser Communication and Ka-band downlink



Q/V-band communication and propagation



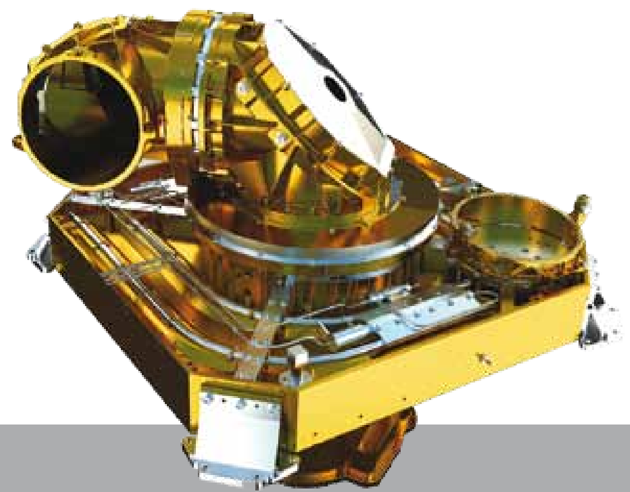
Environmental testing and radiation Sensor

↖ ESA's Technology Demonstration Payloads as hosted payloads on Alphasat I-XL

Advanced Laser Communication Terminal (LCT)

Developed by TESAT (DE) and Ruag Space (CH) with support from the German space agency DLR, the Swiss Space Office and coordinated by ESA, this TDP is a data relay mission to link observation data from LEO observation satellites towards a ground station through the geostationary Alphasat.

The data-relay link between LEO and GEO will enable direct downloads from Earth observation satellites to small terminals, allowing for example, rescue workers to see near-realtime satellite imagery of the region where they are working.



↑ Advanced Laser Communication Terminal (TESAT-Spacecom)

The TDP1/LCT is composed of a Laser Communication Terminal (LCT) and a radio frequency downlink. It provides a 2 Gbps bidirectional data link between the LEO satellite and the Alphasat GEO satellite using laser diode pumped Nd:Yag (neodymium-doped yttrium aluminium garnet) crystal lasers transmitting infrared light at an ultrastable wavelength of 1.064 µm.

The LCT includes two major functions: to relay Earth observation data from LEO satellites (for example, Sentinel-1), and to verify the bidirectional optical link (experiment results, such as error counts, sensor data, etc., are transmitted via Alphasat telemetry to the ground for evaluation).

The major advantage of laser communication terminals compared to conventional RF payloads is their very high data rate, and this is the first time that such an optical LEO-to-GEO link will be verified in orbit. This TDP is a precursor of an operational optical communication system that will be used in the European Data Relay System (EDRS).

The satellite laser terminal acquires the very weak signal from the optical beam of an optical counter terminal, which may be up to 50 000 km away. Once acquired, the data transmission between the two laser terminals (LEO and GEO) starts. Considering that LEO satellites travel at about 8 km/s (28 000 km/h), and the GEO satellite at about 3 km/s (11 000 km/h) in different directions, accomplishing this link is indeed a big challenge.

The received data are then downlinked via the Ka-band transmitter to the DLR ground station. More than ten LEO-to-GEO links per day in the first years of operation are expected.

Q/V-band communication and propagation

Developed by Thales Alenia Space (IT) and Space Engineering (IT), a Q/V-band communication repeater explores the use of these frequencies for future applications. With the amount of available spectrum becoming smaller and smaller, investigations into the use of higher frequency bands need to be made. However, the higher the band, the more elements can block the signal. A simple rain shower can be detrimental to transmissions using Q/V bands.

Given the very strong atmospheric fading that can be experienced at Q/V frequencies, the communication experiment is aimed at demonstrating the capability of 'interference and fading mitigation techniques' (IFMT), and site diversity in improving the link quality in a real Q/V band satellite link.

↑ Q/V-band communication repeater (TASI & SPENG)

The communication experiment is accompanied by scientific experiments to explore the most significant propagation parameters that intervene in radio channel modelling and to obtain new data permitting to optimise the design of RF payloads adopting adaptive techniques, such as adaptive coding modulation (ACM) techniques, onboard antenna pattern reconfigurability, uplink and downlink power control and other IFMTs.

The main objective of the TDP5 mission is to show the effectiveness of ACM techniques. With the ACM technology, satellite systems are able to adapt the signal parameters to the quality of the link in real time. In the past, static systems required high margins calibrated for rare fading events, wasting the available satellite channel capacity. ACM systems provide two important gains: moving to high data rate in clear sky conditions, which is particularly efficient in Ka-band or in Ku-band over tropical regions, and the ability to protect the signal very robustly under heavy rain conditions, improving system availability.

ACM development has also been supported by ESA through its ARTES programme. The implementation of this experiment includes a Q/V-band transmit/receive transponder on Alphasat linked to three independent RF beams with landing points in northern and southern Europe.

Parallel to the communication, the propagation experiments will be conducted using Ka-Band and Q-band propagation transmitters with two single RF beams. Two beacons at 20 and 40 GHz will radiate continuously while two very stable sinusoid signals (in amplitude and frequency) will cover western Europe and part of North Africa and will allow reception by narrow-band receivers during the whole lifetime of this TDP. Various Earth stations will be equipped with two receiving chains for the simultaneous co-polar and cross-polar signals reception.

Active Pixel Sensor star tracker

Developed by Jena Optronik (DE), the Active Pixel Sensor (APS) star tracker is included to gain early flight heritage on this new product. It is capable of very accurate and autonomous attitude acquisition. The sensor is highly resilient to the radiation experienced in geostationary orbits.

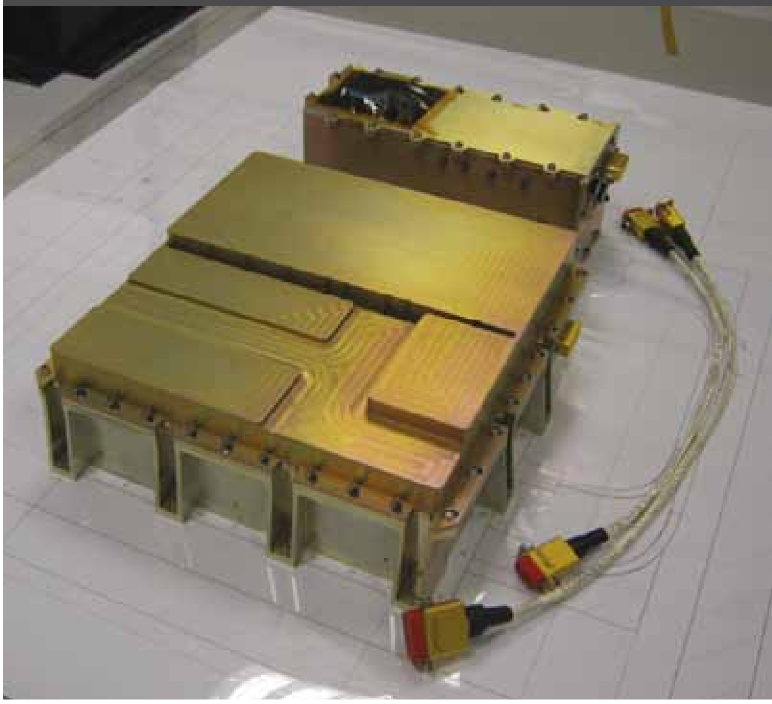
← Active Pixel Sensor star tracker (Jena-Optronik GmbH)

Star trackers are used for attitude control of current generation communication satellites. By using stars as reference points, star trackers are help to make sure that a satellite keeps in the same position and points in the right direction. The higher the accuracy, the better a satellite can operate and spend less fuel, allowing a longer life in orbit. A star tracker can be heavily influenced by the radiation and sunlight. Jena Optronik's new generation of star tracker offers higher precision.

Environmental testing and radiation sensor

Developed by EFACEC (PT), in cooperation with University of Aveiro (PT) and DAS Photonics (ES), the environment effects facility (AEEF) tests electronic components and solid-state materials in the radiation environment of a geostationary orbit. An energy selective particle spectrometer measures these radiation levels in parallel.

↓ Environmental testing and radiation sensor (EFACEC)



The scientific data provided offers a better understanding of the spacecraft environment resulting in better models, consequently reducing required margins and costs. The accompanying radiation effects package will flight-test several important electrical, electronic and electromechanical (EEE) component technologies of types applicable to future telecoms missions. The objectives include full validation of hardening methods used in design, validation of new testing and analysis methods and demonstration of novel EEE component technologies. Additionally the validity of ground-based testing compared to in-flight results will be studied.

← Half of the repeater module of Alphasat during construction at Thales Alenia Space Italy in 2009

Hosted payload opportunities on board EDRS

In September this year, ESA signed a contract with Astrium (DE) for the construction of the European Data Relay System (EDRS). The system will consist of two payloads carried by satellites in geostationary orbit. User data will be transmitted via dedicated terminals from satellites in lower orbits to either of the EDRS nodes and then relayed to the ground. The EDRS nodes are stationed over Europe in geostationary orbit, able to provide continuous visibility from the EDRS ground stations and enable immediate broadband data transfer whenever a customer satellite is within view of the EDRS nodes.

The first EDRS payload – a laser communication terminal and a Ka band inter-satellite link – will be carried on the Eutelsat host satellite, Eurobird-9B, built by Astrium and positioned over 9°E.

The second EDRS payload will be flown on a dedicated satellite built by OHB (DE) that will use the SmallGEO platform. SmallGEO is under development through a public–private partnership scheme between OHB and ESA. The launch of the second satellite is planned for 2015. ESA issued an Announcement of Opportunity for the selection of hosted payloads on this satellite. The response has been positive, with ESA reviewing more than 20 proposals from European industry wishing to participate in this endeavour. The selection process is now going through a competitive dialogue phase with selected proposals and with a final selection planned by early 2012.

Win-win-win situation

The hosted payload concept is gaining worldwide momentum. New groups and alliances are forming to

→ Alphabus service module and Alphasat repeater module stand side by side before mating which took place at Astrium in Toulouse, France, in March 2011 (Astrium)

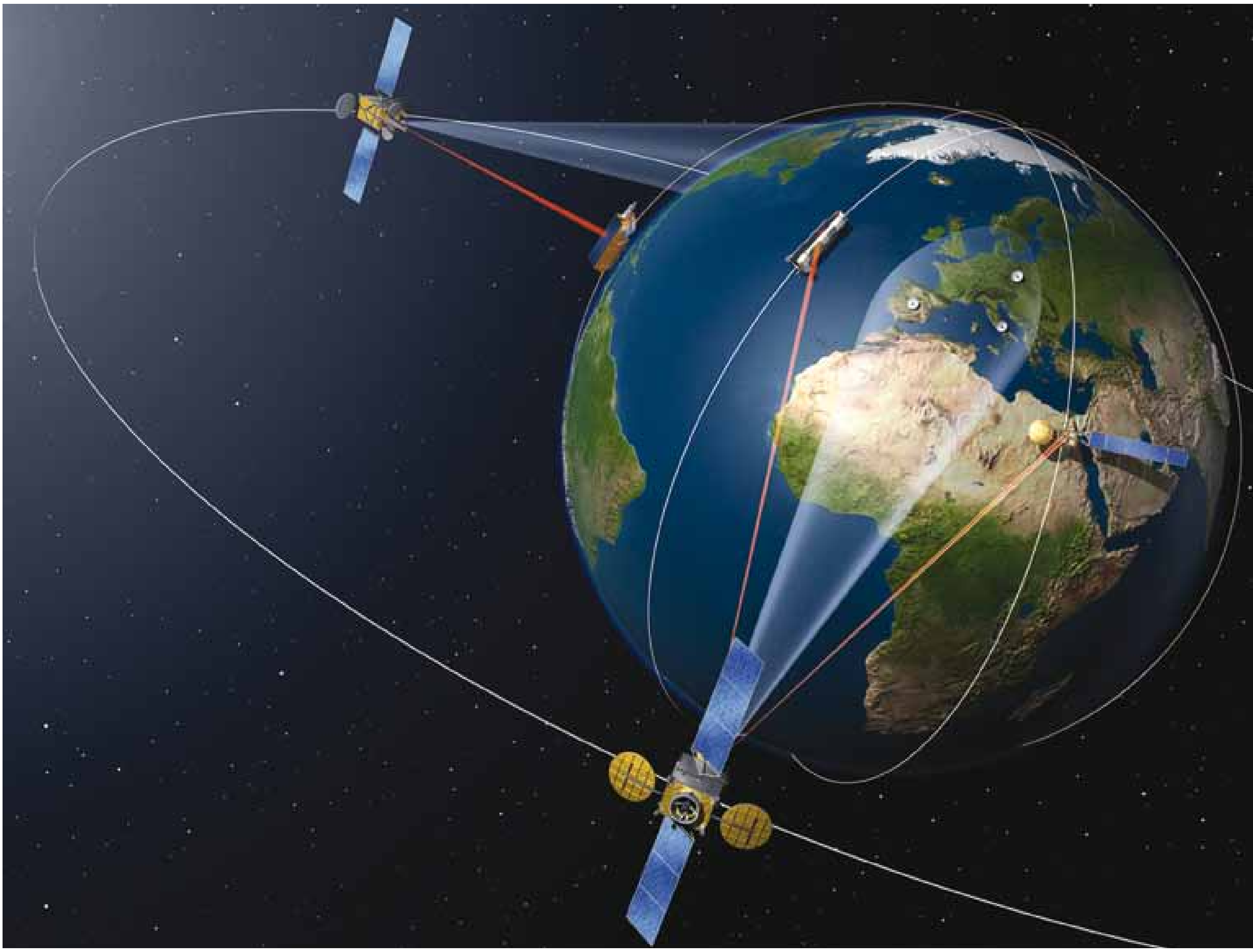
promote it. It can prove to be the most cost-effective way for government institutions and industry to validate the newest and most efficient technologies available, giving them flight heritage and introducing them in the commercial market. ESA is analysing the interests and needs for 'flight heritage' of innovative items in satellite telecommunication. ESA is defining possible new programmatic methods to ease the introduction of those items into the numerous commercial flight opportunities, either embedded in the missions or as passengers through the hosted payloads approach.

Beyond technology demonstrations, future hosted payloads may be the most economical way to launch a new service or complement an existing one, and thereby increase the value of the orbital position for a satellite operator. The additional satellite payloads can be operated in a win-win-win situation for operators, industry and public institutions like ESA.

Hosted payloads benefit from available capacity on commercial satellites to accommodate additional transponders, instruments, or other applications that have to be operated in space. Partners share the satellite platform. This arrangement takes less time and money to implement, allowing advances in satcom technologies and services and new businesses to grow.

For ESA, cooperation to launch new technologies is nothing new. One only has to look at Alphasat to see ESA Member States and the companies within them working together to launch Europe's biggest telecommunications satellite – embarking innovative hosted payloads – demonstrating Europe's capability in this market for years to come. ■

↓ The European Data Relay System, showing the first EDRS payload on the host satellite positioned over 9°E



Ed Harris, in the film 'Apollo 13' which highlighted the major role of simulators behind the success of space missions (Imagine/Universal)

→ VIRTUAL REALITY FOR REAL OPERATIONS

Developing and using Operational Simulators

Vemund Reggestad, Mauro Pecchioli and Mario Merri
Directorate of Human Spaceflight and Operations, ESOC, Darmstadt, Germany

"I want people in our simulators working reentry scenarios," ordered Flight Director Gene Kranz, played by Ed Harris in the film 'Apollo 13'. The major role of simulators in spaceflight was made famous in Ron Howard's 1995 film about the ill-fated Apollo mission.

Both the development and use of Operational Simulators are fascinating parts of a space mission. Nowadays, the big hardware simulators of the 1960s have been replaced with cheaper software, but the concept remains the same.

Put simply, an Operational Simulator is a software tool that is used extensively before the launch of a spacecraft to validate the ground segment and to train the flight control teams to respond quickly and correctly in routine or unexpected situations. Ultimately, the Operational Simulators remain an essential tool in spacecraft operations to achieve the goal, as Gene Kranz put it, that "Failure is not an option!"

Imagine one day entering the European Space Operations Centre (ESOC) in Darmstadt, and finding yourself in the main control room. The room is crowded with people, all looking intently at their screens and listening to announcements on their headsets. There is excitement and tension in the air. After a couple of hours, you might think that you had just witnessed one of the most critical phases of a mission, such as Mars Express going into orbit around the Red Planet, for example. Only at the end of the day, when the Flight Director calls for a debriefing, do you realise that it was not real – it was just a simulation.

Simulation campaigns

So how is it possible that the simulation can be so realistic? How can you train for a complete scenario several months ahead for operations on a spacecraft that is not even launched yet? The answer to these questions is the Operational Simulator.

The Operational Simulator is a complex system that allows you to execute complete scenarios so realistically that it is virtually impossible to notice the difference between the simulated scenario and the real operation. ESOC uses this system to run an intensive simulation campaign ahead of every critical event that occurs in a space mission.

A simulation campaign is usually built up of a series of full-day simulations, covering nominal scenarios as well as scenarios where unexpected events and failures are introduced. The goal is to build an integrated flight control team capable of rapidly responding to anything that may occur during the operations of the spacecraft so that the mission can be completed successfully. Simulation programs can cover several scenarios representative of any moment in the entire lifetime of a mission, starting with the launch itself, instrument calibration, important orbit manoeuvres, planetary swingbys or orbit insertions for deep-space missions, and various scenarios for routine operations. Finally, there may be scenarios for the final disposal of a spacecraft at end of its life.

The scenarios with unexpected events and failures are called 'contingency' simulations and are especially important to achieve the mentioned goals of the simulation campaigns.

↓ ESA's 'real' mission controllers: Spacecraft Operations Managers (or SOMs) at ESOC, Darmstadt, Germany. SOMs are responsible for operating the spacecraft and managing the Flight Control Team, and are assigned to each mission, which can last anywhere from a year to over a decade (ESA – J. Mai)

↑ The 'real' Flight Director of Apollo 13, Gene Kranz (right), in NASA's Mission Control Room in 1970 (NASA)

With such challenging goals, it is obviously equally challenging to develop an Operational Simulator to be one of the main 'actors' in any simulation campaign.

