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bulletin

→ space for europe

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European Space Agency

European Space Agency

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

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

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

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

The ESA headquarters are in Paris.

The major establishments of ESA are:

ESTEC, Noordwijk, Netherlands.

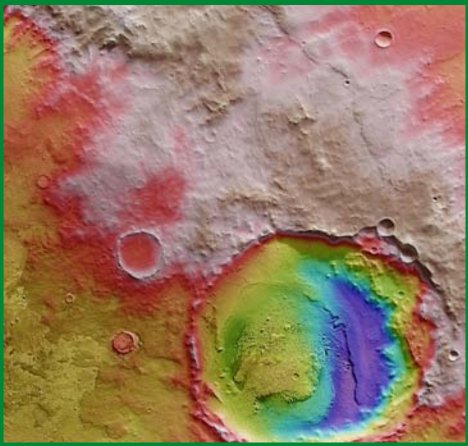
ESOC, Darmstadt, Germany.

ESRIN, Frascati, Italy.

ESAC, Madrid, Spain.

Chairman of the Council: D. Williams

Director General: J.-J. Dordain



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Schiaparelli is a large impact basin about 460 km across, located in the eastern Terra Meridiani region of Mars. The Mars Express image shows just a small part of the basin's northwestern rim cutting diagonally across the image and a smaller crater, 42 km in diameter, embedded in its rim (ESA/DLR/FU Berlin)

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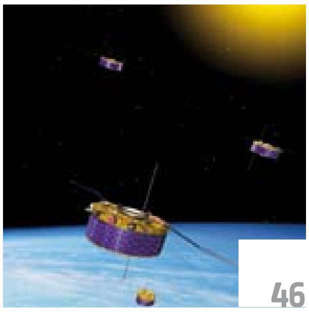
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"I hope that this famous portrait of Yuri Gagarin will witness again many more passages of astronauts and cosmonauts on board the spaceships of the future, including, hopefully, one that will take humans towards Mars."
– Jean-François Clervoy

→ "I SEE EARTH! IT IS SO BEAUTIFUL!"

The first human in space: Yuri Gagarin

Carl Walker
Directorate of Legal Affairs and External Relations, ESTEC, Noordwijk, The Netherlands

"The world's first spaceship, Vostok, with a man on board, was launched into orbit from the Soviet Union on 12 April 1961. The pilot space-navigator of the satellite-spaceship Vostok is a citizen of the USSR, Flight Major Yuri Gagarin."

To the world of 1961, this was an electrifying announcement, made while Gagarin was still in space. The Americans were stunned, but the congratulations they sent to Moscow were genuine. This historic 108-minute flight, orbiting once around Earth, made Gagarin the first human in space, and an international hero. He was only 27 years old.

His feat was amazing at the time. NASA rushed to get an astronaut into space and, in May 1961, Alan Shepard became the first US astronaut, albeit making a suborbital ballistic flight. It wasn't until the next year that a US astronaut flew in orbit, when John Glenn circled Earth aboard Mercury *Friendship 7* in February 1962.

Two days after the return of Vostok 1, Gagarin was back in Moscow, where he appeared on the balcony of the Kremlin with Premier Nikita Khrushchev. Forty-eight hours earlier, he was unknown; now he was arguably the most famous man on Earth. He embarked on a worldwide tour during which cheering crowds greeted him wherever he went.

↓ After the flight, Yuri Gagarin at the Kremlin with Soviet leaders (*Life*)

↗ Gagarin signs an autograph in Budapest, Hungary (B. Sándor)

→ Gagarin during a tour of Moscow (**old.moskva.com**)

← Gagarin visited European countries including UK, here with Prime Minister Harold McMillan in London (*Life*)

Gagarin's international visits were extraordinary because they came at the height of the Cold War. Here was someone who could travel not only between Earth and space, but also between the open and closed worlds of the east and west.

↓ Gagarin later famously met US astronauts Ed White and James McDivitt at the Paris International Air Show in 1965. Also shown are US Vice President Hubert Humphrey (seated) and French Premier Georges Pompidou (NASA)

Ideological differences were momentarily forgotten as this man was hailed a hero around the globe.

Gagarin never flew in space again. After touring, he returned home to Star City to continue his work in the Russian space programme. He was in training for an early flight of the new Soyuz spacecraft in 1967, but was grounded by senior space managers who did not want to risk the life of a Hero of the Soviet Union in another hazardous mission. It is even more of a tragedy then that Gagarin should lose his life during a routine training flight on 27 March 1968, when his plane crashed and he and his instructor were killed. His ashes were placed in the Kremlin Wall and a lunar crater and asteroid 1772 Gagarin are named in his honour.

What is Gagarin's legacy?

Space is an inspirational subject and human spaceflight in particular has motivated many young people to follow careers in science and engineering. Space now affects our everyday lives and makes an important contribution to the economies of the world. This is the legacy of the early days of spaceflight, but it is often also associated with Yuri Gagarin and the astronauts who followed him.

Yes, it is true that space now touches many aspects of our daily lives – from the vital role it plays in monitoring our

planet and protecting the environment, to the technical advances that space exploration has brought to materials science, computing, engineering, communications, biomedicine and many other fields.

Satellites are now able to show us our home planet in extraordinary detail and tell us about the way that we are changing it on local and global scales. Spaceprobes have made landings on distant planets, moons and asteroids and are even now journeying to the very edge of our Solar System. Orbiting astronomical telescopes have given Earth-based scientists insights into the creation of life and of the Universe itself.

But the fact is the Space Age was already well under way in 1961. Scientists and engineers were already making discoveries and inventing new technologies for spaceflight. By the time of Gagarin's flight, the Soviet Union and the USA had made over 100 launch attempts, and both had succeeded in putting satellites in orbit and sending probes out into interplanetary space.

Since the launch of the first artificial satellite Sputnik in October 1957, the Soviet Union had notched up a set of 'firsts'. They placed the first living creature, the dog Laika, into space in November 1957 and sent Luna 1 to pass close to the Moon in January 1959. Luna 2 would be the first probe to impact the Moon in September 1959 and Luna 3 the first to photograph its far side in October the same year. In February 1961, Venera-1, the first truly planetary probe, was launched toward Venus – an important milestone in spacecraft design.