The Operational Simulator

In order to achieve the goals of the simulation campaign, the Operational Simulator must be able to simulate not only the spacecraft, but also many other elements that are required to run a realistic simulation. The most important additional elements are the space environment in which the spacecraft is flying and the ground stations used for communication between spacecraft and Earth. Putting together the Operational Simulator for a given mission is almost like playing with Lego bricks: the complete system is built by plugging together all the software building blocks that are needed for that mission. The fundamental building blocks are the software models, and in order to keep the cost down, the Operational Simulator runs on standard operating systems, for instance Linux, and on standard high-end PC hardware.

The Spacecraft Model

The Spacecraft Model is typically the most demanding part of the Operational Simulator. ESOC is operating mainly scientific missions that are usually the-first-of-their-kinds and each spacecraft is different. This implies that also the Spacecraft Models are different and they need to replicate exactly the behaviour of their actual respective spacecraft. In particular, two spacecraft subsystems require detailed modelling: the Data Handling Subsystem (DHS) and the Attitude and Orbit Control Subsystem (AOCS). The DHS is responsible for the onboard management of data traffic and the AOCS supports the control of the spacecraft orbit and attitude.

Without an extreme high-fidelity modelling of these subsystems, the correctness of the overall Operational Simulator would be limited. Common to both the DHS and the AOCS is that they are large and complex parts of the onboard systems and that they are implemented in software. This software is called the onboard software (OBSW) and typically runs in the onboard central processors of the spacecraft. In order to achieve maximum fidelity, the Operational Simulator runs exactly the same software as that on the spacecraft.

In fact, despite using very different hardware from the spacecraft, the Operational Simulator is capable of software-emulating the spacecraft central processors, which allows the execution of the actual spacecraft OBSW. This approach also allows keeping the Operational Simulator in synchronisation with the spacecraft with minimal effort: any change to the OBSW either before or after launch can be very easily integrated in the Operational Simulator. Actually, since the Operational Simulator is able to execute the exact

← ESA's new Mission Control Room today ESOC, Darmstadt, Germany same memory images, the upload of new software to the spacecraft is typically tested and verified ahead on the Operational Simulator.

Space Environment Model

You would buy a car only if you were confident that it had been properly tested in all possible weather conditions and, in particular, those conditions in which you are going to use the car most. Similarly, the flight control team wants to be prepared to operate the spacecraft in all the space environments it is going to fly in. For this reason, the Operational Simulators contain a complete model of the space environment that the spacecraft will experience during its lifetime. For spacecraft that fly in environments where spacecraft have been before, typically there already exists knowledge of what to expect and the job of modelling the space environment becomes easier.

Other spacecraft explore parts of the Solar System where no spacecraft have been before and for them the job of creating a realistic space environment model is more of a challenge. It becomes almost a philosophical question: how can you prepare to fly a spacecraft into a completely unknown environment? Fortunately, today, no environment in the Solar System is completely unknown. Most space environment properties have been observed remotely, and more and more precise predictions are being made year on year.

The key to simulating such environments is to build into the Operational Simulator the capability to rapidly switch from the best-case scenario to the worst-case one, and vice versa. Because the simulation campaign consists of a number of simulations covering each critical phase of the mission, the ability to change the environmental conditions can be used to run simulations with dramatic changes in the space environment surrounding the spacecraft.

↑ A new software tool known as the 3DROV planetary rover simulation environment allows early-stage virtual modelling and 'shakedown' testing of mobile surface missions for both Mars and the Moon

Ground Station Model

Typically, spacecraft are operated via a network of ground stations: their number, location and characteristics depend on the mission phase and also on the type of mission. For example, a spacecraft is usually tracked by more ground

↑ ↗ Automated Transfer Vehicle (ATV) physical docking simulator at Val de Reuil, France

↑ A realistic simulation must account for the ground stations as well. The Ground Station Model creates accurate 'virtual replicas' of the ground stations in the Operational Simulator

stations during the launch and early orbit phase than later during routine operations. Also, the diameter of the ground station antenna dish can range from a few metres up to 70 m depending on the distance of the spacecraft from Earth, larger dishes being used for deep-space missions.

Clearly, a realistic simulation must account for the ground stations as well, also because the mission control team needs to be trained on their use. Of course, it would be largely inconvenient and expensive to involve the actual ground stations in the simulation campaign and this is why the Ground Station Model creates accurate 'virtual replicas' of the ground stations in the Operational Simulator. Since the same ground station is used for many missions, so is the corresponding Ground Station Model. In this way, the cost of developing the Ground Station Models can be shared among several missions.

Technically, the main requirement for Ground Station Models is that the interface exposed by the virtual ground station to the control centre matches exactly the actual interface. International standardisation helps here, because several ground stations conform today to the Space Link Extension interface defined by the Consultative Committee for Space Data Systems, which implies that the Ground Station Model has to comply only with this single interface. This is a good example where standardisation leads to dramatic simplifications and cost savings in both the actual and virtual worlds.

Other key technical characteristics

At any time, the simulation can be stopped and a complete scenario can be stored into a file called a 'breakpoint'. A set of those files can be created to make it possible to start a simulation from any predefined moment in the mission.

On top of this, a script engine allows the serialisation and automation of any operation on the simulator to be able to reach certain conditions simply by running a script prepared in advance. Results of the script can be either analysed in the log or the reached state saved into a breakpoint for further reuse.

↑ ATV mission control centre in Toulouse, France

The Operational Simulator as test tool

So far we have talked a lot about using the Operational Simulator for training of the flight control team ahead of critical operations. However this is not the only use of the simulator. It is used as well for testing of both the mission control system and the onboard software itself.

Mission Control System testing

For every mission, ESOC develops not only the Operational Simulator but also the Mission Control System. This is the system the spacecraft operators will use to control the spacecraft. Its development follows a life cycle similar to the development of the Operational Simulator. In order to ensure a successful launch, it is equally important to ensure the correct behaviour of the Mission Control System in order to train the spacecraft operators.

To make sure that the Mission Control System behaves as expected and guarantee a nominal usage by the operators, it goes through an extensive test campaign lasting as much as two years before launch. This test campaign contains all sorts of tests aimed at building confidence in the system. Examples of key tests to be executed are performance tests and long-duration tests. For these scenarios, it is equally important that the simulator behaves realistically with respect to the spacecraft, since the software can only be expected to work in the conditions in which it has been tested.

The direct impact on the Operational Simulator of this is that it is not only required to be accurate down to the level of what an human operator can observe, but also down to the level of what other software systems can observe. Since the Mission Control System is a real-time system, timing issues are extremely relevant and create strict constraints on the simulator itself. Only a few milliseconds or microseconds inaccuracy in the timing of events can cause software to misbehave.

> **"The Operational Simulator needs to incorporate detailed knowledge of everything that makes up a space mission"**

Onboard software testing

The Operational Simulator executes the same image of onboard software as loaded on the real spacecraft. This is not only allows a very cost-effective way to replicate spacecraft behaviour in this area, but also brings other advantages. For example, it allows the flight control team to contribute actively in the test campaign of the spacecraft onboard software prior to launch. The main responsibility for the testing of the onboard software remains with the spacecraft developers where the real hardware can be used to run the tests. However the Operational Simulator does offer a unique testbed for the flight control team to assess areas other than those done by the spacecraft developers.

← A post-simulation debriefing during the preparations for CryoSat-2 (ESA – R. Francis)

→ CryoSat-2 Mission Control team during a simulation at ESOC in December 2009 (ESA – R. Francis)

Examples include answering questions like:

- Are the OBSW features sufficient for operating the spacecraft?
- Does it give sufficient diagnostic information to trouble shoot problems on board?
- How does the OBSW interact with the ground-based systems?

Furthermore, since the Operational Simulators are a pure software-based environment, it is much easier to check the response of the OBSW to unforeseen events, such as hardware failures. After all, to simulate hardware failure on real hardware can be a quite costly affair. In the simulator on the other hand, any hardware misbehaviour can be easily programmed in. For example, scenarios with spurious or corrupted signals can be executed again and again until the overall system behaviour is well understood.

Validation of extreme recovery

Along the same lines as operational validation, it is not rare that an Operational Simulator is used to test a new condition in the mission lifetime. A spacecraft already flying can reach an unexpected situation, as consequence of a failure on board or a wrong launcher injection. Before declaring an end to the mission, any and every possible solution, however extreme, is explored. Without the need of risking the real spacecraft, many options can be validated against the Operational Simulator in relatively short timeframes to develop a prompt recovery action. Any type of contingency on board, whether a hardware or software failure, or extreme environmental conditions, can be imitated on the Operational Simulator, thanks to its flexibility in being able to 'fail' any equipment via user commands or even changing the environment through configuration of the Environmental Model.

How to develop a successful Operational Simulator?

It should be clear by now the complexity of the Operational Simulator – this software tool needs to incorporate detailed knowledge of everything that makes up a space mission. ESOC has been developing these systems for several decades and has consolidated an approach that has proven to be very successful. This approach is based on three main pillars: strong project management, reuse of simulator software infrastructure and international standardisation.

Strong project management

The development of an Operational Simulator is a relatively large project and the completion of the project in time is fundamental to support operations preparation and launch. Typically, the main use starts with the validation of the Mission Control System and of the Flight Operations Procedures and continues, about six months before launch, with the simulation campaign.

For the other cases of procedure preparations and control system validation, a simulator is needed even earlier. From experience, we know that the development of an Operational Simulator takes at least two years, and that this work cannot start before the suitable preparations for the development are made. The preparations include clarifying the detailed requirements and selecting a company responsible for the development. This process takes around six months, so together,

this means that a simulator project needs to start three years before the launch of the spacecraft. Three years may sound like a long time, but for a space project this is actually very short.

In fact, the short duration and the ability to develop an Operational Simulator is essential for its success. After all, in order to start preparing a simulator development, detailed knowledge of the spacecraft behaviour is required. This implies that the Operational Simulator development cannot start until the planning of the spacecraft itself has reached a very mature state. On the other hand, the Operational Simulator development needs to be finished and in a fully functional state at least six months before the spacecraft itself is ready to be launched.

So it is unavoidable that the simulator developers often find themselves faced with a 'squeezed' schedule. The way to handle this is like many other situations in life – it is very important to be very flexible and well-prepared when the information arrives, so that you can start working efficiently on it right away. Obviously, this introduces another problem in the development, since there is no design of a spacecraft that is perfect at the first attempt.

> **Simulators are used almost everywhere in modern engineering and many other fields, so ESA is actively promoting these, even outside the space sector**

ESOC is the critical point of contact between the simulator and spacecraft development communities. The information flow must never stop and is continuously injected via the requirement review cycle. The simulator developers need to constantly take input from the spacecraft development and keep track of the latest design. They will frequently 'phase in' situations where the input has changed. This can be compared with trying to shoot at a moving target. You have to train yourself to re-aim your development at the new target as soon as you get updated information about how the spacecraft works.

Another way to prepare is to make sure that lessons learned and information are carried forward from one project to another. This is of vital importance particularly in the areas where several projects are similar. ESA has several initiatives to make sure that every development does not need to 'reinvent the wheel'. Here, the development of a generic infrastructure that is reusable between every mission has had an important role.

↑↗ Training on simulations – a Spacecraft Operations Course at ESOC

Reuse of simulator software infrastructure

In addition to a successful outcome for each project, these standards and working methodologies have another goal. During the last few years, ESA has built a complete set of infrastructure components marketed under the umbrella brand name of EGOS, or 'European Ground Operational Software'. Under EGOS, a number of software packages are included to support the development of the Operational Simulators.

The most relevant elements are inside the Simulus and Tevalis software packages:

Simsat: A generic simulation environment allowing execution of any model developed according to the SMP standards. It offers services to control and monitor the simulation itself.

UMF: A modelling tool allowing efficient development of SMP-based models.

Ground Models: A set of models that allows modelling of the Ground Station network.

Generic Models: A set of models containing the space environment, thermal models, electrical networks and other elements of a spacecraft that is similar on several missions.

Emulator suite: A software package allowing emulation of several types of onboard processors.

For every mission where an Operational Simulator is developed, an effort is made to ensure that these software packages are really up to date and represent the best possible starting point for development. The main aim is to make sure that every development only needs to work on what is truly unique for that mission. This approach saves time, money and effort, and increases the quality of the final software.

International standardisation

In addition to the Space Link Extension, another area where standardisation is essential is in the development processes and methods used. In particular, the Simulation Model Portability (SMP) standard is of crucial importance to the way ESOC develops Operational Simulators.

Operation preparation is not the only use of simulation models in a space mission. Simulations are used in all phases of the development and hence, for every mission, there exists a number of models for various cases developed by the different groups involved in the mission development. The main aim of the ECSS-E-TM-40-07 SMP technical memorandum is to facilitate the exchange of such models. The ECSS version of the SMP was approved in January 2011, but ESA has a long experience in developing simulators with various previous revisions of the standard.

The main benefits of the standard include:

- ensuring platform independence of simulator models (particularly important for space projects, where spacecraft lifetimes often span over different generations of computer systems);
- facilitating model exchange by making models independent of a simulation environment (for example, models developed for the Matlab environment can be repackaged inside SMP and easily be reused within Operational Simulators);
- standardises inter-model communication (this allows a model of a specific subsystem of a spacecraft to interact with other subsystems developed according to the same standard).

The ability to achieve these goals has been well perceived and demonstrated by ESA in the development of many Operational Simulators. This is why ESA has a central role in developing this standard. Simulators are used almost everywhere in modern engineering and many other fields and so, since there is nothing space-specific about the standard, ESA is actively promoting its use for simulation activities, even outside the space sector. ■

→ FAREWELL TO ERS-2

Last 'tango' in space: adding to unique information from previous tandem missions, ESA's ERS-2 was paired up with Envisat for a final campaign in 2010. Data from this final duet are being used to generate 3D models of glaciers and low-lying coastal areas

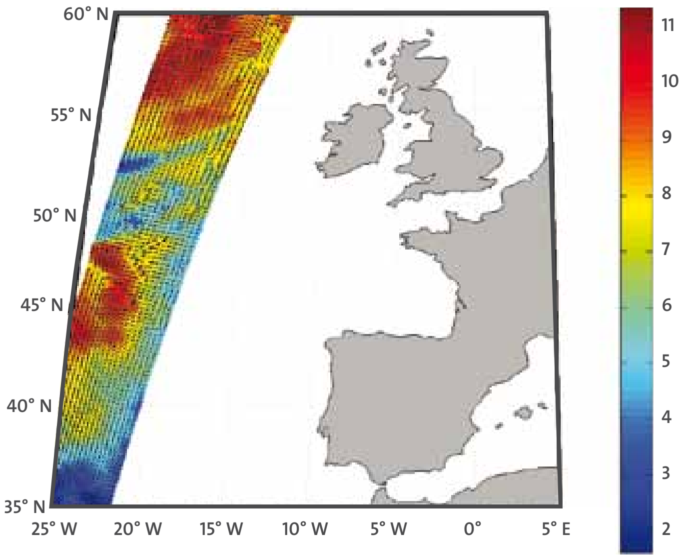
On 5 September the ERS-2 satellite was shut down after 16 years of service. Even in its final months, this sophisticated spacecraft continued to innovatively collect data about Earth's surface and atmosphere.

ERS-2 was launched in 1995, four years after ERS-1, the first European Remote Sensing satellite. With 20 years of continuous measurements, the two missions paved the way for the development of many new Earth observation techniques.

Both satellites carried the same suite of instruments that included the first long-term imaging synthetic aperture radar, a radar altimeter monitoring sea-level change and other powerful instruments to measure ocean-surface temperature and winds at sea.

ERS-2 also carried the first European high-precision instrument to measure atmospheric ozone. It was crucial for observing the evolution of annual ozone depletion over Antarctica.

Although ERS-2 was originally meant to be a three-year mission, it far exceeded its planned lifetime and continued to deliver crucial Earth observation data until the very end.



↑ Some of the last ERS-2 scatterometer data acquired on 3 July 2011. The ERS-2 scatterometer provided information on wind speed and direction at the sea surface. The ASCAT instrument on board MetOp continues the scatterometer measurements initiated by the ERS missions

↑ ERS-2 in the cleanroom at ESTEC, 1994

The ERS-2 'Ice Phase'

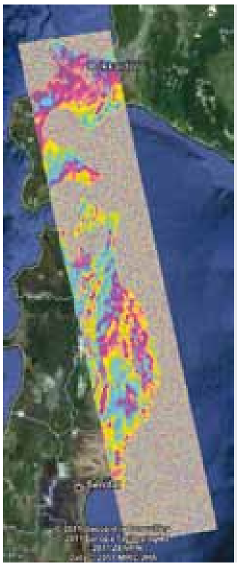
In response to a long-standing request from the cryosphere science community, and to achieve the maximum scientific benefits during the last months of ERS-2 activity, the satellite's orbit was lowered slightly in the spring of 2011. In this new orbit, ERS-2 was able to capture radar images of the same area on the ground every three days, rather than its previous 35-day cycle. The scientific objectives of this mission were to monitor ice-stream dynamics, glaciers, ice caps and post-seismic and volcanic deformation.

This new cycle immediately proved useful to the international community. The three-day repetition provided partial coverage over Japan, which had recently been struck by an earthquake and subsequent tsunami on 11 March 2011. Scientists used ERS-2 radar data to map post-seismic activity, such as aftershocks, further improving our understanding of such tectonic events.

Additionally, radar images acquired during this 'Ice Phase' revealed rapidly changing glacial features in Greenland. Frequent views of the Kangerdlugssuaq glacier showed that its ice stream was advancing steadily at about 35 m per day.

The final images were also compared to those taken by sister satellite ERS-1 in 1992, showing that the Kangerdlugssuaq ice stream's calving front had retreated by at least 5 km in the past 19 years.

"Now that ERS-2 is retired, no other flying or planned satellite is able to accurately detect the grounding line location of ice streams," says Marcus Engdahl, scientific coordinator of the ERS-2 Ice Phase. "This makes the data gathered by ERS-2 during its final months all the more valuable to scientists."