↓ A plaque in memory of Yuri Gagarin, presented to General Kuznetsov, commander of the Star City training centre, by Dr George M. Low, acting Administrator of NASA, in a ceremony in Moscow in 1971 (NASA)

→

The image of Gagarin lives on in most current space activities: from left, the crew of STS-76 and Soyuz TM-23 on the Mir space station in 1996; Alexander Kaleri, Mike Foale and André Kuipers on the ISS in 2004, and the Mars500 crew in 2010

On the American side, progress was equally impressive. Explorer 1 was launched in January 1958, and besides being the first US satellite, it is known for discovering the Van Allen radiation belts. This success was quickly followed by other satellites, notably the first communications satellite SCORE, also launched in 1958, and Pioneer 5, the first scientific probe around the Sun, launched in March 1960. TIROS-1, the first weather satellite, and Transit, the first operational navigation satellite, were both launched a month later.

In Europe, scientists from 10 countries, the 'Groupe d'etudes europeen pour la Collaboration dans le domaine des recherches spatiales' (GEERS), had already set up a commission at which governments would decide on possibilities for European cooperation in space. By 1961, the 'Commission préparatoire européenne de recherches spatiales' (COPERS) was defining a structure for the envisaged European Space Research Organisation.

So what, then, could be Gagarin's legacy? Until pictures of Gagarin appeared in the news, there were no real 'space heroes' for the public to identify with. The scientists and engineers working behind the scenes rarely appeared in the media. In the west, youngsters had comic book characters, science fiction and could aspire to be jet pilots. The US Mercury astronauts, although appearing in magazines such as *Life* since their selection in 1959, had yet to prove themselves.

With Gagarin came the first human face for space exploration. The photographs of this brave, helmeted space explorer became iconic of the 20th century and defined the image of the cosmonaut, much like the picture of Buzz Aldrin on the Moon in 1969. The thing that most people remember about Gagarin is his smile. The images of his smiling face would humanise space for the public, and they would also give a human quality to the Soviet society at that time.

The Soviet authorities chose their first man well. It would appear that they were also looking beyond the spaceflight, namely to make Gagarin an ambassador for the Soviet Union. Certainly the pictures of the first human space explorer transcended political differences and caught the imagination of people around the world. Gagarin projected the image of confidence, professionalism, team spirit, modesty, bravery, leadership and concern for others, like that of his American counterparts (all had the same background as military jet pilots, so this was not surprising). These qualities became forever associated with cosmonauts and astronauts and still inspire today.

But more importantly, during the flight of Vostok 1, Gagarin was the first human being to see Earth from space. With so many images of Earth from space now available, it is hard to

Prof. John Zarnecki

Principal Investigator of the Surface Science Package on ESA's Huygens probe that landed on Titan in 2005

"...I really became hooked on space exploration in 1961 and had a chance encounter with this man – Yuri Gagarin – the first man in space and overnight the most famous man on Earth. London was the first place he'd come on his world tour and I was standing a few feet from him in Highgate cemetery. He was dwarfed by his military cap and he stood there saluting the tomb of Karl Marx. I was thinking, 'Bloody hell, he's been into space.' If I had a eureka moment about wanting to be an astronaut, that was it."

imagine how it felt to be the first person to view Earth from that perspective. This one aspect of his flight was so significant, transforming it from an impressive technical achievement to a milestone in human history. Could this be his legacy?

More than 500 people have travelled into space since, representing over 30 countries. Like Gagarin, most of them came back from space with a changed viewpoint and reverence for planet Earth. They describe seeing a world with no political boundaries, no borders between countries.

For a few months, Gagarin was the only person on Earth to have had such a unique view of our planet. He was struck by its beauty and fragility, and realised it was humankind's duty to protect it. For a flight that lasted only one hour and 48 minutes, one orbit of Earth, it provoked important political, social, cultural and technical changes, and forever altered our perspective of our place on Earth.

Fifty years on

When Gagarin was launched to become the first human in space, his first words after lift-off were 'Poyekhali!', Russian for 'Let's go!' The phrase takes on a different meaning 50 years later, with most of the world's space agencies now discussing a common strategy for peaceful human and robotic space exploration, focusing on destinations within the Solar System where humans may one day live and work.

Sustainable space exploration is an opportunity for all humankind, and a challenge that no single nation can meet on its own. During the International Astronautical Congress held in the Czech Republic last year, leaders in space exploration spoke the same words: international cooperation. ESA's Director General Jean-Jacques Dordain said the importance of Gagarin's flight was hard to overestimate. "His deed belongs to the history of mankind and world history of cosmonautics. It's good that 12 April is no longer celebrated only in Russia, but now celebrated all over the world to demonstrate that Gagarin was not just a Soviet citizen but a citizen of planet Earth. Space and human spaceflight in particular have been the drivers for a specific vision, which is, that our future is global. In the next 50 years, we'll see increased partnerships. We are going there, whether the Moon or Mars, together."

Paolo Nespoli, ESA's astronaut now on the ISS for his six-month MagISStra mission, was only four years old at the time of Gagarin's flight. With the ISS partners, including ESA, tackling new ways to increase and optimise flight opportunities for Europe to the ISS beyond 2015, Nespoli is enthusiastic about the future of space exploration, "The first person who will travel to Mars has already been born." ■

Further reading

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- http://yurigagarin50.org
- http://www.federalspace.ru
- http://www.esa.int/history

→ Gagarin's legacy

Vladimír Remek

Member of European Parliament
Czech cosmonaut, Soyuz 28
First European in space

"For me, then a 13-year-old boy who longed for adventure, discovery and accomplishment, the first human flight into space was an extraordinary experience. It was, however, also an impulse. I was aware that something very special had just happened, but only over the years have I come to understand the significance of this event as an important milestone in the history of humankind. The orbital flight of Yuri Gagarin gave me motivation and helped make my childhood dream come true. After only 17 years, I was given the opportunity to follow Yuri Gagarin and 86 other Soviet cosmonauts and American astronauts. Only 50 years since this first step, 'space flying' is today an ordinary phenomenon for us. Its face, however, will always remain that of Yuri Gagarin."

Ulf Merbold

ESA astronaut, STS-9, STS-42,
Soyuz TM-20
First ESA astronaut in space

"This has to be compared to the voyage of Christopher Columbus. For the Russians it had tremendous political meaning but, for Gagarin himself, it cannot be rated high enough in terms of courage. He was only 27 years old, but he must have understood what he was letting himself in for, to be strapped to a rocket and not know if he would come back. Like John Glenn, the first American to orbit Earth, he became a political figure and was forbidden to fly again in space. Glenn later flew on the Shuttle, but Gagarin sadly never got another chance to do what he really loved. So, his flight really was unique."

Frank De Winne

ESA astronaut, Soyuz TMA-1,
Soyuz TMA-15
First European ISS commander

"Fifty years ago, Yuri Gagarin was the first human being to fly in space. Having flown into space from the same launch pad at Baikonur, Kazakhstan, it continues to amaze me what we are capable of as human beings, and also what a tremendous achievement it was in 1961, with the state of technology at that time, and what tremendous courage Yuri Gagarin must have had to sit on top of Vostok 1."

Dr Helen Sharman

British astronaut, Soyuz TM-12
First Briton in space

"Yuri Gagarin was given the international crown for inspiration. Wherever he went, crowds of people thronged the streets to catch a glimpse of the person who embodied the abilities of fellow humans, the bravery of exploration, and the desire to discover what is new. On my last night in space, reflecting on my time, I realised that being away from Earth reinforced what my Russian friends had told me on the ground – what's important is personal relationships and what people can do together. Space is grand and being part of it makes people feel grand."

Christer Fuglesang

ESA astronaut, STS-116, STS-128
First Swedish astronaut

"I was only four when Gagarin became the first human to fly in space, however, I soon learnt of his flight – an extraordinary and inspirational event. He orbited Earth in one and a half hours, news of his flight rounded the world in a day and he toured the world in the following years. This was one of those remarkable moments that will forever shine in the history of humankind and it has undoubtedly inspired millions, probably billions, of people during the 50 years since, and it will continue to do so."

Pedro Duque

ESA astronaut, STS-95,
Soyuz TMA-3
First Spanish astronaut

"The more I learned about space in my years of training, the more I admired the tremendous effort put into conquering space for the first time. Courage was needed to ride those first rockets, and Gagarin had a lot of it. He was the only visible representative of thousands of brilliant Soviet engineers, forever remaining unknown because of the secrecy of their work. Even their Chief Engineer, Sergei Korolev, was shaded from the outside world. In contrast, Gagarin was photographed to exhaustion, shown everywhere and used as a symbol of the Soviet Union. I can only start to imagine the pressure he endured, again with courage. We astronauts admire Gagarin, his picture posted inside our Space Stations, not only because he flew first, but also because we know a little what his life was like."

Reinhold Ewald

ESA astronaut, Soyuz TM-25

"When I first arrived at Star City in 1990, the enormous statue of Yuri Gagarin in the middle of the site seemed to be part of the Soviet propaganda. But when I got to know the people, some of whom actually witnessed this event, I quickly learned that there was indeed a pride of having achieved this dream of centuries past, but in the best sense and as an invitation to ALL others that followed, not only to the glory of just one country. While I was going through the demanding training, this feeling of following in the footsteps of a great historical breakthrough was a constant source of renewed motivation for me. I still have this feeling, after more than 20 years, especially whenever I stand at the same place at the foot of the Gagarin monument."

Claude Nicollier

ESA astronaut, STS-46,
STS-61, STS-75, STS-103
First Swiss astronaut

"When I look at pictures of Yuri Gagarin, before and after his flight, I am really impressed by the visibly strong personality and courage of this 27-year-old man. Life was not easy in his childhood, but he had the passion for flying machines and the drive for achievement, and demonstrated uncommon will and talent in so many disciplines relevant to space travel that he was the natural choice for opening this new frontier. Gagarin is a tremendous source of inspiration for all cosmonauts and astronauts today. He is an extraordinary role model for young men and women, and will always remain so for future generations..."

Michel Tognini

ESA astronaut, Soyuz TM-15, STS-93
Head of European Astronaut Centre

"Gagarin's flight came at the start of the space race of the 1960s, when space exploration was shackled by political competition. But Gagarin will always be the 'face' that symbolises pioneering spaceflight even though by the time I flew, things had already changed. It is now all about international cooperation, about what our various space agencies can achieve together for the benefit of mankind."

"Circling Earth in my orbital spaceship I marvelled at the beauty of our planet. People of the world, let us safeguard and enhance this beauty – not destroy it!"

→ Celebrating a human reaching outer space

Dmitri Dorin Prunariu
Romanian Space Agency
Romanian cosmonaut, Soyuz 40

The moment he reached outer space, Yuri Gagarin became a symbol for all humankind, regardless of the competition between the great powers or the political motivation for his launch into space.

From the cosmic heights, planet Earth appears as a unique entity, revealing itself to be more profound than the differences and intrigues that exist on its surface. Gagarin opened the way for at least 500 representatives of 'Terra' in the 50 years following his spaceflight.

Having become men of the Universe, having understood the globalism of terrestrial matters and the necessity for cooperation in, and promotion of, the uses space, going beyond national borders, even before the fall of the Berlin wall, a number of these outer space explorers founded their own planetary professional association, the Association of Space Explorers (ASE). At present, having over 300 members from 35 states, ASE represents a model of international understanding and cooperation in this special and inspirational field of space exploration.

Twenty years after Gagarin's spaceflight, I was fortunate enough to have had the chance to become the 103rd explorer of outer space, to subsequently take part in the foundation of ASE and to now lead its European branch. So, let us celebrate Gagarin, let us celebrate the 50th anniversary of a HUMAN BEING reaching outer space.