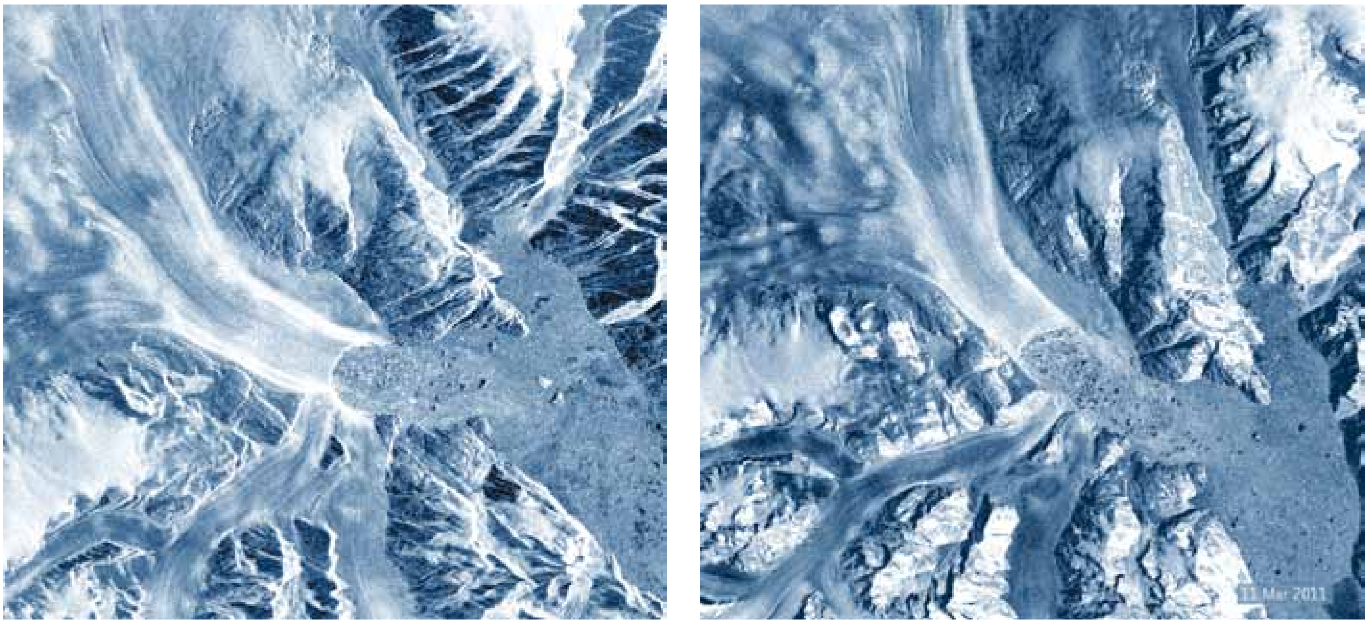


← ERS-2 SAR interferogram over the northern part of Honshu Island, Japan, in March 2011. The three-day ERS-2 revisiting time during the ice phase in Spring 2011 allowed for almost continuous monitoring and the extracting of the co-seismic deformation field with the post-seismic deformation filtered out

Mission complete

The ERS-2 satellite travelled 3.8 billion km in 16 years, providing data for thousands of scientists and projects. After orbiting nearly 85 000 times around Earth, the risk that the satellite could lose power at any time was high. To avoid it ending up as a piece of space debris, ESA decided to bring it down to a lower orbit while there was still enough fuel to do so. The lower orbit reduces the risk of collision with other satellites or space debris. With Earth's gravitational pull, the satellite is expected to burn up in the atmosphere in about 15 years.

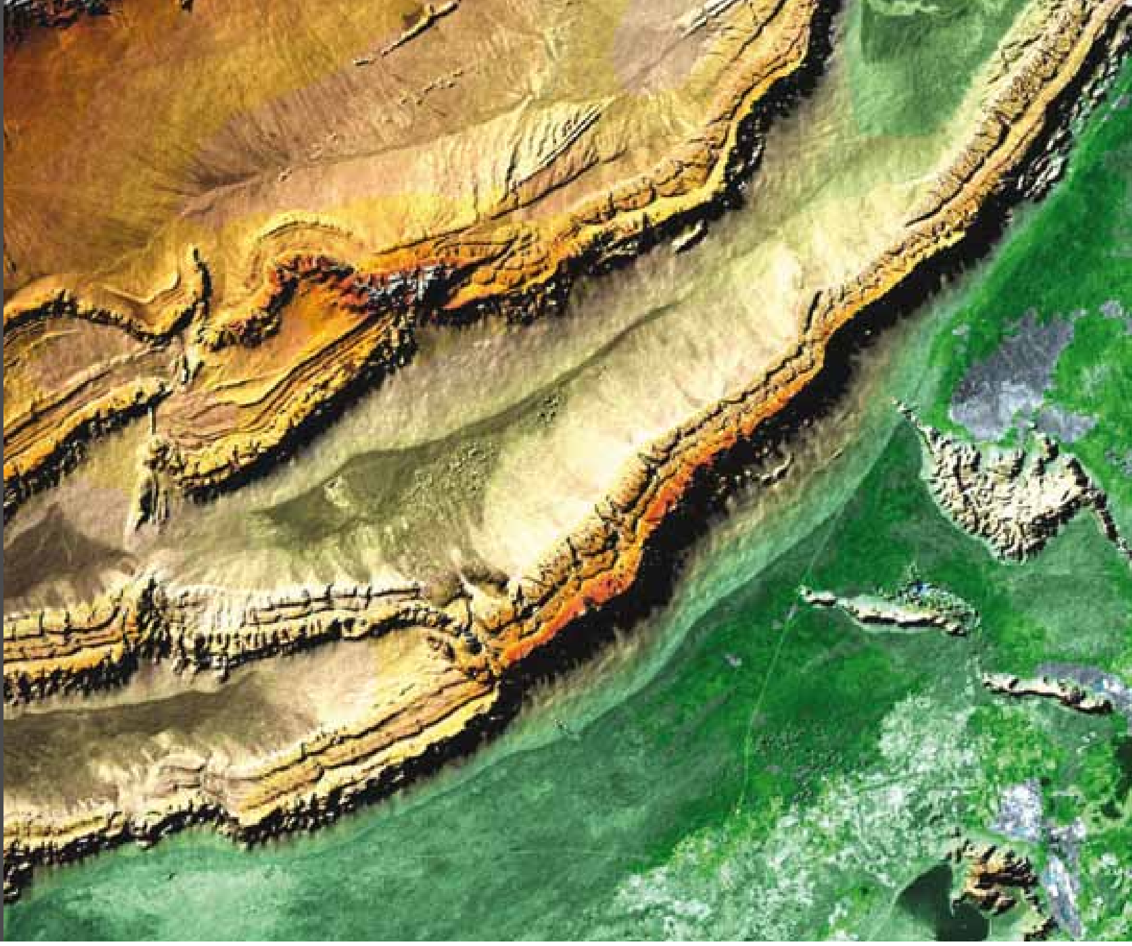
The first in a series of thruster firings to lower ERS-2 from its initial 785 km orbit began on 6 July. The burns each

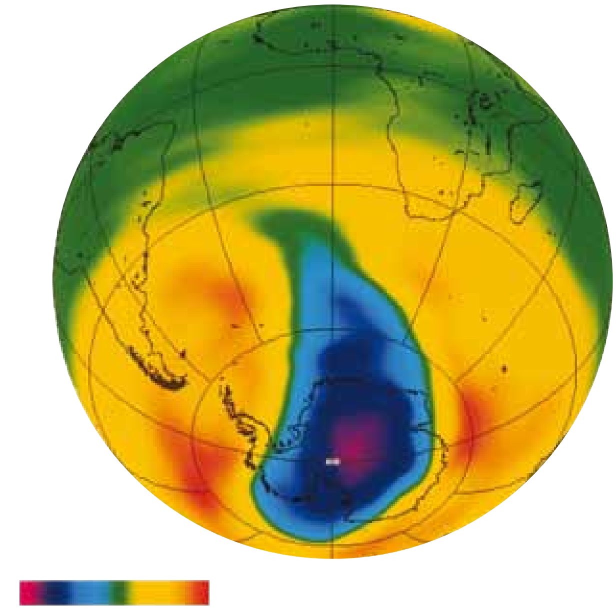


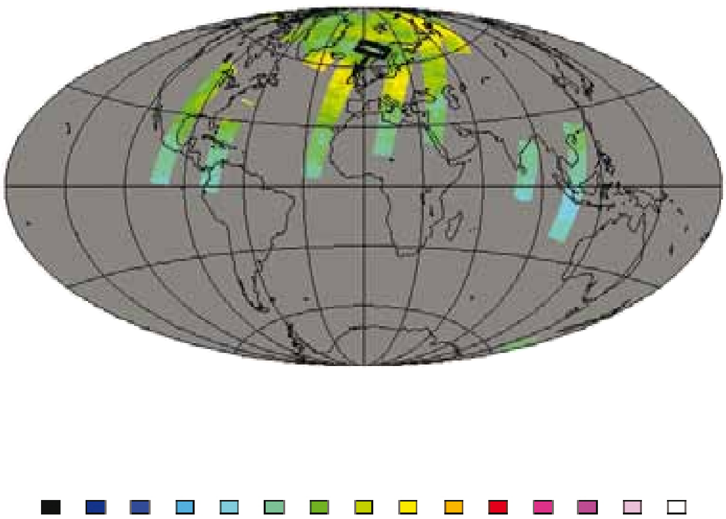
↑ ↗

Two ERS images of the Kangerdlugssuaq glacier in eastern Greenland, left in 1992 and right in 2011, show that the ice stream's calving front has retreated by 5 km in the past 19 years. Thinning in the ice stream and surrounding ice sheet is also evident

→ Varied elevations of Bachu and the nearby Tian Shan mountains in western China, in an image developed using data from the two ERS satellites. The ERS missions pioneered the technique of processing satellite radar data into digital elevation models, 3D relief maps to study changes in the terrain







↑ ERS-2 carried an instrument called GOME that helped to monitor the ozone layer around Earth. This is a GOME ozone measurement from October 1996, showing the opening of the ozone hole during austral spring (image produced from GOME-derived data from KNMI, pre-processed by DLR/Univ. Bremen)

↑ Last Global Ozone Monitoring Experiment map, acquired on 4 July 2011. The GOME instrument aboard ERS-2 was one of the longest serving ozone monitors in the world, with its success leading to a string of similar satellite sensors like GOME-2 on MetOp or SCIAMACHY on Envisat (KNMI) lasted about 300 seconds, and were commanded by the mission control team at ESA's European Space Operations Centre in Germany. Engineers closely monitored the manoeuvres via ESA's ground stations in Kourou, French Guiana, and in Malindi, Kenya.

Once the satellite had been lowered to about 570 km, ERS-2 entered the final 'passivation' phase in late August 2011 aimed at ensuring that all energy sources and pressurised systems were depleted or rendered safe. This primarily comprised of exhausting the fuel, disconnecting the batteries and switching the transmitters off.

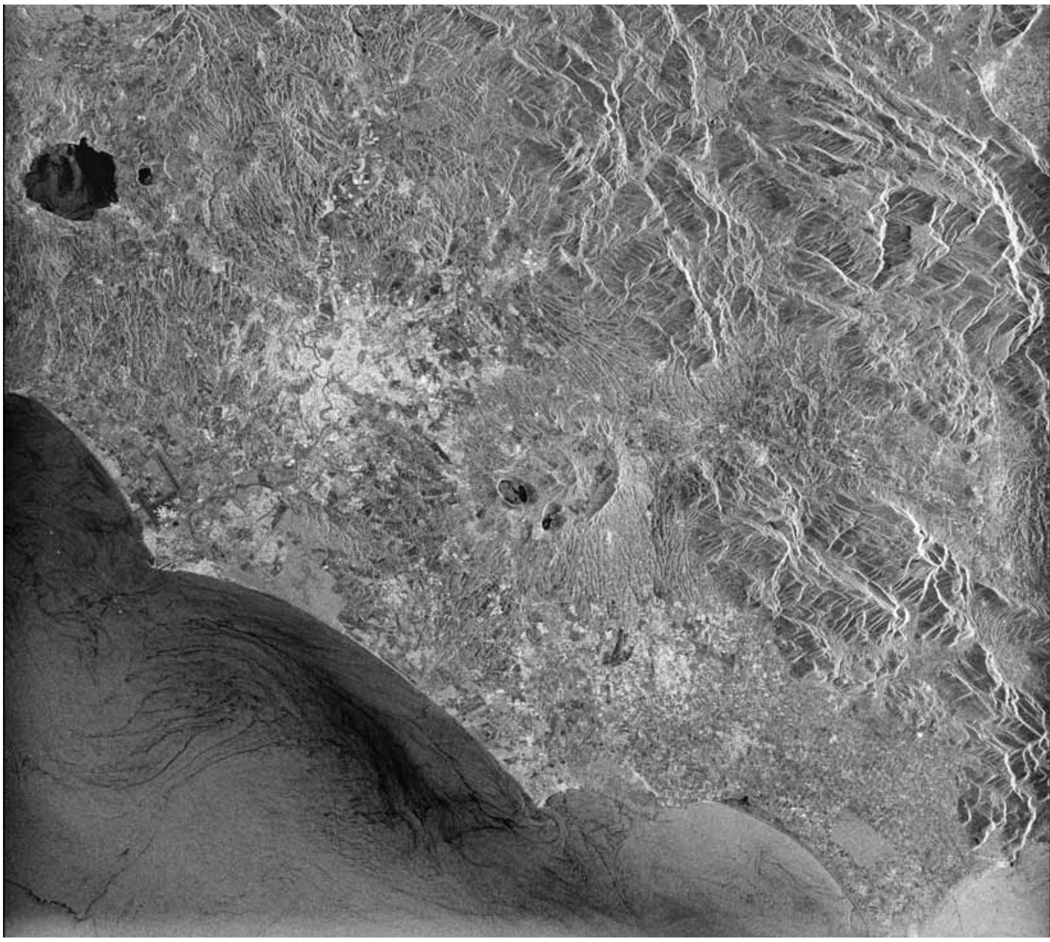
Unlike a car, ERS-2 has no convenient gauge that indicates when fuel is running low. So to exhaust the remaining fuel, controllers conducted a series of thruster firings that alternately raised and lowered the spacecraft altitude slightly. Doing this, controllers could monitor the fuel depletion by judging if the thrust had become uneven or intermittent.

The firings occurred while the satellite was tracked by ESA's ESTRACK ground stations in Kiruna (Sweden), Maspalomas (Canary Islands) and Kourou. Additional tracking support was provided by the Japan Aerospace Exploration Agency station in Katsuura, and the Svalbard station operated by Norway's Kongsberg Satellite Services.

"ERS-2 deorbiting [was] conducted in compliance with ESA's space debris mitigation guidelines. This indicates the strong commitment by the Agency to reduce space debris, which can threaten current and future robotic and human missions," says Heiner Klinkrad, Head of ESA's Space Debris Office.

The veteran satellite was finally shut down on 5 September, but the end of flight operations does not mean the end of the mission's usefulness. Twenty years of data acquired by both ERS missions will continue to be used by scientists for their Earth observation and climate change studies for years to come. The missions have also paved the way for imaging radar and interferometry technologies, which are now being implemented in several current and future satellites.

"We will continue exploiting data gathered by ERS-2, especially the radar imagery," said Volker Liebig, ESA's Director for Earth Observation Programmes. "Combining this rich scientific heritage with new data delivered by improved radar instruments on the GMES Sentinel-1 mission will generate strong synergies as we work to understand our planet's climate." ■



← Last ERS-2 image over Rome, acquired using the Synthetic Aperture Radar on 4 July 2011

→ NEWS IN BRIEF

On the eve of launch, the Russian Soyuz is poised for its first liftoff from Europe’s Spaceport in French Guiana in October

Galileo and Soyuz make history

In a milestone mission, the first pair of satellites for Europe's Galileo global navigation satellite system was sent into orbit by the first Russian Soyuz vehicle ever launched from Europe's Spaceport in French Guiana.

The Soyuz VS01 flight, operated by Arianespace, lifted off from the new launch complex in French Guiana at 12:30 CEST on 21 October. This was the first Soyuz to be launched from a site other than Baikonur in Kazakhstan or Plesetsk in Russia.

"This launch represents a lot for Europe: we have placed in orbit the first two satellites of Galileo, a system that will position our continent as a world-class player in the strategic domain of satellite navigation, a domain with huge economic perspectives," said ESA's Director General, Jean-Jacques Dordain.

"Moreover, this historic first launch of a genuine European system was performed by the legendary Russian launcher that was used for Sputnik and Yuri Gagarin, a launcher that will, from now on, also lift off from Europe's Spaceport.

"These two historical events are also symbols of cooperation: cooperation between ESA and Russia, with a strong essential contribution of France; and cooperation between ESA and the European Union, in a joint initiative with the EU.

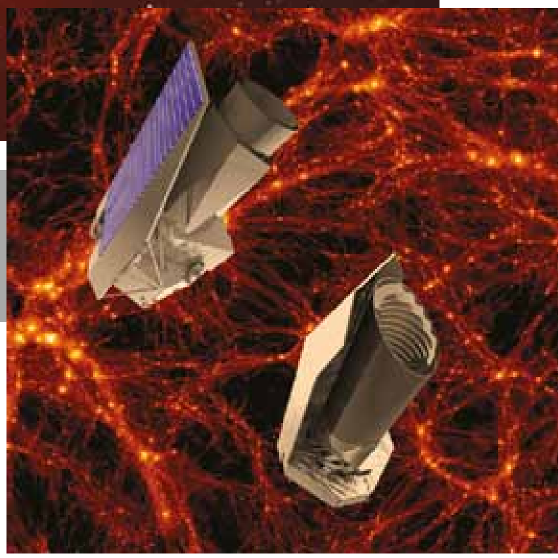
"This launch consolidates Europe's pivotal role in space cooperation at the global level. All that has been possible thanks to the vision and commitment of ESA member states," said Mr Dordain.

The new site for Soyuz in French Guiana, operated by Arianespace, adds to the flexibility and competitiveness of Europe's fleet of launchers. Launching from close to the equator allows the European Soyuz to offer improved performance. From French Guiana, Soyuz can carry up to 3 tonnes into the 'geostationary transfer orbit' typically required by commercial telecommunications satellites, compared to the 1.7 tonnes that can be delivered from Baikonur.

The two Galileo satellites are part of the In-Orbit Validation (IOV) phase that will see the Galileo system's space, ground and user segments extensively tested. The next two Galileo satellites, completing the IOV quartet, are scheduled for launch in summer 2012.