→ 'I met Yuri Gagarin in space'

Jean-François Clervoy
ESA astronaut, STS-66,
STS-84, STS-103

Yuri Gagarin will remain as the first Earth explorer of space that all astronauts and cosmonauts recognise in one form or another. He opened the door to space travel for humankind. Of course, he was not the first living being to venture into space, but he was the first one to be able to describe and recall, with the intelligence that characterises mankind, the emotions and sensations experienced in the very special environment of space.

One should not underestimate the importance of his first words sent from space, "I feel well." The mission controllers on the ground anxiously awaited these first words. Would the first representative of humankind be able to survive this flight and present space in a way that would be acceptable to the rest of us on Earth? Or would he suffer so much that it would forever break our will to make fantastic trips to the Cosmos?

On the STS-84 mission of the Space Shuttle *Atlantis*, in May 1997, I stayed nearly five days on the Russian Mir space station. When you enter of the core module of Mir, you could not be unaware of the photo of Gagarin. He held court over the living quarters where the crew met several times a day for meals, break times or sometimes repairing various instruments on the central dining table that occasionally doubled as a do-it-yourself workbench.

Gagarin dominated also the access to the two sleeping berths on either side of this dining room. He was accompanied by a photo of Tsiolkovski, the visionary father of astronautics in Russia. The serene but concentrated look of Yuri characterised the professional attitude of the first explorers of space. His calm face indicated his mission of peace. He had become a universal icon in the history of the conquest of space.

I could not remain indifferent to this black and white portrait that had already travelled on preceding Russian space stations, the yellow edges of which evoked the successive events and incidents experienced by generations of space explorers. I had to bring back a memory of this legendary face that I had the honour to mix with during about one hundred Earth orbits, with the admiration and respect that I felt towards the first pioneer of the Cosmos.

Astronaut Mike Foale immortalised these instances for me with his Nikon F4 camera the day before of our departure from the Russian station. The photo unites my family with our hero of human kind.

I hope that this famous portrait of Yuri Gagarin will witness again many more passages of astronauts and cosmonauts on board the spaceships of the future, including, hopefully, one that will take humans towards Mars.

→ On the trail of Gagarin

Thomas Reiter
Executive Board of the German Space Agency (DLR), ESA astronaut, Soyuz TM-22, STS-121

This was one of the most remarkable events of the century. We always see these firsts as something very remarkable, for example when climbers reach the top of very high mountains, or pilots make the first flight of a new aircraft. In this sense, Gagarin really opened an era.

Humans have been looking towards the skies for centuries, and were fascinated by space, and at every moment there has been a longing to see what is really out there. Even though our understanding of the Universe has changed over thousands of years, I am absolutely sure there has been the same desire to see what is behind this 'black curtain' that comes up every evening. With Gagarin, we got a little bit closer to seeing for ourselves.

The Universe is infinite, and human spaceflight is a very difficult endeavour, but at least this was the first step. I consider his flight to be a kind of relief that, finally, after such a long time, it was possible to overcome the gravity of our planet, to have the technology available to go into space.

I don't remember it well, because I was just short of three years old in 1961, but later I saw this as a fantastic endeavour of human beings. My father was a keen glider pilot and I can say that I partly grew up on the glider field close to our home. My mother also flew gliders until a few months before I was born. From being told about flying gliders and planes and then the logical step of someone flying in space, I started to follow the US Gemini and early Apollo missions from 1966 onwards.

↓ In a Russian tradition, Paolo Nespoli is blessed by a priest before the MagISStra mission in December 2010

↑ Cady Coleman, Dmitri Kondratyev and Paolo Nespoli sign the visitor book in Gagarin's office at Star City

But I was definitely influenced by this first step of going into space, and later in my career the influence of Yuri Gagarin continued. When I was training in Star City near Moscow, I had the chance to meet Gagarin's wife – she was still living there at the time.

You always talk about Star City and Gagarin in the same sentence (the Russian cosmonaut training facility is called the Y.A. Gagarin Cosmonauts Training Centre, GCTC). There is a museum full of items from his training and his actual spacesuit. There is a room where he had his former office, where every crew goes before leaving Star City for Kazakhstan for a flight. They are left alone to write a few words in a visitor's book, and each crew since then has done this little ceremony.

When you look at the Soyuz capsules we flew in, there is an impression of those early days of spaceflight. For me, when I was on the Euromir '95 mission, this impression was very evident and it always reminded me that this was what it must have been like almost 40 years before. If you compare a Shuttle launch to a Mercury or Gemini, they are very different. Of course the rocket engines, the structures, the guidance and avionics and so forth are new developments in the Soyuz, but they are still very robust and the general appearance of my spacecraft and launcher was similar to Vostok. It felt similar, or at least you imagined that it was similar.

You notice this at the beginning of your training, but also very strongly when you are on your way to the launch pad. The Russians have some rituals before a launch, and on the way to the launch pad you make a stop where you can, for the last time before launch, decrease your weight a little. Cosmonauts do this because Yuri Gagarin had such a stop before he arrived at the launch pad. With things like that, you are reminded at every point that you are on the trail of this person who opened the space age for humankind.

ATV *Johannes Kepler* being readied for flight at Europe's Spaceport at Kourou, French Guiana

→ SETTING SAIL FOR THE ISS

ATV *Johannes Kepler* readies for flight

Nico Dettmann & Charlotte Beskow
Directorate of Human Spaceflight, ESTEC, Noordwijk, The Netherlands

Now in the final stages of its launch campaign, the second Automated Transfer Vehicle *Johannes Kepler* will start its voyage to the International Space Station this February.

Almost three years have passed since the maiden flight of ESA's Automated Transfer Vehicle (ATV), one of Europe's main contributions to the International Space Station (ISS). Whereas a two-year gap was planned from the beginning of the project, to allow adequate time for the implementation of post-flight analysis results, some equipment production problems and launcher availability issues led to the slightly later-than-planned launch date in February 2011.

The post-flight analysis came up with 130 recommendations: about 30 were taken up by the project, some of them representing significant design modifications. The most important ones were the redesign of the pressure regulator, the redesign of the multilayer insulation of the ATV outer skin and several improvements in the flight application software, which were mainly to allow easier operations at the ATV Control Centre (ATV-CC) at the premises of the French space agency CNES in Toulouse.

In addition, several modifications have been implemented to finalise the generic ATV qualification, and to increase the upload performance of the ATV.

Both the ESA ATV team and the industrial set-up have changed significantly during the transition from a 'proto-flight development' to a recurring production project. The ESA team moved from Les Mureaux in France back to ESTEC in the Netherlands, and the industrial prime contractor responsibility moved from Astrium Les Mureaux to Astrium Bremen, Germany.

The ATV Control Centre has not only implemented numerous lessons learned from the ATV *Jules Verne* post-flight analysis, but also has undergone a major refurbishment of the infrastructure in order to adapt the new standards, as well as a significant exchange of key personnel in the operations team.

The ATV *Jules Verne* flight was a major success. Nevertheless, it was a challenging task to arrive at the point of launch readiness for ATV *Johannes Kepler*, and excellent work by all involved parties and the ATV team spirit of cooperation was a prerequisite for this achievement.

The planned launch rate of one ATV per year over the next four years will be the next challenge after ATV-2, and we should not be misled that one successful launch and the low 'production' rate means smooth and mature processes in all areas. Constant high levels of attention and continuous improvement will be required.

Owing to the slightly increased launcher performance since the ATV *Jules Verne* flight, *Johannes Kepler* will be the heaviest spacecraft ever launched by ESA. After the retirement of the Space Shuttle in 2011, ATV will gain a particular role for the ISS and the international partnership.

ATV has the largest upload capability of all ISS visiting vehicles, and it is the only vehicle besides the Russian Progress that can provide refuelling, attitude control and reboost functions.

Before the new US commercial resupply service vehicles become operational, timely ATV launches are key for the logistic supply of the ISS and its crew. In this respect, the international partners are counting strongly on ESA's reputation for reliability. Failure could result in the need to reduce ISS crew sizes and would therefore affect the utilisation of the ISS.

→ The ATV Control Centre (ATV-CC) at the CNES premises in Toulouse

The challenge of operating ATV is not just technical. With so many parties involved, planning and coordination is of utmost importance. A large effort is devoted to organising the operational interfaces with the partners. Dedicated multi-element procedures describe exactly what each controlling party does and how they report their status to each other. This is vitally important to avoid misunderstandings.

The flight of ATV *Johannes Kepler*

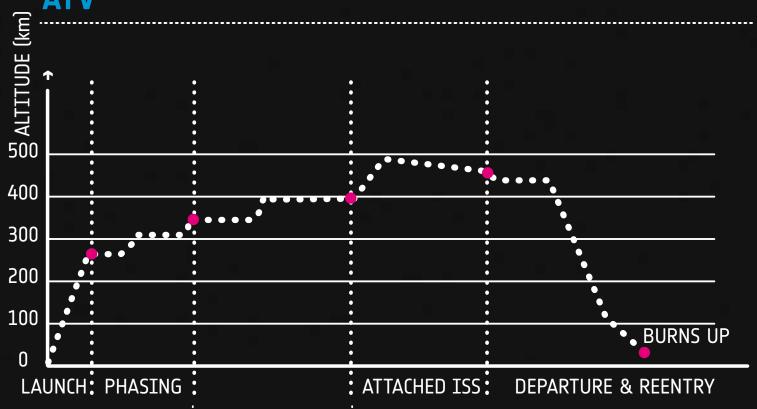
The ATV will separate from the Ariane 5ES rocket's upper composite when it reaches its 260 km circular orbit at the same inclination as the ISS orbit of 51.6 degrees. From this point on, the ATV's challenging mission will be controlled from ATV-CC in Toulouse. During the next part of the flight, an eight-day phasing period, the ATV uses the GPS system for navigation. Data communication between ATV-CC and ATV can follow one of two different paths, either via the NASA TDRSS system or via the ESA Artemis satellite.

← View of ATV *Johannes Kepler*'s nose, with rendezvous systems and docking probe (under red protective covers), almost as it will be seen by the ISS crew when it arrives at the Station

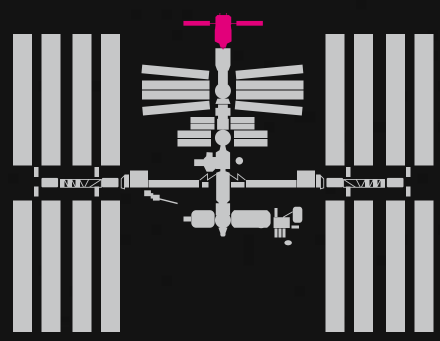
After the phasing, the rendezvous phase will be initiated at a distance of 30 km from the ISS. From here, the ATV software performs the guidance, navigation and control functions autonomously. The ATV-CC performs health checks at pre-defined hold points and authorises the go-ahead for the subsequent automatic approach sequence.

A third communication path is also activated when ATV arrives at the 30 km rendezvous starting point: the radio frequency link with the ISS. The Russian Zvezda service module on the ISS will transmit Russian GPS receiver data via this link to the ATV. The ATV's guidance, navigation and control software calculates the vehicle's position relative to the ISS, based on at least four GPS satellites as seen by both the ISS and the ATV. As soon as ground controllers can confirm that the relative GPS function has been properly established, the 'Go' for rendezvous will be given.