→ Soyuz flight VS01 thunders away on 21 October, carrying the first two Galileo In-Orbit Validation satellites

↑ The moment of ignition of Soyuz, before lifting off for the first time from Europe's Spaceport in French Guiana on 21 October



↑ Solar Orbiter

→ Artist impression of two Euclid concepts

Light and dark: ESA's next science missions

The powerful influence of the Sun and the nature of mysterious 'dark energy' motivate ESA's next two science missions. Solar Orbiter and Euclid have been selected for implementation, with launches planned for 2017 and 2019.

These two missions are medium-class missions and are the first in ESA's Cosmic Vision 2015–25 Plan.

Solar Orbiter will venture closer to the Sun than any previous mission. It is designed to make major breakthroughs in our understanding of how the Sun influences its environment, in particular how the Sun generates and propels the flow of particles in which the planets are bathed, known as the solar wind.

Solar Orbiter will be close enough to the Sun to sample this solar wind shortly after it has been ejected from the solar surface, while at the same time observing in great detail the process accelerating the wind on the Sun's surface. The mission's launch is planned for 2017 from Cape Canaveral with a NASA-provided Atlas rocket.

Euclid is a space telescope mission that will map out the large-scale structure of the Universe with unprecedented accuracy. The observations will stretch out 10 billion light years into the Universe, revealing the history of its expansion and the growth of structure during the last three-quarters of its history.

One of the deepest modern mysteries is why the Universe is expanding at an ever-accelerating rate. This cosmic acceleration must be driven by something that astronomers have named 'dark energy'. By using Euclid to study its effects on the galaxies and clusters of galaxies that trace the large-scale structure of the Universe, astronomers hope to be able to understand the exact nature of dark energy. Euclid's launch is planned for 2019 on a Soyuz vehicle from Europe's Spaceport in French Guiana.

Washable wearable antenna

A 'wearable' radio antenna is making a big splash in the world of search and rescue. ESA-provided research and development guidance for Finnish company Patria, with the help of Tampere University of Technology, has led to a new kind of search and rescue radio antenna that can be sewn into a life vest.

Made from a highly flexible, lightweight material that is robust against water exposure and moist conditions, and resistant to wear and tear, this special antenna has been designed for use by the Cospas-Sarsat worldwide search and rescue satellite system.

Cospas-Sarsat has been operating for almost 30 years and has helped to rescue more than 26 000 victims in distress. Sponsored by Canada, France, Russia and the United States, the system operates 24 hours a day, 365 days a year, and aims to reduce the time required to alert rescue authorities in emergencies.

The Cospas-Sarsat system consists of emergency radio beacons carried by aircraft, ships or people, receivers on satellites, ground receiving stations, mission control centres and rescue coordination centres. When a carrier is in distress, the emergency beacon is activated. As satellites orbit Earth, they 'listen' for active beacons and report their position to rescue authorities.

This new antenna works as part of the Cospas-Sarsat distress transmitter. Recent field trials with the antenna show that someone lost at sea wearing a life vest equipped with this new technology can be pinpointed within minutes.

The life vests were designed by Viking life saving equipment, based in Denmark. In addition to integrating antennas into a life vest, a second attachable antenna is designed for use with a diving vest.

↑ A life vest with an incorporated search and rescue antenna being tested in a field trial in Finland

Mars500 crew open the hatch

The 520 days of isolation for the Mars500 crew are over. On 4 November, the crew arrived 'back on Earth' when the hatch of their 'spacecraft' was opened for the first time since June last year.

Even so, they had to go into quarantine for four days for medical checks, while scientists eagerly awaited the final samples as the crew counted the hours to liberty.

Scientists are already happy with the quality of the unique material they have from the 17-month simulated Mars mission and are looking forward to working with all the new information.

"The scientists have already highlighted the importance of their investigations for terrestrial medical issues," says Patrik Sundblad, ESA human life sciences specialist.

But although teasing answers from the scientific results takes a while, the main question is already answered: "Yes, the crew can survive the inevitable isolation for a mission to Mars and back. Psychologically, we can do it," said Patrik Sundblad.

← The Mars500 crew emerge on 4 November (IBMP\O.Voloshin)

Did Earth's oceans come from comets?

ESA's Herschel infrared space observatory has found water in a comet with almost exactly the same composition as Earth's oceans. The discovery revives the idea that our planet's seas could once have been giant icebergs floating through space.

The origin of Earth's water is hotly debated. Our planet formed at such high temperatures that any original water must have evaporated. Yet today, two-thirds of the surface is covered in water and this must have been delivered from space after Earth cooled down.

Comets seem a natural explanation: they are giant icebergs travelling through space with orbits that take them across the paths of the planets, making collisions possible. The impact of Comet Shoemaker-Levy 9 on Jupiter in 1994 was one such event. But in the early Solar System, when there were larger numbers of comets around, collisions would have been much more common.

However, until now, astronomers' observations have failed to back up the idea that comets provided Earth's water. The key measurement they make is the level of deuterium – a heavier form of hydrogen – found in water.

All the deuterium and hydrogen in the Universe was made just after the Big Bang, about 13.7 billion years ago, fixing the overall ratio between the two kinds of atoms. However, the ratio seen in water can vary from location to location. The chemical reactions involved in making ice in space lead to a higher or lower chance of a deuterium atom replacing one of the two hydrogen atoms in a water molecule, depending on the particular environmental conditions.

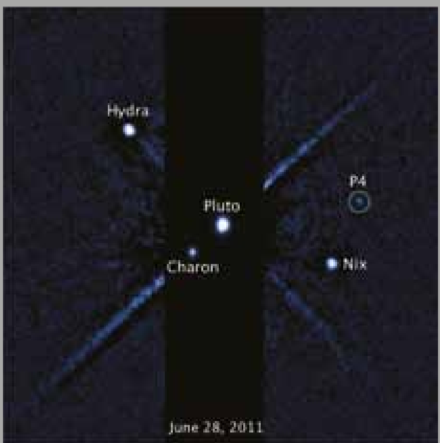
Thus, by comparing the deuterium to hydrogen ratio found in the water in Earth's oceans with that in extraterrestrial objects, astronomers can aim to identify the origin of our water.

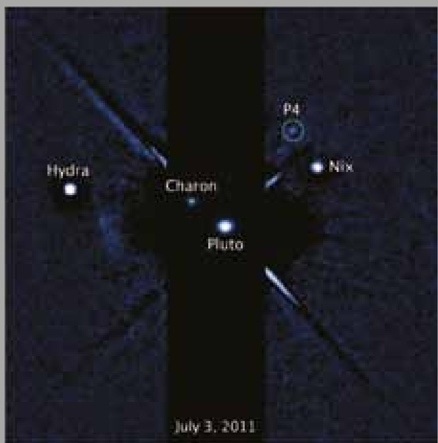
All comets previously studied have shown deuterium levels around twice that of Earth's oceans. If comets of this kind had collided with Earth, they could not have contributed more than a few percent of Earth's water. In fact, astronomers had begun to think that meteorites had to be responsible, even though their water content is much lower.

Now, however, Herschel has studied Comet 103P/Hartley 2 using HIFI, the most sensitive instrument so far for detecting water in space, and has shown that at least this one comet does have ocean-like water.

"Comet Hartley's deuterium-to-hydrogen ratio is almost exactly the same as the water in Earth's oceans," says Paul Hartogh of the Max Planck Institute for Solar System Studies, Germany, who led the international team of astronomers in this work.

New moon for Pluto





The NASA/ESA Hubble Space Telescope has discovered a new moon circling Pluto. P4, as it is currently called, is the smallest moon yet found orbiting Pluto, with an estimated size of 13–34 km. By comparison, Pluto's largest moon, Charon, is 1043 km across, while Nix and Hydra are 32–113 km wide. The new moon lies between the orbits of Nix and Hydra, two satellites discovered by Hubble in 2005.

↑ ↗ Pluto's moon P4 was first seen with Hubble's Wide Field Camera 3 on 28 June. The sighting was then confirmed in follow-up Hubble observations on 3 July and 18 July. Long exposures are needed to see the new moon and this creates the speckled background from 'noise' in the camera (NASA/ESA/M. Showalter - SETI Institute)

↑ Two-thirds of Earth's surface is covered in water and this must have been delivered from space. New observations suggest that perhaps Earth's oceans came from comets after all (Adam FX)

↑ Comet 103P/Hartley 2's nucleus as seen by NASA's Deep Impact space probe during its 700-km flyby in 2010 (NASA)

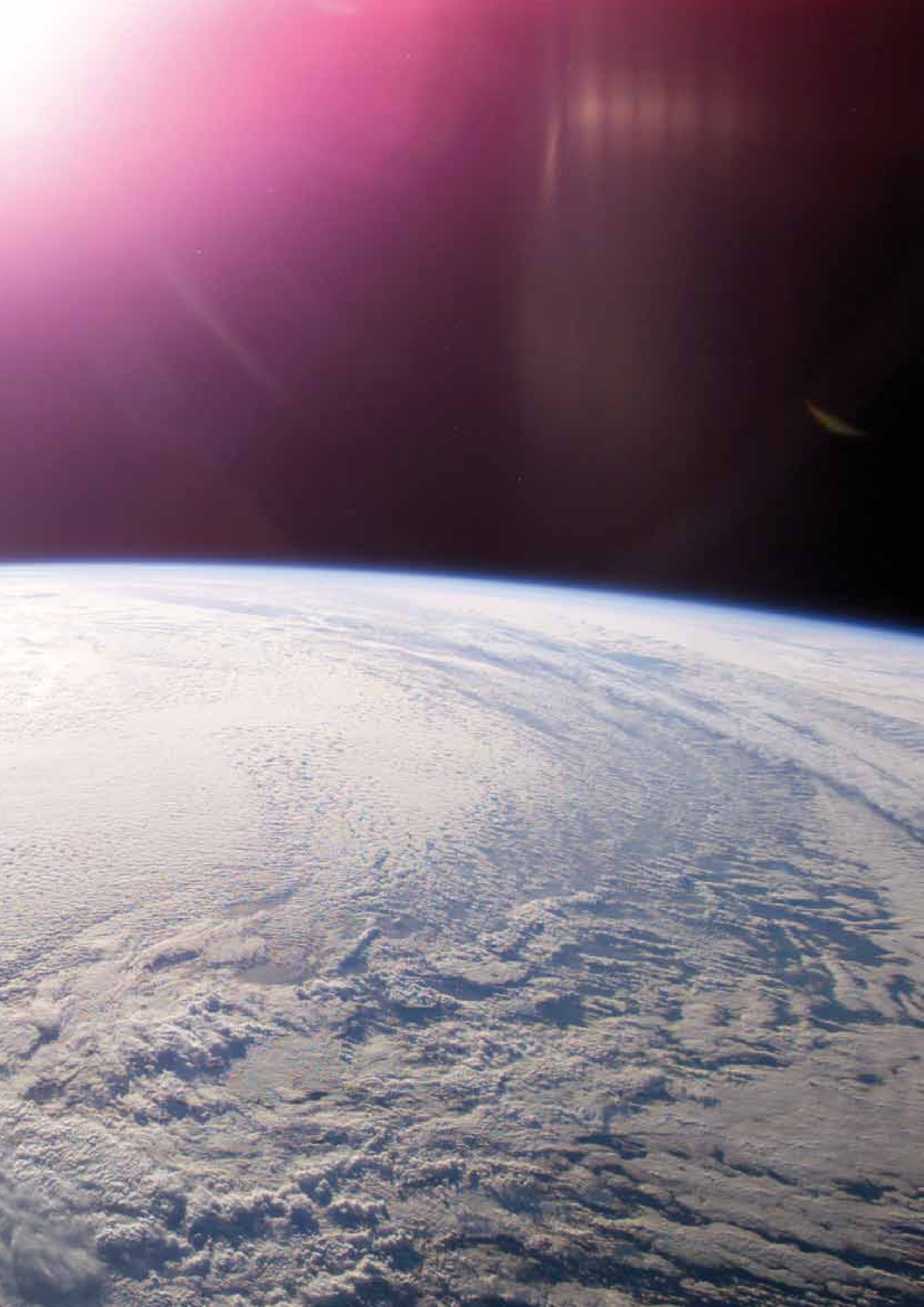
The key to why Comet 103P/Hartley 2 is different may be because of where it was born: far beyond Pluto, in a frigid region of the Solar System known as the Kuiper Belt. The other comets previously studied by astronomers are all thought to have formed near to Jupiter and Saturn before being thrown out by the gravity of those giant planets, only to return much later from great distances.

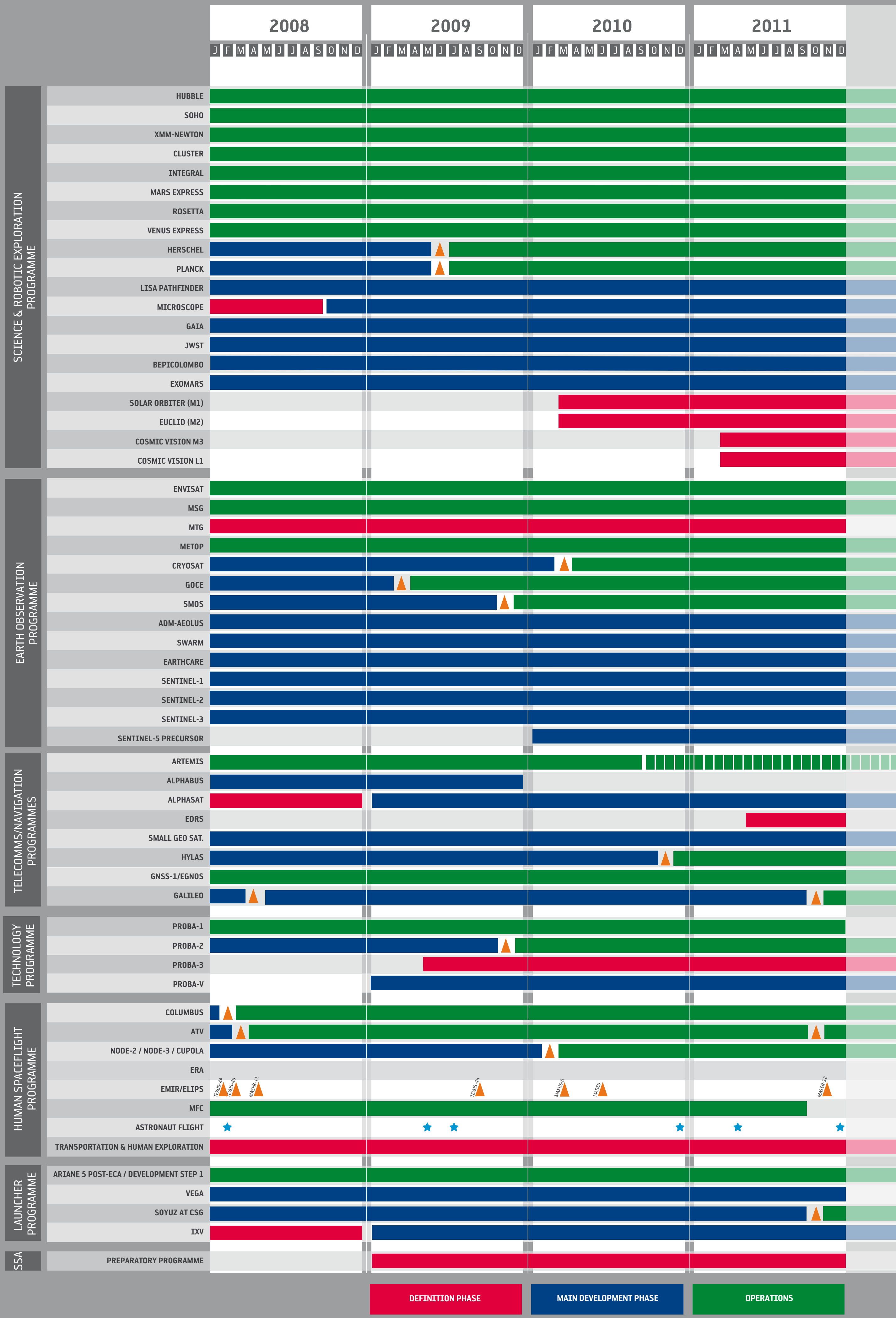
Thus the new observations suggest that perhaps Earth's oceans came from comets after all – but only a specific family of them, born in the outer Solar System. Out there in the deep cold, the deuterium-to-hydrogen ratio imprinted into water ice might have been quite different from that which arose in the warmer inner Solar System. Herschel is now looking at other comets to see whether this picture can be backed up.

"Thanks to this detection made possible by Herschel, an old, very interesting discussion will be revived and invigorated. It will be exciting to see where this discovery will take us," said Göran Pilbratt, ESA Herschel Project Scientist.