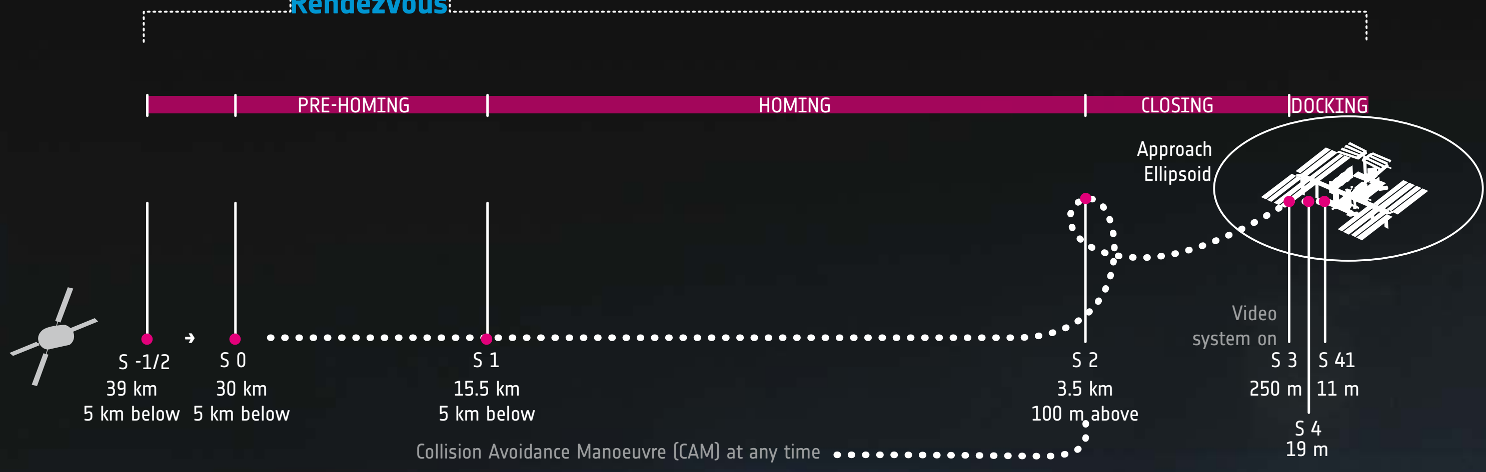
ATV



Position on the ISS



Rendezvous



→

SIMVOL image showing ATV *Jules Verne* closing on the ISS. The image was transmitted from the ISS to MCC-M and then to ATV-CC

A series of manoeuvres will bring the ATV to the first hold point at 3.5 km from the ISS. Once authorised to proceed, ATV will move closer to another hold point, at 250 m from the ISS. At this point, ATV will switch over from relative GPS navigation to relative 'videometer' navigation. The videometer is based on imaging sensor technology, where a laser light source is used to illuminate a target on the Zvezda module. The resulting image is then processed by the ATV's software to provide range, line-of-sight angles and relative attitude. This system will be used up to the docking.

From the 250 m hold point, the ATV will move in a straight line towards the ISS with another two hold points at 19 m and 11 m. At each hold point, the vehicle stops, allowing time for ground controllers and the ISS crew to assess all the ATV's systems and behaviour before authorising the next step. In total, the rendezvous takes roughly three and half hours.

As it approaches the ISS, the ATV provides a regular stream of data for the Station. Selected parameters are displayed either on the crew's laptop computer or on a monitoring display called SIMVOL. In addition, a Russian system installed on the ATV ('Kurs') provides independent range and range-rate data. For ISS safety reasons, the crew has the capability to intervene in case of problems.

The ATV will dock to the Zvezda module at the aft end of the ISS. The Station has no window facing out in this direction, but the crew can observe the ATV approaching the ISS via a camera mounted at the end of the Zvezda module. The camera is aligned with a target on the ATV, providing the crew with necessary visual information. With this video image, the Kurs and the ATV's own range and range data, plus other important parameters from ATV and ISS all displayed on the SIMVOL, the crew are also an independent authority to assess the safety of the operations.

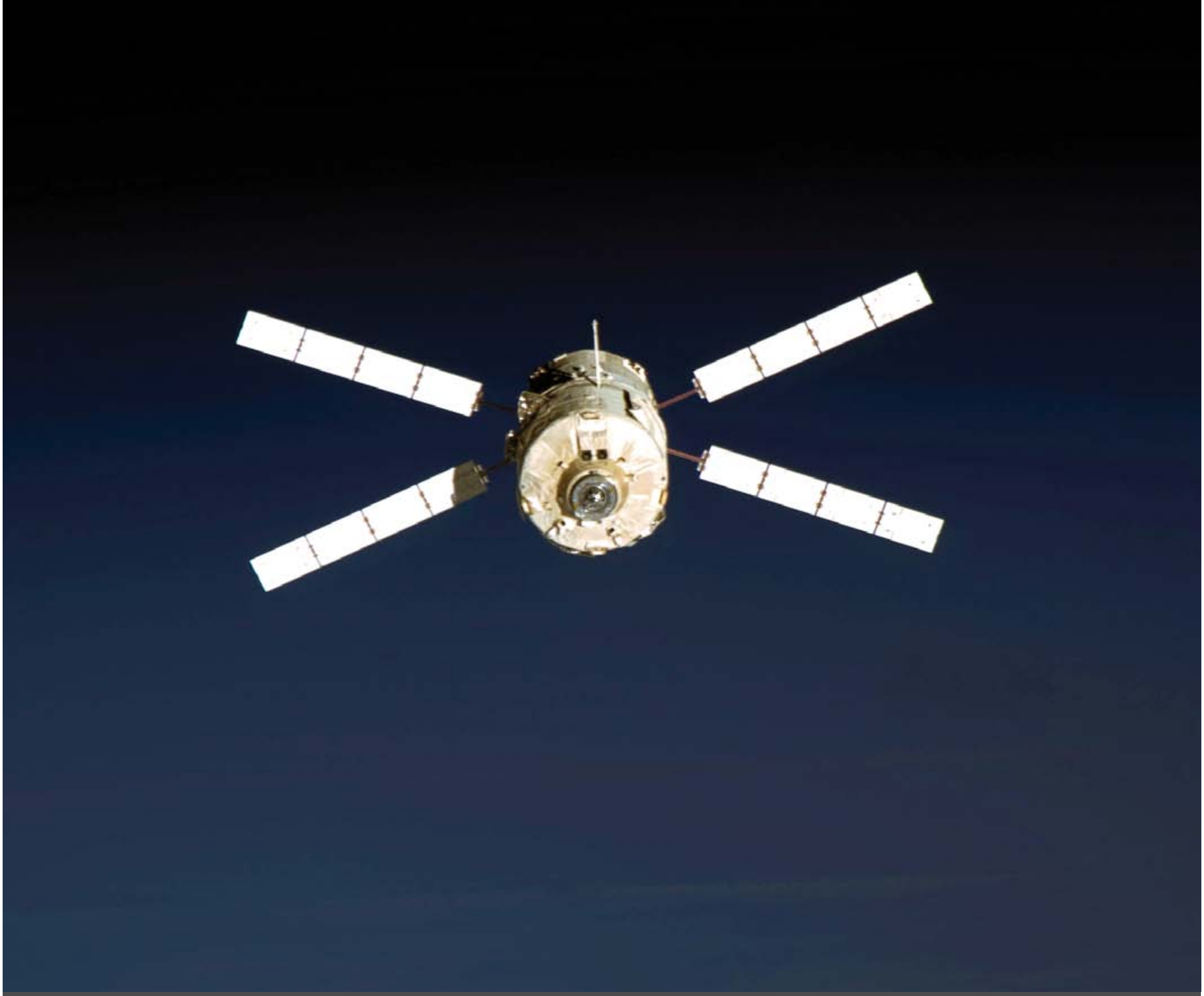
The docking phase starts as soon as the ATV's nose probe touches the inside of the docking cone. The docking system automated sequence controls this phase, which includes the retraction of the probe to bring the two vehicles close enough to close the hooks, and the connection of fluid, electrical and data interfaces. The communication via the radio link is stopped and the data are transferred to the 1553 bus link. The docking occurs at a relative speed of about 7 cm/s. ATV *Jules Verne* met the docking port centre point with a precision of 10 cm.