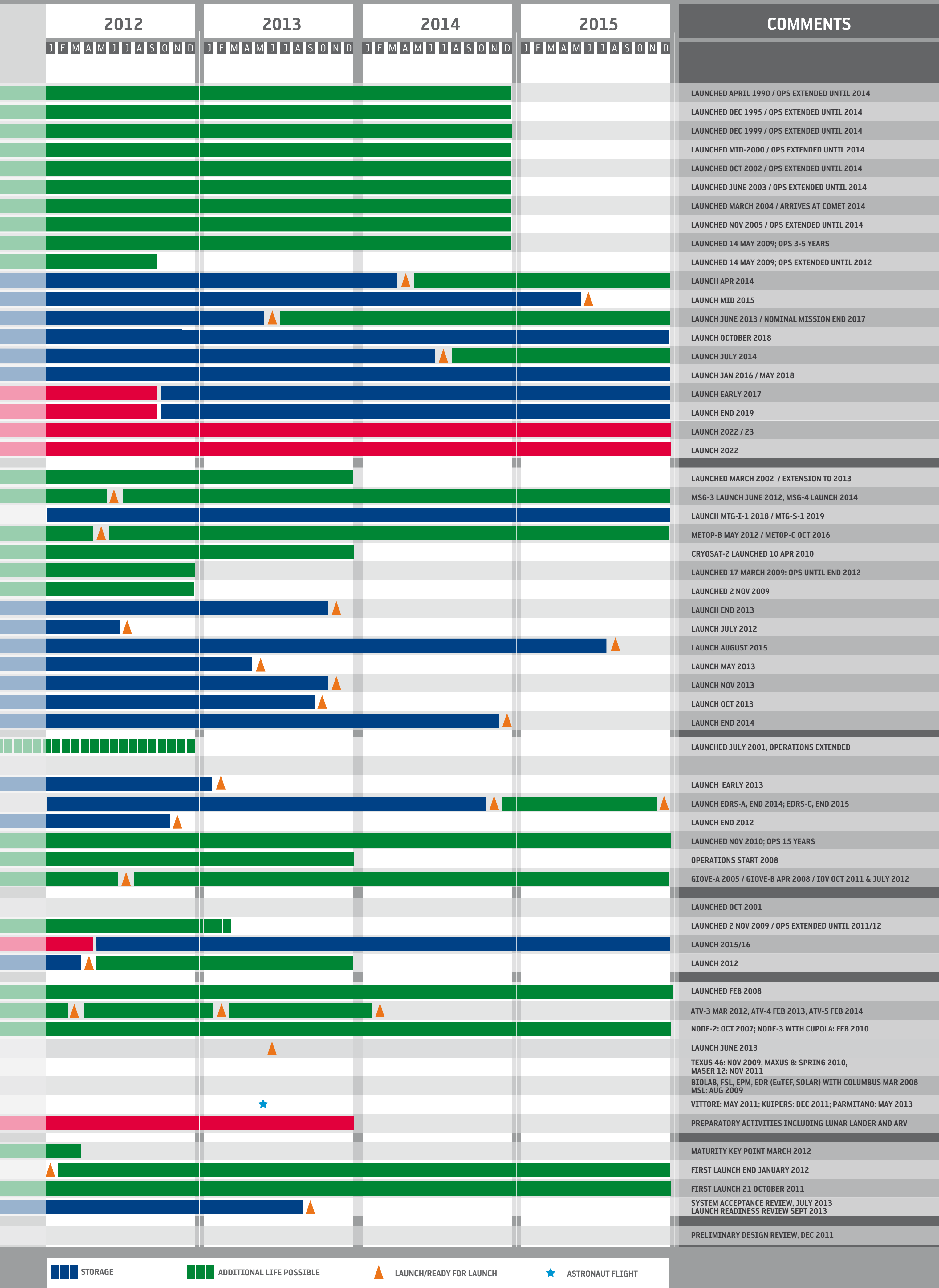
→ PROGRAMMES IN PROGRESS

Status at end of October 2011





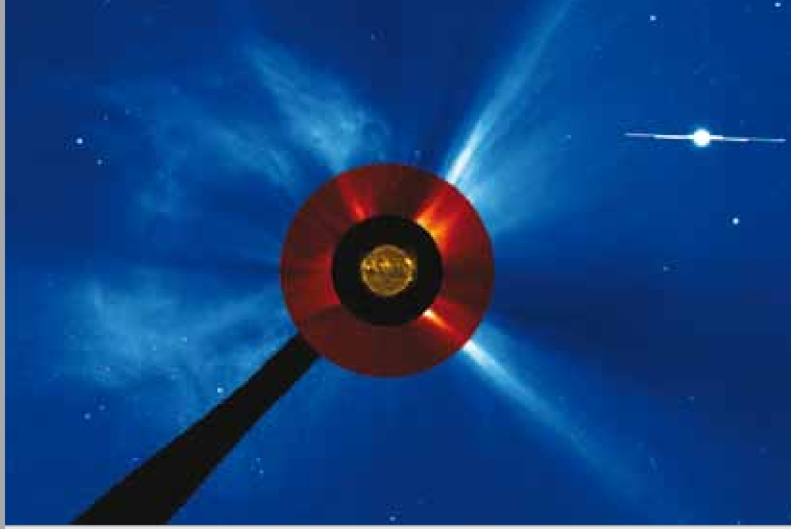
2008
2009
2010
2011
J F M A M J J A S O N D
SCIENCE & ROBOTIC EXPLORATION PROGRAMME
HUBBLE
SOHO
XMM-NEWTON
CLUSTER
INTEGRAL
MARS EXPRESS
ROSETTA
VENUS EXPRESS
HERSCHEL
PLANCK
LISA PATHFINDER
MICROSCOPE
GAIA
JWST
BEPICOLOMBO
EXOMARS
SOLAR ORBITER (M1)
EUCLID (M2)
COSMIC VISION M3
COSMIC VISION L1
EARTH OBSERVATION PROGRAMME
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
EDRS
SMALL GEO SAT.
HYLAS
GNSS-1/EGNOS
GALILEO
TECHNOLOGY PROGRAMME
PROBA-1
PROBA-2
PROBA-3
PROBA-V
HUMAN SPACEFLIGHT PROGRAMME
COLUMBUS
ATV
NODE-2 / NODE-3 / CUPOLA
ERA
EMIR/ELIPS
TEXUS-44
TEXUS-45
MASER-11
TEXUS-46
MAXUS-8
MARES
MASER-12
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


2012
2013
2014
2015
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
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 APR 2014
LAUNCH MID 2015
LAUNCH JUNE 2013 / NOMINAL MISSION END 2017
LAUNCH OCTOBER 2018
LAUNCH JULY 2014
LAUNCH JAN 2016 / MAY 2018
LAUNCH EARLY 2017
LAUNCH END 2019
LAUNCH 2022 / 23
LAUNCH 2022
LAUNCHED MARCH 2002 / EXTENSION TO 2013
MSG-3 LAUNCH JUNE 2012, MSG-4 LAUNCH 2014
LAUNCH MTG-I-1 2018 / MTG-S-1 2019
METOP-B MAY 2012 / METOP-C OCT 2016
CRYOSAT-2 LAUNCHED 10 APR 2010
LAUNCHED 17 MARCH 2009: OPS UNTIL END 2012
LAUNCHED 2 NOV 2009
LAUNCH END 2013
LAUNCH JULY 2012
LAUNCH AUGUST 2015
LAUNCH MAY 2013
LAUNCH NOV 2013
LAUNCH OCT 2013
LAUNCH END 2014
LAUNCHED JULY 2001, OPERATIONS EXTENDED
LAUNCH EARLY 2013
LAUNCH EDRS-A, END 2014; EDRS-C, END 2015
LAUNCH END 2012
LAUNCHED NOV 2010; OPS 15 YEARS
OPERATIONS START 2008
GIOVE-A 2005 / GIOVE-B APR 2008 / IOV OCT 2011 & JULY 2012
LAUNCHED OCT 2001
LAUNCHED 2 NOV 2009 / OPS EXTENDED UNTIL 2011/12
LAUNCH 2015/16
LAUNCH 2012
LAUNCHED FEB 2008
ATV-3 MAR 2012, ATV-4 FEB 2013, ATV-5 FEB 2014
NODE-2: OCT 2007; NODE-3 WITH CUPOLA: FEB 2010
LAUNCH JUNE 2013
TEXUS 46: NOV 2009, MAXUS 8: SPRING 2010,
MASER 12: NOV 2011
BIOLAB, FSL, EPM, EDR (EuTEF, SOLAR) WITH COLUMBUS MAR 2008
MSL: AUG 2009
VITTORI: MAY 2011; KUIPERS: DEC 2011; PARMITANO: MAY 2013
PREPARATORY ACTIVITIES INCLUDING LUNAR LANDER AND ARV
MATURITY KEY POINT MARCH 2012
FIRST LAUNCH END JANUARY 2012
FIRST LAUNCH 21 OCTOBER 2011
SYSTEM ACCEPTANCE REVIEW, JULY 2013
LAUNCH READINESS REVIEW SEPT 2013
PRELIMINARY DESIGN REVIEW, DEC 2011
STORAGE
ADDITIONAL LIFE POSSIBLE
LAUNCH/READY FOR LAUNCH
ASTRONAUT FLIGHT

esa

KEY TO ACRONYMS

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



The halo CME of 24 September, which struck Earth on 26 September and caused a severe (Kp=8) geomagnetic storm that ignited auroras over both hemispheres. The bright (overexposed) object to the upper right is Mercury

→ HUBBLE SPACE TELESCOPE

A fleet of space observatories including Hubble has shown unprecedented details in the region around a supermassive black hole. The black hole lies at the heart of the active galaxy Markarian 509, 500 million light-years away. It is colossal, containing 300 million times the mass of the Sun and growing more massive every day as it continues to feed on surrounding matter, which glows brightly as it forms a rotating disc around the hole.

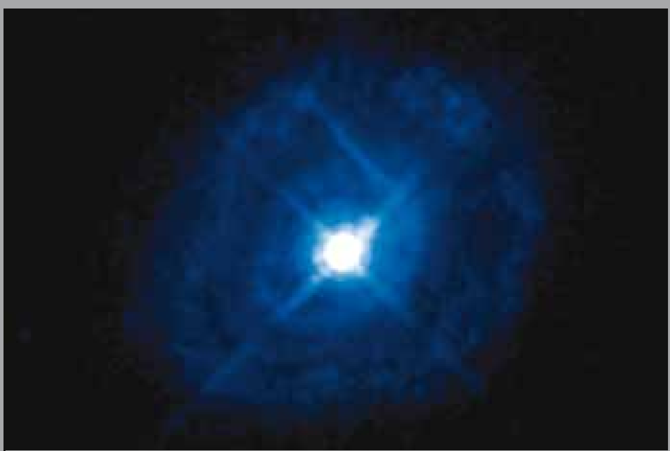
The latest observations, made by a team led by Jelle Kaastra of the Netherlands Institute for Space Research (SRON), reveal 'bullets' of gas being driven away rapidly from the centre and a corona of very hot gas hovering above the disc of matter that is falling into the black hole. They chose to study Markarian 509 because it is known to vary in brightness, which indicates that the flow of matter is turbulent.

The team made use of data from ESA's XMM-Newton and Integral spacecraft (which study X-rays and gamma rays respectively), Hubble (for ultraviolet observations with the COS instrument), NASA's Chandra (X-ray) and Swift (gamma- and X-ray) satellites, and the ground-based WHT and PAIRITEL telescopes.

By using a large number of telescopes, each sensitive to different wavelengths of light, the team had unprecedented coverage running from infrared through to the gamma-ray band.

→ SOHO

At the end of September, the Sun showed a level of activity not seen for many years: two X-class and 16 M-class X-ray flares within a week, numerous coronal mass ejections, some of which were directed towards Earth and led to some of the most spectacular auroras seen in many years, and several large sunspot groups, two of which were even large enough to be seen with the naked eye. *(Note: do not look directly at the Sun without adequate eye protection!)*



Artist's impression of gas swirling around a black hole like Markarian 509 (NASA/M. Weiss)

A supermassive black hole resides at the centre of Markarian 509 (NASA/ ESA/G. Kriss and J. de Plaa)

Still image from a video of the Aurora Australis (Southern Lights) taken by the crew of ISS Expedition 28 in September, over the Indian Ocean between Madagascar and Australia

→ CASSINI–HUYGENS

Last December, the Radio Plasma Wave experiment on Cassini detected powerful lightning discharges in the northern hemisphere of Saturn. These were the first signs of one of the largest storms ever observed on Saturn, which has developed to planetary scale over the past six months. This storm triggered a multi-wavelength observation campaign, still ongoing, combined with ground-based observations. Flash rates of this thunderstorm were recorded to peak at 10 per second. These rates are one order of magnitude higher than those observed during previous storms. The occurrence of such a powerful storm during the early springtime in the northern hemisphere remains puzzling, because the storm season generally peaks after the summer solstice.

→ XMM-NEWTON

One of XMM-Newton's main instruments is the European Photon Imaging Camera (EPIC). EPIC consists of three cameras, two of which use metal oxide semiconductor CCDs, while the third uses a new type of device, the pn-CCD, which was developed and built by the semiconductor laboratory at the Max Planck Institute for Extraterrestrial Physics. Typically, astronomers cite the instrument each time they use its data in a publication. Now the EPIC pn-CCD has reached 1000 citations, which is a remarkable achievement and illustrates the influence of XMM-Newton.

→ CLUSTER

During the summer, the spacecraft reached their lowest altitudes since launch, with one satellite reaching an altitude of around 200–300 km – lower than the International Space Station. To take advantage of this, the mission is targeting low altitude regions, including the inner plasmasphere and the auroral regions. This year saw the beginning of implementation of special operations based on the successful proposals of the Guest Investigator (GI) programme, with an investigation of energetic particles at high latitudes. Other GI studies examining turbulence, reconnection and boundary wave phenomena will be implemented next year. The next eclipse seasons begin in November and end in March 2012.

Bright auroral displays can be caused by a phenomenon known as 'geomagnetic substorms'. The origin of these substorms has been debated for decades, although recent research appears to favour the magnetic reconnection mechanism. A major problem with this theory involves the rapid onset of auroras after the sudden realignment of the magnetic field lines. According to established theory, the energy from the reconnection event is carried by 'Alfvén waves' – a type of electromagnetic wave that propels charged particles in the plasma towards and away from Earth. However, these Alfvén waves travel quite slowly, reaching Earth after only about 250 seconds. They cannot account for some observations of substorm events, which indicate that auroras intensify less than one minute after the onset of reconnection – much earlier than expected.

This discrepancy led to the suggestion that another, faster, type of wave – known as a 'kinetic Alfvén wave' (KAW) – might also be generated during a substorm. In a recent study, Cluster observations were combined with computer simulations to confirm that KAWs could be generated by reconnection and then propagate rapidly away from the site of the explosion, reaching Earth in less than one minute and carrying enough energy to intensify auroras. This research is a striking example of how Cluster data are now being used by theoreticians around the world to verify their simulations and transform scientists' understanding of the complex processes that take place in near-Earth space.

→ INTEGRAL

Integral has obtained an important result in fundamental physics: using Integral observations of the polarisation of the distant gamma-ray burst (GRB041219A), scientists were able to put a new limit (10^{-14}) on the Lorentz invariance violation, four orders of magnitude more stringent than what was obtained previously. This was done using the IBIS/Compton mode, and measuring the difference in polarisation angle for two adjacent energy bands of the gamma-ray burst emission. The Lorentz invariance implies that there is no vacuum birefringence, i.e. light propagates in the same way at all energies and in all directions, and so the difference in polarisation angles should be zero. Integral observations confirm this fact, and show that potential effects induced on light propagation by vacuum birefringence should be very small. The results will strongly constrain quantum gravity theories.

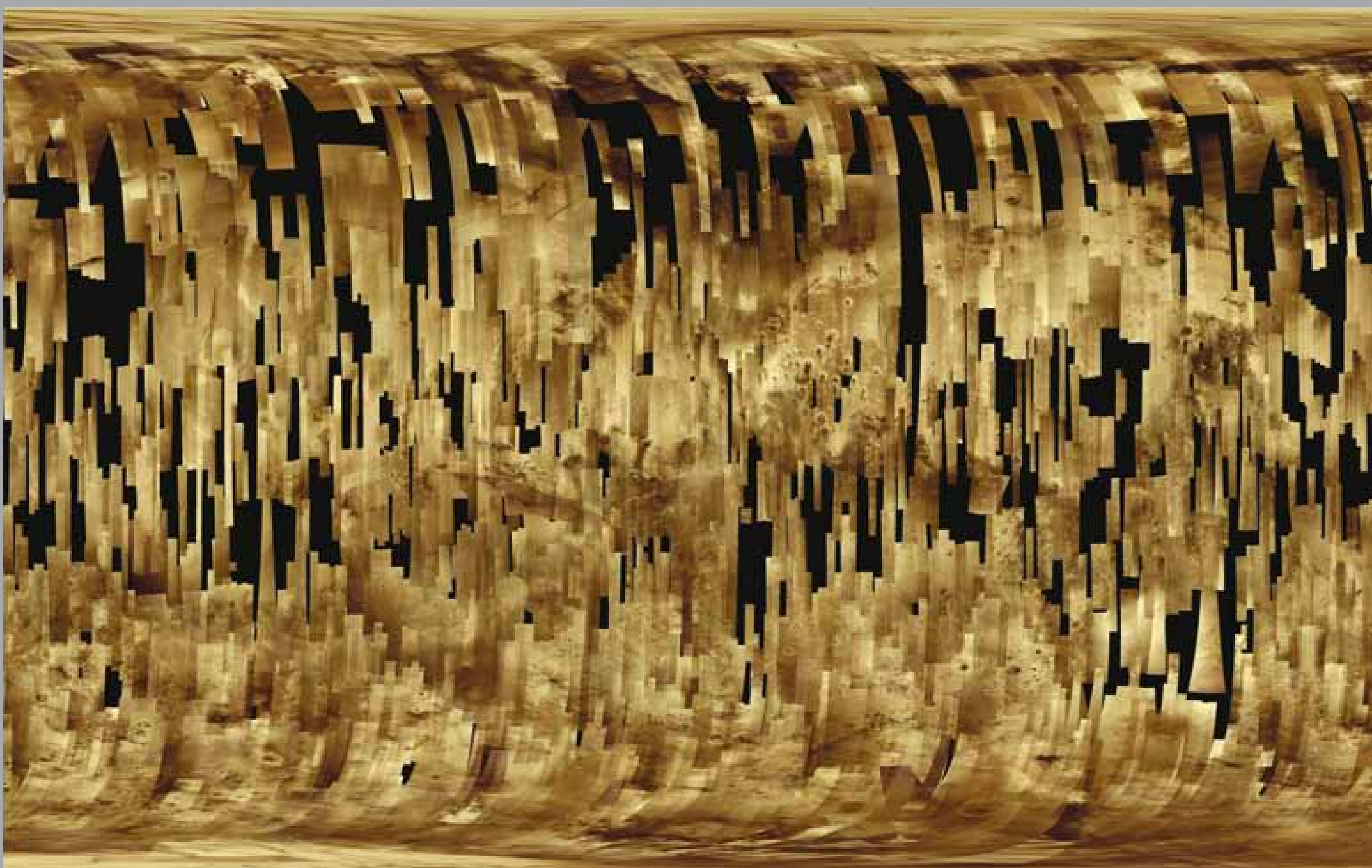
→ MARS EXPRESS

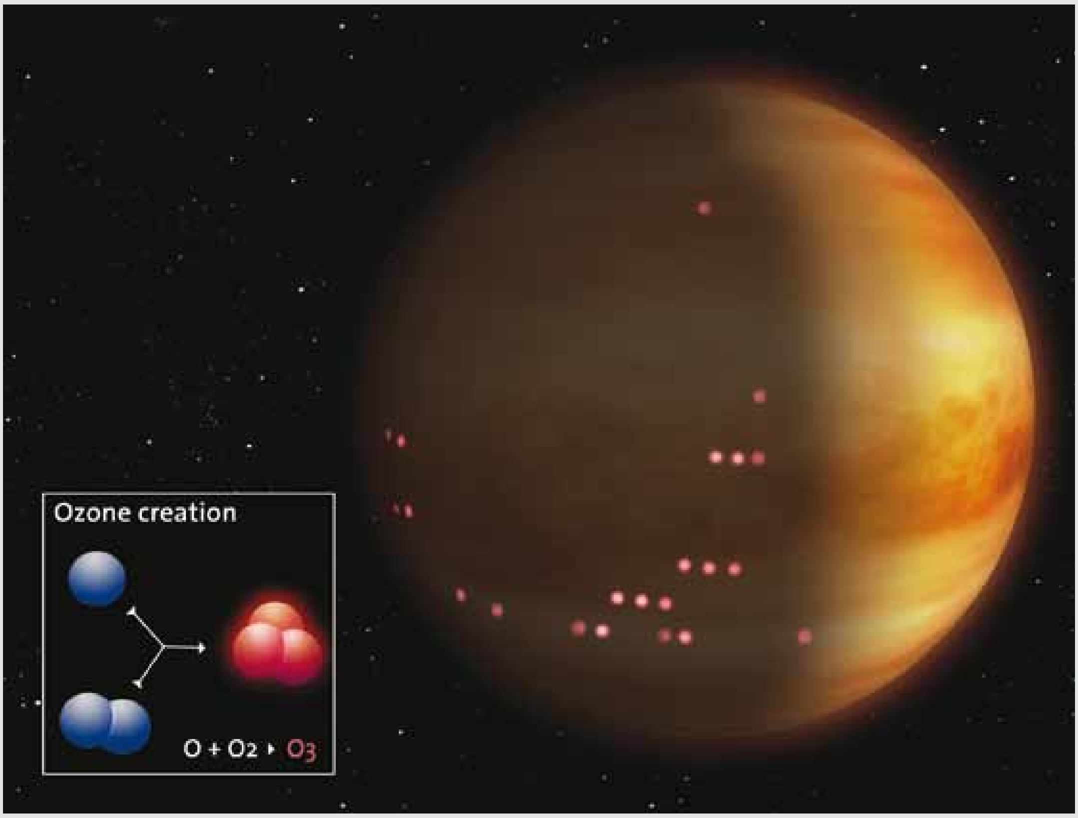
Mars Express results published at the end of September in *Science* indicate for the first time that the planet's atmosphere is supersaturated with water vapour. Supersaturation occurs when some water vapour remains in the atmosphere instead of condensing or freezing. When condensation nuclei (assumed to be dust aerosols on Mars) are too rare, condensation is impeded, leaving substantial amounts of excess vapour. This surprising discovery has major implications for understanding the Martian water cycle and the historical evolution of the atmosphere.

Mars Express will make its 10 000th orbit of Mars on 4 November. To celebrate, this false-colour mosaic was released, covering all the publicly available data in the Mars Express archive obtained by the High Resolution Stereo Camera. The selected observations are largely free of dust, and only images for which red, green, blue and nadir observations were available were used. The remaining gaps (black) will be filled in the coming years (ESA/DLR/FU Berlin)

→ ROSETTA

Rosetta has been in hibernation since 8 June. The Rosetta science and operations teams are continuing detailed preparation of the comet operations phase. The orbits required during the various phases of comet activity are being calculated and evaluated together with the science payload teams, in order to fulfil the needs of the scientific goals during the comet rendezvous phase in 2014–15.





The source of Venus's ozone is most likely oxygen atoms originating from dissociation of carbon dioxide by solar UV on the sunlit side of the planet and then migrating towards the anti-solar point where it descends and combines, first into oxygen molecules and then into ozone. The loss mechanism is more uncertain but may be related to chlorine-related catalytic reactions, like on Earth. Therefore, as in many other cases, comparisons between the two planets will help understanding of both systems.

Mars Express will make its 10 000th orbit of Mars on 4 November. To celebrate, this false-colour mosaic was released, covering all the publicly available data in the Mars Express archive obtained by the High Resolution Stereo Camera. The selected observations are largely free of dust, and only images for which red, green, blue and nadir observations were available were used. The remaining gaps (black) will be filled in the coming years (ESA/DLR/FU Berlin)

→ VENUS EXPRESS

Ozone, the triple-oxygen molecule, has been discovered in the upper atmosphere of Venus. It was found using the SpicaV instrument, operating in stellar occultation mode in ultraviolet light. Before this discovery, ozone had only been found in the atmospheres of Mars and Earth. The total concentration on Venus is only about one in a thousand of that on Earth, but the find is important because it provides important information on the chemistry that takes place in the upper atmosphere. In addition, information on the dynamics of this region can be derived from these data.

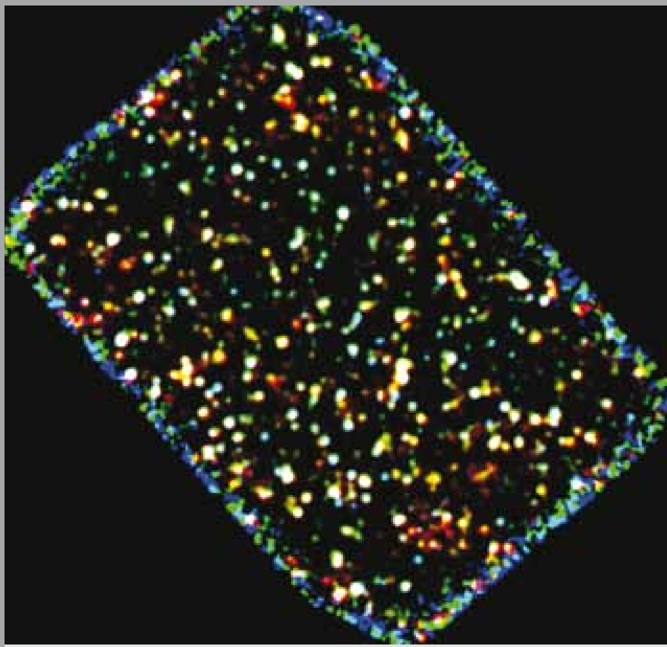
Another interesting aspect of ozone is in the field of characterising exoplanets, because astrobiologists consider ozone, if found in combination with carbon dioxide and oxygen, to be strong evidence for life. However, for this to be true the ozone level has to be at least 20% of that on Earth, so the ozone levels on Venus are not conclusive.

The innovative technique of using the spacecraft itself as a probe for measuring atmospheric density at low altitudes has continued during two campaigns, in May and September. The slowing down of the spacecraft and the tendency to rotate while dipping down into the uppermost parts of the atmosphere can be measured very accurately and these data can be directly converted into atmospheric density. New measurements show a variable density at altitudes between 165 km and 180 km, consistently varying with a periodicity of about two days. This peculiar behaviour is not yet understood but might be related to the polar vortex, which is rotating below at about this rate but at a much lower altitude.

→ HERSCHEL

A major strength of Herschel as an observatory is its capacity to perform a variety of studies of the Universe near and far. It continues to do this well and with high observing efficiency.

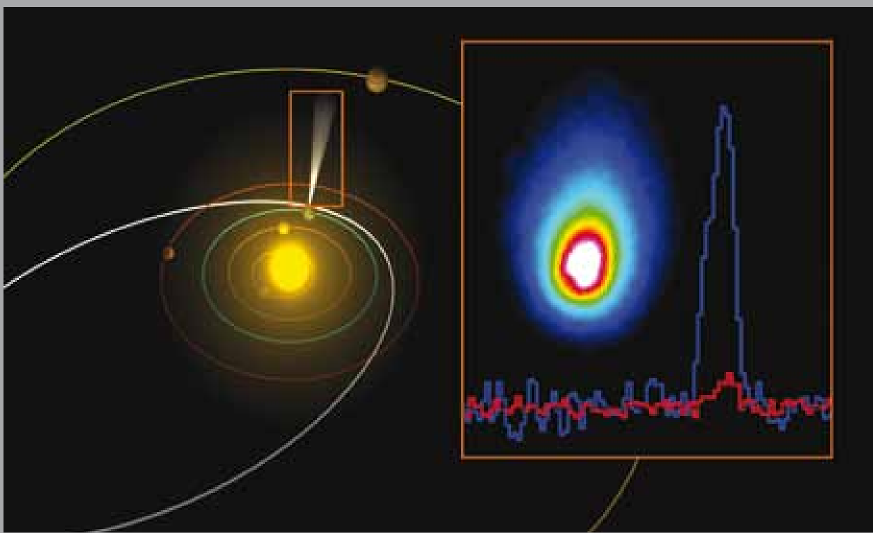
Obtaining its deepest images of the Universe to date in a well-studied field on the sky called 'GOODS-North', Herschel has shed new light on the cosmic star formation history over the last 80% of the age of the Universe, revealing how most stars in the Universe have formed.



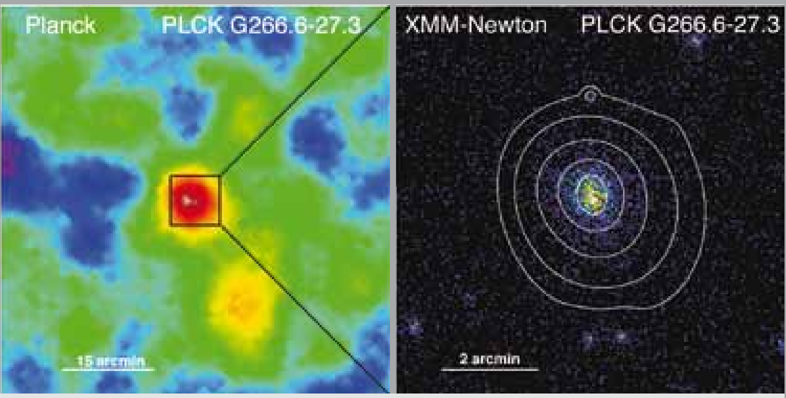
A composite, three-colour view of the GOODS-North field, observed with Herschel/PACS at 100 µm (blue) and 160 µm (green) and with Herschel/SPIRE at 250 µm (red), and based on 124 hours of integration. North is up and east to the left (ESA/GOODS-Herschel consortium)

It is well known that earlier in the history of the Universe interactions and even mergers between galaxies were very much more common than they are now. Such mergers are known to produce compact regions of massive bursts of star formation, causing galaxies to produce stars at rates hundreds, even thousands, of times above what is happening in our home galaxy the Milky Way today. The new data from Herschel, combined with data at shorter infrared wavelengths, surprisingly show that most of the star formation is not produced by these compact bursts, but in a more leisurely and spread out manner, much the same way as in the Milky Way today. The overall contribution by the violent bursts has been revealed to be minor.

Much closer to home, Herschel has observed Comet 103P/Hartley 2, and has found that the isotopic composition of the water in this particular comet is similar to that of Earth's oceans. The origin of Earth's water is hotly debated and, since our planet initially was very hot (causing any original water to evaporate), the water present today must have been delivered from space later, after the early Earth had cooled down. Comets, being giant 'dirty snowballs', seemed a natural contender, but the handful of comets measured to date turned out to have water with the 'wrong' isotopic composition. However, comets come in different 'families' with different histories affecting their isotopic compositions, and Hartley 2 is from a different family than the comets previously studied. With this observation, Herschel has reignited the controversy of the origin of Earth's water.



The orbit of Comet 103P/Hartley 2 in relation to the orbits of the innermost five planets of the Solar System. The inset on the right shows the comet as viewed by Herschel/PACS, and two water lines from the spectrum of the comet obtained with the Herschel/HIFI spectrometer from which the isotopic composition has been derived (ESA/AOES Medialab/Herschel-HssO consortium)



Left, the massive cluster PLCK G266.6-27.3 as discovered by Planck, and right, the zoom on its central portion as confirmed in X-rays by XMM-Newton

→ PLANCK

Planck continues to operate routinely, and is now well into its fifth survey of the entire sky. It is expected that the dilution cooler on board Planck and the detectors of the High Frequency Instrument (HFI) will cease to operate in mid-January 2012 due to exhaustion of the cryogenic fluid. However, the Low Frequency Instrument (LFI) will continue to operate and survey the sky for a period now expected to be around six months.

A publication recently accepted by *Astronomy & Astrophysics* confirms Planck's ability to find and study some of the rarest objects in the Universe: very massive clusters of galaxies observed at very early stages in their formation. Until now it has been very difficult to find such objects, which offer critical clues to understanding the mechanisms of formation of the largest structures in the Universe. Planck, with its ability to find galaxy clusters over the whole sky, now allows them to be searched for systematically

→ COROT

COROT continues to operate nominally without Data Processing Chain #1. It has now spent more than 1750 days in space, of which data has been obtained on 1735. After close to five years of operations, COROT remains fully functional. So far 22 233 identified main sequence stars brighter than 14th magnitude have been observed. Of these, 18 333 are of a solar type. A total of 58 square degrees have been covered (with 10% overlap) in 21 separate pointings. The follow-up of exoplanetary candidates is now being pursued down to a magnitude of lower than 15 (using the Keck telescope provided in a separate agreement with NASA) in particularly interesting cases.

At the second COROT symposium held in Marseille in June, ten new exoplanets were announced. The total now stands at 27 named objects, including the first case in which COROT found two (Neptune-sized) planets transiting the same star.

→ GAIA

All flight mirrors have been integrated on the PLM, and the two telescopes are being aligned to match the two 35 m focal lengths with a difference of less than 3 mm, while still keeping the wavefront errors minimal. Once in orbit, a focusing mechanism will be used for both telescopes to compensate for variation due to thermal effects, lack of gravity and settling after launch.

On the Focal Plane Assembly FM, all 106 flight CCDs, their front-end electronics and the power distribution and command electronics have been integrated. The two prisms that generate the spectra centred in the blue and red optical bands have been mounted and aligned on the structure facing the focal plane.

The Radial Velocity Spectrometer optics are aligned and optical tests are ongoing in preparation for the environmental test campaign. The Basic Angle Monitor system (which will measure the variation of the two telescopes' lines of sight) has been aligned and the environmental test campaign has started.

The mechanical qualification tests will take place at Intespace before the end of the year. The PFM#1 configuration that will be tested foresees the SVM FM, the PLM dummy inside the Thermal Tent FM and the Deployable Sun Shield FM. The latter was delivered in September to Astrium SAS by Sener after two deployment tests under ambient conditions.

The third System Validation Test, in which ESOC controls the spacecraft, is planned to start by the end of November. It will validate additional flight operation procedures on the spacecraft AM.

The Gaia Sun Shield fully deployed in the Sener clean room

→ MICROSCOPE

Activities are still on hold; the CNES decision is now expected by the end of 2011.

→ LISA PATHFINDER

Environmental tests of the LISA Pathfinder FM in launch configuration continued in IABG, Ottobrunn. The propulsion module FM was mated with the Science Module (SCM) SM, and submitted to Vega compatibility shock testing, to simulate the shock at separation of the launcher fairing. The results are being analysed. The SCM FM was integrated with all the LISA Technology Package (LTP) FM units for the electromagnetic compatibility test in September. After this the SCM was prepared for the On-Station Thermal Vacuum test. Only the FMs of the micro-propulsion thrusters and the LTP Core Assembly (LCA) are missing in these tests. The LCA is replaced by a thermo-optical simulator capable of performing an interferometry measurement during the thermal vacuum test, which would not be possible with the LCA FM.

Functional verification of the spacecraft is continuing in parallel.

LISA Pathfinder Science Module FM entering the thermal vacuum chamber in IABG, Ottobrunn, to perform the On-station Thermal Vacuum Test (Astrium Ltd)

Tests to identify the cause of the failure of the FEEP micro-propulsion system in 2010 are continuing. In parallel, ESA and industry have studied two alternative systems, a GAIA-type cold gas system and a reduced Radio-frequency Ionisation Thruster. Both technologies, although presently at different stages of development, are confirmed to be adequate for the LISA Pathfinder needs. A no-return decision is not needed until mid-2012.

Two new launch lock mechanisms have been tested at breadboard level. A PDR is being held to select the best concept.

MIRI optical system Flight Model after cryogenic testing

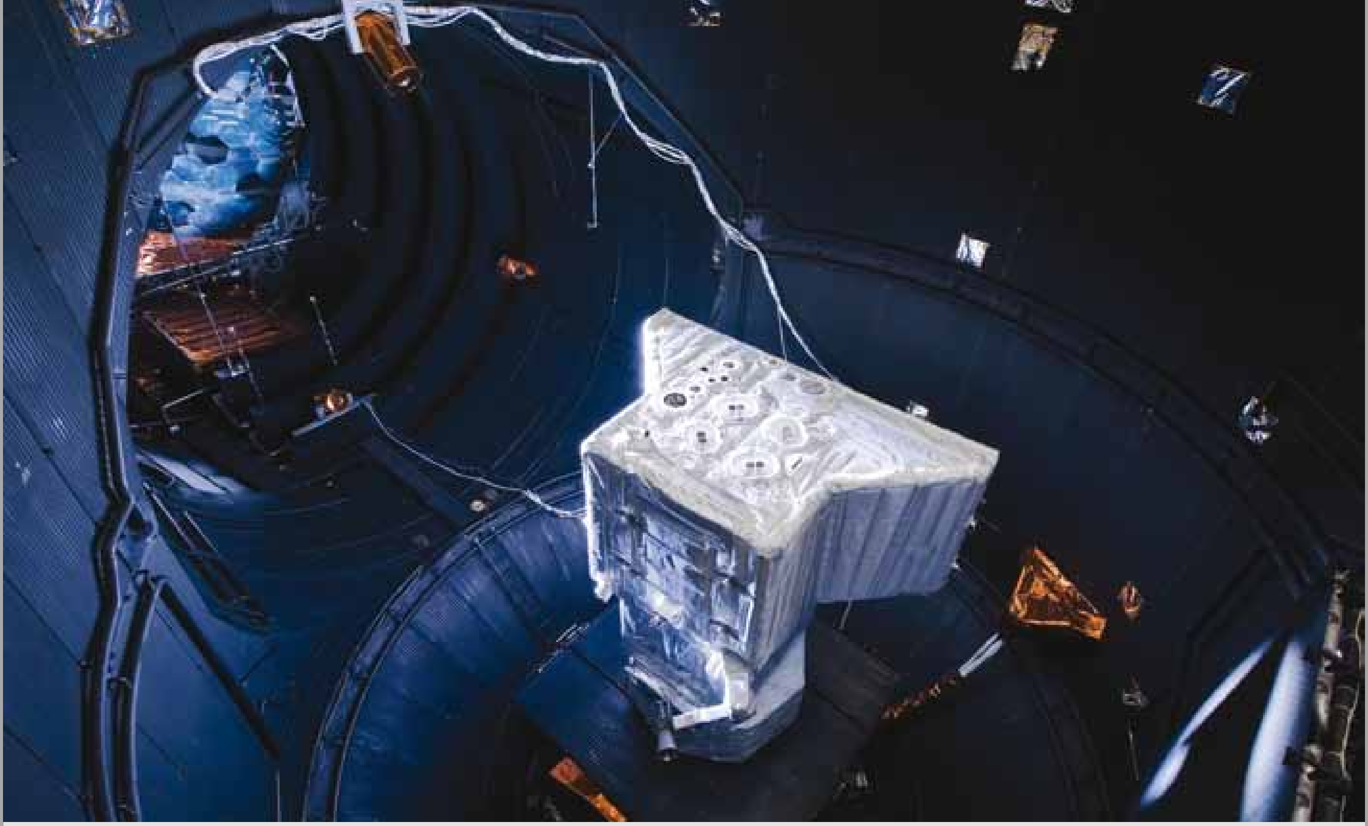
→ JAMES WEBB SPACE TELESCOPE

All primary mirror segments have been polished and gold coated, and 12 have passed final cryo-verification. The secondary, tertiary and fine-steering mirrors have completed final processing. NASA's updated project plan indicates launch readiness in October 2018.