After concluding the mechanical part of the docking (hooks closed and probe retracted), the electrical/data connection and fluid connections take place. As soon as all interfaces are established, the hatch can be opened and the crew can enter the pressurised part of the ATV.

During the attached phase, the ATV is treated as part of the Russian segment. Attached phase operations, such as ISS reboost, attitude control and ISS refuelling, are piloted by Moscow, via the computer in the Zvezda module. The ground controllers in Toulouse ensure that the vehicle is in the correct configuration for the intended operation and then can monitor progress.

↓ ATV *Johannes Kepler* is now being 'tanked up' with fuel at Europe's Spaceport in Kourou

↓ ATV *Jules Verne* seen docked to the aft end of the ISS Zvezda service module



↑ ATV *Jules Verne* in flight in 2008

The cargo

ATV *Johannes Kepler* will carry four types of propellant for two purposes. More than 4000 kg are used by the ATV propulsion system (eight tanks carrying monomethylhydrazine fuel and nitrogen tetroxide oxidiser with mixed oxides of nitrogen). This propellant is used during the attached phase and controlled by the Russian Zvezda module computers for three functions.

Out of the 28 ATV attitude control thrusters, 12 are used to perform ISS attitude control. Russian experts at the Mission Control Centre Moscow (TsUP or MCC-M) calculate the exact manoeuvres to be performed (which thrusters are to be used and what would be the change in speed caused by each thruster). The commands are uplinked from MCC-M and are then executed by the Zvezda computer.

One of the main mission tasks of ATV *Johannes Kepler* is to raise the ISS orbit by about 40 km in order to reduce the residual atmospheric drag experienced by the Station. This stepwise manoeuvre will be performed using two of the four 500 N main engines. If needed, the

↓ NASA and ESA engineers in the Cargo Bench Review for ATV *Jules Verne* in Turin, Italy

ATV can also be used to perform ISS debris avoidance manoeuvres, a capability that was demonstrated during the ATV *Jules Verne* mission.

↑ ATV *Johannes Kepler*'s Integrated Cargo Carrier ready for mating with the spacecraft's Propulsion Module, with the various tanks for fuel, water and gas cargoes visible

→ ATV dry cargo is packed into special bags. Each bag is stowed on a specific shelf and each rack shelf has a unique location code. Items inside the bags have barcodes and each bag also has a barcode label. This allows the planners on ground to keep track of the various items on board the ISS

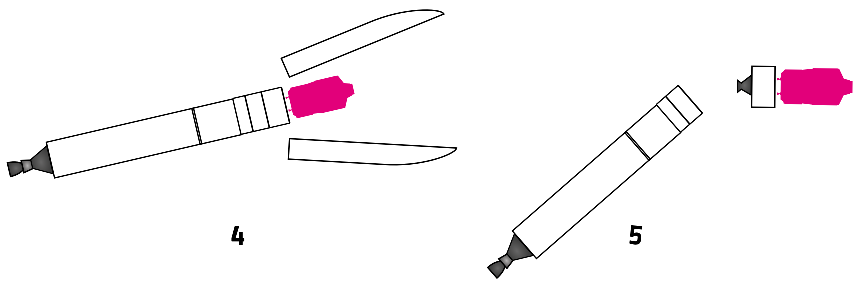
The ATV carries a further 860 kg of Russian refuelling propellants (nitrogen tetroxide and unsymmetrical dimethylhydrazine), which will be transferred into the tanks of the Russian Zarya control module (also known as FGB, which stands for the Russian abbreviation of Functional Cargo Block).

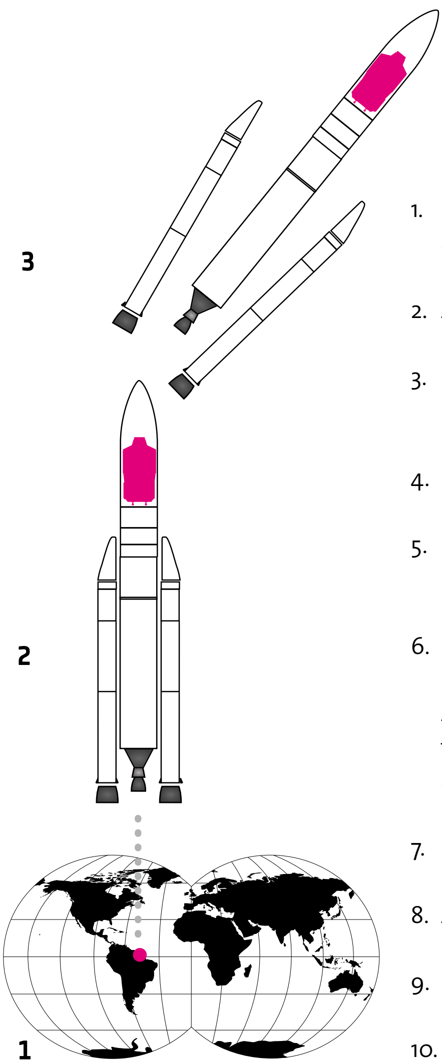
This allows ISS to perform attitude control and reboost when there are no visiting vehicles present. Finally, after being loaded with liquid waste and dry items for disposal from the ISS, ATV *Johannes Kepler* will be undocked on 4 June (to be confirmed with NASA). From here, the ATV starts the last part of its journey to the reentry point over the South Pacific Ocean.