Following the environmental test campaign, detailed inspections of the optical bench of the NIRSPEC instrument found cracks in the bench material that are not acceptable for flight. It was decided to exchange the optical bench with the available spare FM. This will have some impact on delivery of the instrument to NASA.

The final cryo-verification test of the full MIRI instrument optical system has been completed. Detailed analyses of the performance test data are ongoing, and no major non-compliances have been identified.

A solution has been found for the launch and injection of JWST by Ariane 5, resolving the previously reported thermal problems during injection.



BepiColombo's Mercury Planetary Orbiter STM in the Large Space Simulator at ESTEC

→ BEPICOLOMBO

The Mercury Planetary Orbiter (MPO) STM was delivered to ESTEC for environmental testing. A major milestone was completion of the MPO thermal balance test at high solar intensity in ESTEC's Large Space Simulator, as this is critical for BepiColombo. Initial results confirm good performance of the radiator and the high-temperature multi-layer insulation. The new blanket configuration (improved since the sunshield test last year) performed as expected.

The Mercury Transfer Module STM completed propulsion systems leak tests before shipment to ESTEC. A number of equipment-level CDRs were conducted in this period and more will be conducted during the coming months, clearing the way to begin manufacture of flight hardware. Manufacture of the MPO flight structure is nearing completion.

Meanwhile, nine of eleven MPO instrument EMs completed pre-integration to the Engineering Test Bed (ETB) at Astrium, Friedrichshafen. During the summer, the Integrated System Tests were defined supported by ESAC, and eight instruments were tested on the ETB. While the MIXS and SIXS EMs are still undergoing instrument-level testing in preparation for delivery, and the MORE instrument Ka-band transponder has been integrated and tested with the spacecraft communication subsystem on the RF mock-up in Turin. Five MPO instrument CDRs were conducted and the remaining six are scheduled for autumn 2011.

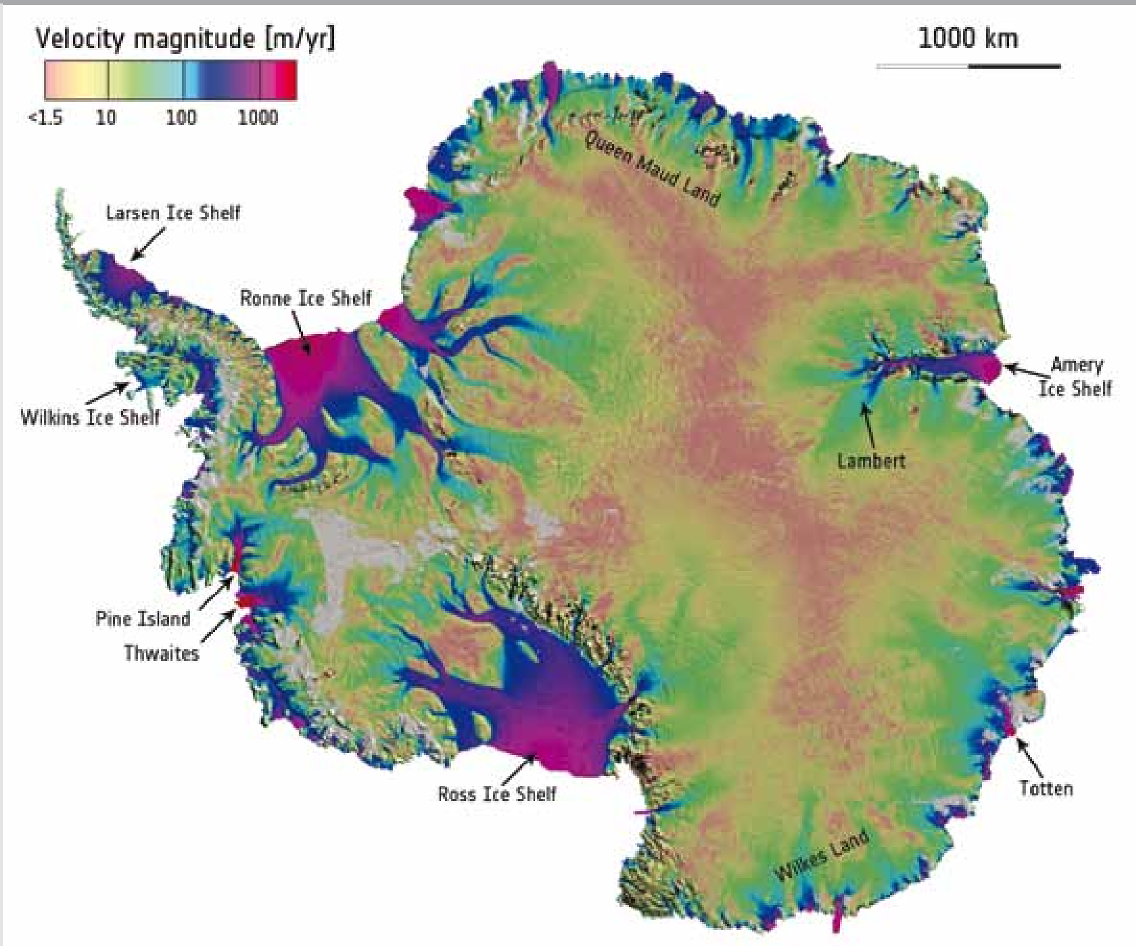
JAXA is preparing to deliver their Mercury Magnetospheric Orbiter (MMO) SM to ESTEC in early November. This will become part of the STM Mercury Composite Spacecraft for mechanical qualification. The MMO FM mechanical- and electrical-interface checks are ongoing at JAXA.

The contract for Ariane 5 launch services was negotiated and signed mid-September. The ground segment completed the Mission Control System PDR. Launch is planned for the Mercury launch opportunity in mid-2014.

→ EXOMARS

Work continued on the baseline mission including the Trace Gas Orbiter and Entry, Descent and Landing Demonstrator Module (EDM) to be launched in 2016, as well as study work on the joint rover to be launched in 2018. The work was supported by a Preliminary Authorisation to Proceed issued by ESA for July to September inclusive. This funding is sufficient to maintain progress on launch-critical subsystems.

The main issue restricting approval for a full Phase-C/D implementation is a delay to a written NASA commitment to the ExoMars programme. NASA is facing budget reviews, and announced a wish to pool all the ESA contributions into a single mission to be launched in 2018, in order to reduce overall mission costs for the cooperation. A joint ESA–NASA study was performed on this scenario, whereby ESA would provide a Data Relay Carrier/Orbiter as well as a contribution to the joint rover, while NASA would provide the other elements as heritage from their Mars Science Laboratory wherever possible. After a month-long study, the feasibility



First map of ice velocity over the entire continent of Antarctica, mainly derived from Envisat, Radarsat-2 and ALOS SAR data, with some contribution of ERS-1/2 and Radarsat-1 data. These new findings are critical to measuring the global sea-level rise resulting from ice flowing into the ocean (E. Rignot et al, *Science*)

of this approach was discussed and the risks evaluated, and it was then decided not to pursue it further.

An alternative approach for implementation of the full programme was initiated in September at the IAF in South Africa. Russia declared itself open to entering discussions with ESA and NASA to join the ExoMars programme, with the idea of participating with mission elements while ESA seeks to acquire a Proton launcher for the 2016 mission. Discussions with Russia will start shortly, with the objective of establishing a framework for cooperation by the end of January 2012.

Study activities for the 2018 mission were slowing down in this period due to the NASA need to study alternative scenarios. Nevertheless, basic agreements for sharing the joint rover and responsibilities for the 2018 mission have been formulated. Furthermore, the ESA requirement to have a European computer on the rover has hardened and NASA has agreed to this, pending a joint review to ensure that the computer can perform all the functions of the mission from launch to cruise phase, entry and landing, and finally rover surface operations. The final architecture for the joint rover will be fixed within the first quarter of 2012 at a Mission Concept Review.

In the domain of payload development, work has continued on the TGO instruments and the EDM surface payload called DREAMS. Furthermore, a camera and entry sensors have been identified and will be provided to industry for integration in the EDM as customer-furnished items. Work continues to support accommodation of the instruments of the Pasteur payload within the new structure of the 2018 single, joint rover mission.

→ ERS-2

After 16 years of operations and a highly satisfactory scientific and applications output, ERS-2 was deorbited during summer 2011, and switched off on 5 September.

ERS-2 is now flying in a circular orbit at about 570 km altitude; its reentry into the atmosphere, where it will burn up, will take between 15 and 20 years depending on the solar activity (i.e. well within the 25-year limit requested in the Inter-Agency Space Debris Mitigation Guidelines).

ERS-2 acquired data until 4 July, with its last months of activity dedicated to a specific Ice Phase (three-day repeat orbit). The results of this mission phase were outstanding. Furthermore, ERS-2 contributed uniquely with its three-day repeat cycle to the observations after the earthquake and tsunami at Sendai, Japan.

→ ENVISAT

Envisat is operating nominally, except for the GOMOS instrument, which has been suffering from several anomalies since August. The SCIAMACHY and MERIS instruments provided remarkable observations of the Grimsvötn volcano eruption in Iceland in May.

In July, a scientific publication based on Envisat Advanced Synthetic Aperture Radar (ASAR) data reported the first observational evidence that a Northern Hemisphere tsunami (the Japanese earthquake of March) can trigger an ice-shelf calving in Antarctica, i.e. more than 13 000 km away. In September, Envisat observed the Arctic sea-ice extent at its record minimum, matching the previous record of September 2007.

Many remarkable results based on Envisat and ERS SAR interferometry were presented at the 8th Fringe workshop in September. Of particular relevance was the first Antarctica ice velocity map, based on SAR data acquired during the International Polar Year in coordination between ESA, CSA and JAXA.

Astrium personnel performing alignment adjustments on the Aladin telescope to minimise the wavefront error

→ GOCE

GOCE continues to operate flawlessly, achieving a 100% data-acquisition and processing record since January.

Based on measured gravity gradients and high/low satellite-to-satellite tracking data, the mission is continuously delivering new insights into the finer details of the gravity field, and thus providing an ever-better reference data set for all scientific domains and applications that are in need of gravity field information.

A full set of gravity field models and geoid products derived from the entire nominal mission data set is planned for release in November. Owing to the excellent health of the space segment, a further extension of GOCE will be proposed in 2012.

→ SMOS

SMOS will celebrate its second year in orbit in November. All data – brightness temperatures (level 1) and soil moisture and ocean salinity data (level 2) – have been released to the science community. The data products are constantly being improved. The first mission reprocessing will be carried out until end-2011. The first SMOS science workshop took place on 27–29 September with over 100 participants.

→ CRYOSAT

CryoSat is performing well, with both space and ground segments behaving as expected. A major upgrade of the processors has been completed, to begin operations early next year.

→ ADM-AEOLUS

The first laser transmitter FM integration is close to completion. Excellent performance has been achieved in ambient conditions and the long-term vacuum test will be completed in 2011. The transmitting and receiving optics unit is being refurbished with four new optical assemblies, to secure its resilience to laser-induced damage and contamination.

Integration of the *in situ* cleaning subsystem FM will begin imminently, with most equipment undergoing final acceptance testing. The Oxygen Safety Board has confirmed the design and declared materials to be safe for high-pressure oxygen operations.

The satellite and instrument contractors have agreed to a combined test sequence to optimise the total assembly, integration and test duration, and a consolidated schedule has been established.

Swarm in the magnetic test facility of IABG, Ottobrunn (Astrium GmbH)

→ SWARM

The three satellites are in the IABG test facility in Munich, completing final delivery tests. The first satellite completed thermal vacuum and vibration tests and is ready for the magnetic characterisation, mass properties and stack tests. The second satellite completed its suite of environmental tests, including magnetic characterisation in the magnetic chamber, and is ready for the stack test with the launcher adaptor (acoustic, fit check and shock). The Electrical Field Instrument FM2 acceptance testing has been completed, demonstrating the correct implementation of the interfaces, and it is being shipped to Friedrichshafen for mounting on the second satellite. The third satellite is being prepared for the mechanical tests.

Ground segment preparation activities are proceeding according to plan. Khrunichev's recovery actions on the Rockot launcher are expected to be complete by November.

→ EARTHCARE

The project is presently entering into Phase-C/D and the detailed design of all spacecraft elements is proceeding according to the post-PDR configuration. Selection of the subcontractors for the spacecraft subsystems is nearing completion.

The development of ATLID is progressing and good performance results have been achieved with the ATLID transmitter breadboard, in particular with a higher than specified efficiency of its harmonic stage (UV). Meanwhile, the PDR of the transmitter proper has been initiated as planned.

The Multi-Spectra Imager SM mechanical test campaign has been completed without major issues. Significant progress has been achieved on the instrument detectors with the delivery of the first FM Short Wave Infrared (SWIR-1) detectors, and the ongoing qualification tests of Visible, Near Infrared and SWIR-2 detectors.

Development of the Broad-Band Radiometer is proceeding satisfactorily and the first fully representative micro-bolometer detectors have been delivered for the qualification campaign. A representative model of the instrument mechanism is undergoing a life test and has already achieved 10% of the foreseen cycles.

In Japan, JAXA and its industrial consortium are progressing the Cloud Profiling Radar (CPR) subsystems towards CDR. The CPR SM mechanical tests will resume in the last quarter of 2011.

→ METEOSAT

Meteosat-8/MSG-1

Completing its ninth year in orbit, MSG-1 provides the Rapid Scan Service (one picture every five minutes of the northernmost third of Earth, in 12 spectral channels), complementing the full-disc mission of the operational Meteosat-9/MSG-2.

Meteosat-9/MSG-2

In very good health and with excellent performance this is Eumetsat's nominal operational satellite at 0° longitude, performing the full-disc mission (one image every 15 minutes on 12 spectral channels), as well as data collection, data distribution and search-and-rescue missions.

MSG-3

MSG-3 completed the Integrated System Test (functional and performance verification of the satellite and all subsystems, including an Optical Vacuum Test). Testing will continue with the rehearsal of all launch site procedures. The launch window has been redefined as mid-June to mid-July 2012, meaning a departure for Kourou in April.

MSG-4

Disassembly of the SEVIRI Drive Unit is finished, and testing confirmed that the suspected part is indeed the cause of the problem. A new part is under manufacture.

→ MTG

Good progress has been made in addressing the issues raised at the MTG SRR. The objectives and detailed procedure for the MTG Baseline Design Review (BDR) have been established. Both these reviews have focused the industrial effort on defining and justifying a secure system baseline design for both MTG-I and MTG-S.

The Best Practice Procurement process is well under way, with more than 30 ITTs/RFQs released and approximately 15 procurement actions concluded. Of particular note is the selection of the schedule-critical instrument detectors and cryogenic coolers.

Finally, the introduction of Astrium Germany into the Core Team is now well advanced which should allow readiness for full contract signature with Thales Alenia Space France before the end of the year.

→ METOP

MetOp-A

The satellite and all remaining instruments continue to perform excellently in orbit. MetOp-A will complete its nominal five years of life on 19 October. Its operation has been extended up to the MetOp-B end of commissioning.

MetOp-B

The PLM, SVM and Solar Array (SA) have completed their acceptance test campaign at module level. The SVM and PLM have been mated in Astrium Toulouse and the SA is at Dutch Space, Leiden, undergoing the last steps before shipment to join the SVM and PLM and be integrated with them.

Final satellite level tests will include flight software verification and system verification tests combining the satellite with the Eumetsat ground segment for routine operations and with ESOC for the launch and early orbit phase (LEOP).

Launch preparation is progressing well, with the Final Mission Analysis Review fixed for December. Because of the Soyuz failure in August, the launch date has been rescheduled for 23 May 2012.

→ SENTINEL-1

Platform development by Thales Alenia Space Italy shows good progress. After the test campaign of the integrated avionics test bench, the Data Handling and Transmission subsystem has been fully integrated and is undergoing extensive tests.

With respect to the SAR instrument (Astrium, Friedrichshafen), the production of the antenna tiles is progressing, with six units out of the 14 in different stages of assembly and testing, including the FMs of the Electronic Front-End modules (Thales Alenia Space Italy) being delivered on time for integration. The FMs of the antenna mechanisms (deployment mechanisms and hold-down-and-release mechanisms) are already delivered, awaiting completion of the antenna structure assembly. The SAR electronics EM is under test in Astrium, Portsmouth.

Development of the Optical Communication Payload (OCP) is in progress. The OCP is provided to the Sentinel-1 programme in kind by DLR.

The launcher preliminary mission analysis with the launch service provider, Arianespace, is progressing according to plan for a Soyuz launch from Europe's Spaceport.

→ SENTINEL-2

The Sentinel-2 Multi Spectral Instrument functional and performance test campaign conducted on the instrument EM confirmed excellent radiometric performance for the Visible and Near Infrared and Short Wave Infrared detection chains.

The EM of the OCP that will be used to return instrument data to the ground processing centres through European Data Relay Satellites will be integrated with the Sentinel-2 EFM and functionally tested in November. The OCP is provided to the Sentinel-2 programme in kind by DLR.

Fully qualified protoflight models of the silicon carbide telescope baseplate and of the platform (integrating the propulsion system and the flight harness) were delivered to the instrument and satellite prime contractors. This allows instrument and satellite protoflight AIT activities to start. To this end, several equipment FMs were already delivered for integration, like the instrument Calibration and Shutter Mechanism (CSM) and the Solar Array Drive Mechanism.

Image quality activities conducted by CNES, including the Level 1c Ground Prototype Processor, are progressing nominally.

Sentinel-2 protoflight platform with propulsion and harness (CASA/Astrium GmbH)

The Sentinel-2 Payload Data Ground Segment prime contracts have begun. Following approval by the Industrial Policy Committee, contracts for the provision of two launch services will be negotiated with Eurockot (first satellite) and Arianespace (second satellite) before the end of the year.

→ SENTINEL-3

Sentinel-3 Phase-C/D development activities are proceeding regularly, with the CDR process completed, with the exception of the SLSTR instrument, where progress is being made. The SLSTR STM tests are ongoing. All the other instruments have now entered testing of their EMs, while the first set of FMs has already been manufactured. In the case of SRAL, the instrument with the highest level of maturity, both antenna FMs are already delivered.

At spacecraft level, activities are now concentrating on preparing the start of the AIT campaign. At platform level, after a successful integration readiness review of the Propulsion subsystem at the end of September, integration has started. In the meantime the satellite structure passed the Static Test and will be delivered to the platform contractor by the end of October.

Negotiation of launch service contracts for the Sentinel-3 A and B models has started, following assessment of the tenders and authorisation to proceed from the relevant management bodies.

→ SENTINEL-5 PRECURSOR

The Tender Evaluation Board was performed in August, and the IPC has authorised placing the Sentinel-5 Precursor Phases-B2/C/D/E1 contract with the team led by Astrium Ltd (UK).

Following a successful TROPOMI payload-level PDR held in May, Phase B/C/D is proceeding. Preparations for subsystem and unit-level PDRs are in progress.

→ SMALLGEO

An extension to the contract for the development of the SmallGEO geostationary satellite platform was signed on 29 September. The added features in this extension contract will optimise the SmallGEO platform for a number of different commercial satellite services beyond Hispasat AG1 mission. By expanding SmallGEO's capabilities, the costs of the entire platform as well as production and process costs will be reduced.

The SmallGEO mission CDR started in September, and will cover all aspects of the satellite, ground segment (LEOP and in-orbit tests), operations and launcher interfaces. The payload CDR is being held in parallel. It is due to complete in November, followed by the start of the system protoflight model manufacture and AIT. At unit level, the industrial team is already producing FMs. Meanwhile, both EM tests and STM manufacturing are progressing.

→ EUROPEAN DATA RELAY SYSTEM (EDRS)

A public–private partnership contract has been signed with Astrium. The first EDRS payload – a laser communication terminal and a Ka-band inter-satellite link – will be carried on the Eutelsat-9B satellite, built by Astrium and positioned over 9°E. The first of the two EDRS nodes will be launched in 2014. The second EDRS node will be launched in 2015 on a dedicated satellite built by OHB that will use the SmallGEO platform.

→ ALPHABUS AND ALPHASAT

The satellite mechanical test campaign has qualified the Alphabus platform for an Ariane 5 launch. The test campaign was completed in August. The TDP 5 (Q/V-band experiment) and TDP 6 (star tracker) FMs were delivered and integrated into Alphasat.

In the Alphabus Extension programme, the SRR was completed in September. On the Alphasat ground segment, a contract has been approved with Inmarsat on a network extension for multiple voice communication and data telemetry services.

Alphasat after mechanical test campaign

→ ARIANE 5 POST-ECA

The Ariane 5 Mid-life Evolution (ME) launch system PDR began on 31 August, a major milestone for the project. The review covers four PDRs (launcher system, upper stage, avionics and ground segment). The Rider-1 to Ariane 5 ME Phase-1 offer was received in July. The Vinci M4 engine test campaign is ongoing at the DLR Lampoldshausen facilities.

→ VEGA

Acceptance of the various launch vehicle stages has been completed in Europe for a shipment to Kourou. The remaining qualification reviews at subsystem level were completed (Roll and Attitude Control System, Telemetry Antennas, Flight Programme Software). On P80, the solid rocket motor, the close-out of the few remaining reservations to qualification is progressing.

The final mission analysis was held with the qualification flight 'passenger' representatives (LARES, Almasat and Cubesats) and preparations in Kourou began. The qualification flight trajectory was optimised for safety constraints.

The Flight Readiness Review was held on 13 and 14 October. Based on this review, ESA's Director General approved the start of the Vega qualification launch campaign, with Arianespace's operating staff providing support. The stages for the qualification launcher arrived in Kourou, French Guiana, on 24 October, and the launch campaign started on 7 November with the transfer of the first stage to the launch pad. The first launch is scheduled for January 2012.

ESA, Arianespace and ELV, the launcher production prime contractor, signed a contract in September for the production of four new Vega operational launchers. This contract complements the purchase of a first launcher in

A full-scale mock-up of Vega on the launch pad at Europe's Spaceport in French Guiana, after a dry-run rehearsal of the countdown in April an agreement signed last year within the framework of the Verta contract, covering the five launches that follow Vega's qualification flight.

The studies for the launch of LISA Pathfinder, using a Vega launcher from the Verta batch, started in September. The mission has a launch window of October 2013 to September 2014.

→ SOYUZ AT CSG

The test campaign on the Soyuz ST-B ground procedures was performed in June and the Post Test Review was held on 7 July. The Launcher System Qualification Review and the Mobile Gantry's Technical Qualification Post Test Review were held in August. The Qualification at System Level Review covering both versions of the launcher (ST-A and ST-B configurations) was concluded on 29 September. The Flight Readiness Review took place in July, giving a green light to start the first launch campaign on the ELS launch pad on 16 August. Soyuz ST-B assembly activities started on 12 September in the MIK building.

The Soyuz ST-B for flight VS01 Galileo IOV stands ready at Europe's Spaceport in French Guiana on launch day, 21 October 2011 (ESA/CNES/Arianespace/Optique Video du CSG)

The historic mating of the twin Galileo satellites, encapsulated in the Upper Composite, with the Soyuz launcher on 14 October

On 20 October, following an anomaly detected during fuelling of the launcher's third stage, the final countdown was interrupted. Soyuz and its two Galileo IOV satellites, along with the new launch facility, were placed in a safe mode. After work performed on the launch facility and the associated additional checks, Arianespace decided to restart the countdown operations for launch on 21 October.

Liftoff of flight VS01 Galileo IOV/Soyuz ST-B took place at 12:30 CEST on 21 October. All of the Soyuz stages performed perfectly and the Fregat MT upper stage released the Galileo satellites into their target orbit at 23 222 km altitude, 3 hours 49 minutes after liftoff.

→ FUTURE LAUNCHERS PREPARATORY PROGRAMME

Intermediate eXperimental Vehicle (IXV)

The industrial proposal for the Phase-D and early-Phase-E activities was evaluated and negotiated, allowing placement of a rider that ensures the continuity of the industrial activities from Phase-C to Phase-D/E in line with the planning. The IXV Phase-D/E1A for flight segment manufacture and ground segment procurement was also started.

Soyuz lifts off for the first time from Europe's Spaceport carrying the first two Galileo In-Orbit Validation satellites (ESA/CNES/Arianespace/Optique Video du CSG)

Next Generation Launcher (NGL)
In System Activities, the work on 'PPH-type' concepts (solid propellant for the first two stages, cryogenic for the upper stage) is progressing. The first main milestone (Key Point 1) took place in July. The following main objectives were achieved:

- for each of the four launch system concepts (HHSC, HHGG, PPH, CH), elements of definition of the launch vehicle concept were reviewed against the Mission Statement, along with proposed improvements (technology, architecture, staging);
- preliminary results of the boosted configuration were reviewed;
- proposed alternative technologies/architectures were reviewed and selected for study as concurrent activities in Phase-2.

The baseline for each of the concepts (technology, architecture, staging) was agreed and will be the starting point for the continuation of the Design Activities

A second rider, covering activities of the SCORE-D (Stage Combustion Rocket Engine Demonstrator) up to the PDR maturity of the demonstrator and its subsystem, was signed in June at the Paris Air Show.

In solid propulsion, the Pressure Oscillation Demonstrator activities are progressing with the Manufacturing Release Review (MRR). The industrial proposal for continuation of the activity post-MRR has been evaluated, and the technical and financial limits have been negotiated.

In upper-stage propulsion, the storable propulsion project is preparing the technologies needed for pressure-fed engines in the thrust category 3–8 kN. The work is progressing with the PDR held in June.

Industrial activities for Cryogenic Upper Stage Technologies (CUST) are progressing, with the CDR of the Versatile Thermal Insulation completed. The CDR of the Propellant Management Device (PMD) in-flight experiment, to be flown on a Texus sounding rocket, was completed.

→ HUMAN SPACEFLIGHT

On 6 August, the first real-time 3D video transmission from the ISS took place. NASA astronaut Ron Garan operated the ERB-2 (Erasmus Recording Binocular) camera to open a new window on the ISS through stereoscopic eyes, in high-definition quality. As Flight Engineer for Expedition 28 and a video blogger himself, Garan set up the futuristic-looking camera in Europe's Columbus laboratory. While talking about the work on the ISS, he enhanced the sense of depth and presence by playing with an inflatable Earth globe. The video can be seen on YouTube.

→ DEVELOPMENT/ISS EXPLOITATION

ATV *Edoardo Amaldi* was loaded on the vessel MN *Toucan* in Bremen harbour on 12 August. The ship arrived safely in Kourou on 25 August, where the ATV was unloaded. *Edoardo Amaldi* is planned for launch in early 2012. Two more ATV launches will follow in 2013 and 2014.

ATV *Edoardo Amaldi* being unloaded from the vessel MN *Toucan* in Kourou on 25 August

Expedition 30 will be the 30th long-duration mission to the International Space Station, starting in December (from left, Anton Shkaplerov, Dan Burbank, Anatoli Ivanishin, André Kuipers, Oleg Kononenko and Don Pettit)

→ UTILISATION

The AO for Climate Change Studies on ISS has been published in close cooperation with the Directorate of Earth Observation. The ISS can potentially be used as an additional observation platform for instruments and experiments relevant to global change studies, supplementing ongoing and planned observations from dedicated satellite platforms. The European Columbus module has an External Payloads Facility (CEPF) that has four payload attachment sites on the end of the module, permitting nadir, zenith and side (limb) viewing. The Cupola module has multiple windows and provides a location for operating internally mounted instruments.

European science and research facilities inside Columbus

The European Physiology Module (EPM) facility was activated on 9 August to run another session of the 'Passages' experiment by astronaut Ron Garan. 'Passages' is an experiment that studies how astronauts perceive and interpret what they see. It is presumed that the human brain has developed 'tricks' to make the processing of information from the retina as quick as possible. These 'short cuts' can, however, also generate misinterpretations, leading to common visual illusions. 'Passages' is designed to test whether any such illusions might occur due to weightlessness. The human brain may have evolved perceptual strategies or mechanisms that assume that gravity is always there.

European science inside Destiny

The Materials Science Laboratory (MSL) Solidification and Quenching Furnace was set up by Mike Fossum on 16 August for running the first samples for the 'Batch 2' experiments, which incorporate the second set of samples for the CETSOL (Columnar-to-Equiaxed Transition in Solidification Processing) and MICAST (Microstructure Formation in Casting of Technical Alloys under Diffusive and Magnetically Controlled Convective Conditions) experiments and the first set of samples for the SETA (Solidification along a Eutectic path in Ternary Alloys) experiment. The first Batch 2 sample was processed on 25–26 August.

Educational Activities

A Space Medicine Workshop was held at EAC from 4–8 July, with 28 students from ESA Member States. Experts from ESA, MEDES, NASA and CSA briefed the students on innovative ways to tackle cardiopulmonary resuscitation, artificial gravity and crew data management.

A Teachers' Summer Workshop 2011 was held at ESTEC in July with 40 teachers from ESA Member States, participating in hands-on activities and learning how to use ESA educational materials in their classrooms

André Kuipers' PromISSe mission logo

ESA astronaut Alexander Gerst during extravehicular activity training at NASA's Neutral Buoyancy Laboratory in Houston

→ ASTRONAUTS

The PromISSe mission of ESA astronaut André Kuipers (NL) was announced in two high-profile media events in EAC and ESTEC. This six-month mission will include 28 experiments to be carried out, and also an educational programme called 'Ruimteschip Aarde' ('Spaceship Earth'). After the Progress failure on 24 August, André Kuipers' launch on Soyuz has been postponed to 21 December.

ESA astronaut Alexander Gerst (DE) has been assigned to fly to the ISS on a six-month mission in 2014, serving as a flight engineer for Expeditions 40 and 41. Alexander is the second of the new group of European astronauts to be assigned to a mission. He will be launched aboard a Russian Soyuz spacecraft from Baikonur Cosmodrome in Kazakhstan in May 2014, returning in November.

→ CREW TRANSPORTATION AND HUMAN EXPLORATION

International Berthing and Docking Mechanism (IBDM)
The results from testing the new IBDM Soft-Docking System at the SIRRIS test facility of the University of Leuven (BE) confirm the feasibility of the chosen configuration. This is a step towards solving the incompatibility between the NASA and Russian docking systems.

International Architecture Development and Scenario Studies
A meeting of senior management representatives of the International Space Exploration Coordination Group participating agencies took place in August in Kyoto, Japan. A first version of the Global Exploration Roadmap (GER) was presented. This roadmap is the culmination of work by 12 space agencies during the past year to advance coordinated space exploration. The GER begins with the ISS and expands human presence throughout the Solar System, leading ultimately to crewed missions to explore the surface of Mars.

→ ROBOTICS

A contract with Dutch Space for the European Robotic Arm (ERA) was agreed until the end of October 2013. This contract will cover the activities related to the launch and on-orbit commissioning. An Interface Working Group was held in Moscow in September, where detailed agreements were made on integration of the Russian Multi-purpose Laboratory Module (MLM), communication between sites, operations definition, training and analysis for the qualification review for ERA on a Proton launcher. A new schedule has been established to take into account the launch delay from December 2012 to June 2013.

Artist impression of the European Robotic Arm, which will be sent to the ISS with the Russian Multi-purpose Laboratory Module on a Proton launcher in 2013

→ ESA PUBLICATIONS

Brochures

SpaceWire: Making Links, Building a Market (October 2011)
BR-298 // 8 pp
E-book online

Galileo IOV: Birth of the European Satellite Navigation Constellation (September 2011)
BR-297 // 16 pp
E-book online

The ESA History Project (February 2011)
BR-294 // 94 pp

Hylas-1: Europe's Highly Adaptable Broadband Satellite (November 2010)
BR-293 // 6 pp
E-book online

Sustainable Development 2009–10 Report, Executive Summary (November 2010)
BR-292/EN/FR/DE // 8 pp
E-book online

Cluster 2000–10: A Decade Revealing the Sun–Earth Connection in 3D (September 2010)
BR-290 // 6 pp
E-book online

Earth Explorers: Satellites to Understand our Changing Earth (May 2010)
BR-289 // 8 pp
E-book online

Newsletters

All About ESA: Space for Europe
EN, FR, IT, DE, ES, NL // 14 pp
No charge

Special Publications

GIOVE Experimentation Results (October 2011)
SP-1320 // 124 pp
Price: €30

Sustainable Development 2009–10 Report (January 2011)
SP-1319 // 72 pp
Price: €20

Conference Proceedings

Proc. 20th Symposium on European Rocket and Balloon Programmes and Related Research, 22–26 May 2011, Hyère, France (October 2011)
SP-700 // 683 pp (book)
Price: €60

Proc. 14th European Space Mechanisms & Tribology Symposium (ESMATS 2011), 28–30 September 2011, Constance, Germany (September 2011)
SP-698 // CD
Price: €50

Proc. 4th International GOCE User Workshop, 31 March – 1 April 2011, Munich, Germany (July 2011)
SP-696 // CD
Price: €40

Proc. 5th Int. Workshop on Science & Applications of SAR Polarimetry and Polarimetric Interferometry (PolInSAR 2011), 24–28 January 2011, Frascati, Italy (March 2011)
SP-695 // CD
Price: €50

Proc. DASIA 2011 Conference, 17–20 May 2011, San Anton, Malta (August 2011) SP-694 // CD
Price: €60

Proc. CryoSat Validation Workshop 2011, 1–3 February 2011, Frascati, Italy (June 2011)
SP-693 // CD
Price: €30

Proc. 7th European Symposium on Aerothermodynamics, 9–12 May 2011, Brugge, Belgium (August 2011)
SP-692 // CD
Price: €60

Proc. 9th European Space Power Conference, 6–10 June 2011, Saint Raphael, France (October 2011)
SP-690 // CD
Price: €60

→ HOW TO ORDER

Selected ESA publications and conference proceedings can be ordered online at **www.spacebooks-online.com**

ESA brochures* (BR-xxx)	available as 'e-books', online only.	
Periodicals and selected monographs	also available for download at no charge at:	**www.esa.int/publications**
ESA *Bulletin* subscriptions ***Annual Report* requests**	contact **esapub@esa.int** or write to	ESRIN Communication Office, Casella Postale 64, 00044 Frascati, Italy
Public relations material	(General ESA literature, posters, photographs, films, etc.)	ESA Communication Department 8–10 rue Mario Nikis, F-75738 Paris Cedex 15, France Tel: +33 1 53 69 71 55 Fax: +33 1 53 69 76 90

** under special conditions (e.g. for educational purposes) and on ESA approval, ESA brochures (BR-xxx) can be ordered as hard copies. Please contact us for these requests at* **esapub@esa.int** *or write to ESRIN Communication Office, Casella Postale 64, 00044 Frascati, Italy*

ESA Member States

Austria
Belgium
Czech Republic
Denmark
Finland
France
Germany
Greece
Ireland
Italy
Luxembourg
Netherlands
Norway
Portugal
Romania
Spain
Sweden
Switzerland
United Kingdom

An ESA Communications Production
Copyright © 2011 European Space Agency