Preparing for flight

Every vehicle that visits the ISS undergoes a Crew Equipment Interface Test. For ATV, these take place in the

ATV flight





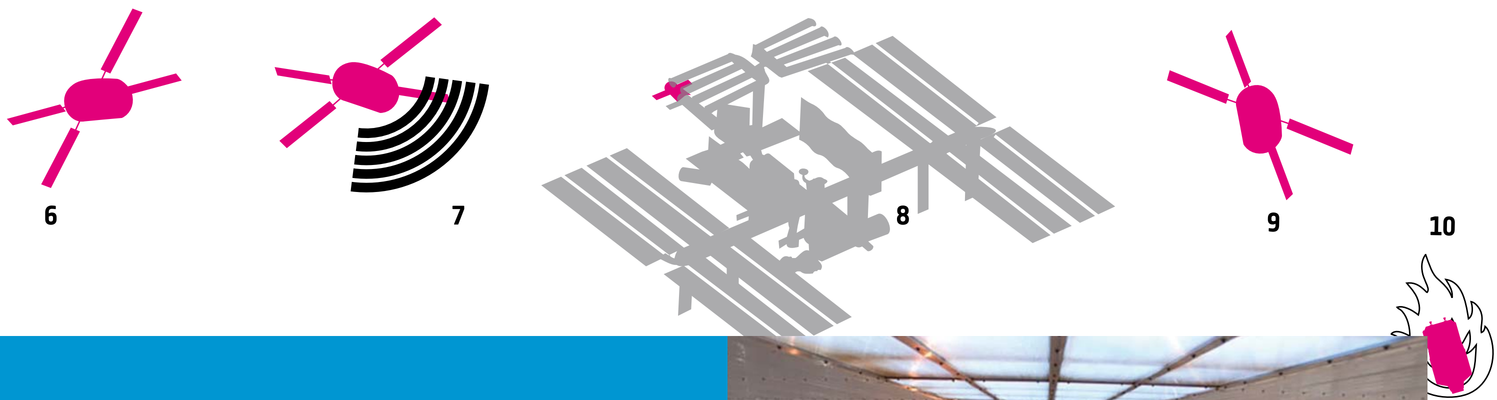
1. Lift-off from Europe's Spaceport at Kourou, French Guiana
2. Ascent
3. Separation of solid-propellant boosters
4. Fairing jettison
5. Ignition of Ariane 5 upper stage to achieve correct orbit
6. Phasing, a set of orbital manoeuvres designed to take ATV from its injection point to a parking orbit, 2000 km ahead of the ISS
7. Rendezvous and docking
8. Attached phase
9. Separation and reentry
10. Burns up in atmosphere

→ When ground teams work inside the Integrated Cargo Carrier they enter via the Aft Access Cone. Once the cargo is loaded, the cone is bolted into place and from then on, entry is via the top hatch only

Astrium facilities in Bremen, Germany, and then again in Kourou. Meanwhile in Toulouse, the ATV Control Centre has been busy preparing and simulating the operational scenarios over the last several months. In total, around 70 simulations and training sessions will have been carried out. Most of them are standalone simulations involving the Flight Control Team and the Engineering Support Team, but several of them also involve joint simulations with Houston and Moscow Control Centres.

By Christmas 2010, ATV *Johannes Kepler* was almost fully assembled and loaded with propellant in the S5C building at the Centre Spatiale Guyanais, Europe's Spaceport in French Guiana.

The next steps were the adapter fit-check, the transfer to the final assembly building where the ATV was mated onto the launcher, followed by 19 days of combined launcher/ATV operations. ■



→ Ariane's 200th flight

ATV *Johannes Kepler* is being launched on the milestone 200th Ariane mission (V200), preparations for which were completed in December at Europes's Spaceport in Kourou. The Ariane 5 ES version of Arianespace's heavy-lift 'workhorse' was fitted with its equipment bay, followed by installation of the EPS upper stage, in the Spaceport's Launcher Integration Building. With these steps completed, the Ariane 5 is ready for transfer to the Final Assembly Building, where the ATV will be installed in January.

← Artist impression showing how ATV is housed under the Ariane fairing during launch

↑ The completion of initial build-up for the 200th Ariane: assembly of the Ariane 5 launcher (ESA/CNES/Arianespace Photo Optique Video CSG)

→ A new step for European space transportation

By Simonetta Di Pippo, Director of Human Spaceflight

For the first time, an ESA astronaut will be on the International Space Station during an ATV mission. Paolo Nespoli will welcome ATV *Johannes Kepler* as the prime astronaut to monitor the docking, a role that shouldn't give him too much trouble: with its own flight control and propulsion systems, Europe's most complex spacecraft has a high level of autonomy. It can navigate by itself and has its own automatic rendezvous capability.

The concept of a transfer vehicle for moving astronauts and equipment to different Earth orbits has been envisaged for decades by several space agencies. So far, this role has been filled by the US Space Shuttle and Russian spacecraft, such as the Progress-M.

Now that the US Shuttle is about to retire, the ATV will become the supply vehicle with the largest capacity available for the ISS. This makes the arrival of the second ATV at the Station one of the highlights not only of Nespoli's mission, but also of the year. The foreseen launch rate of future ATVs also makes it more and more instrumental for the maintenance of the ISS and supply to the astronauts on board.

With ATV *Johannes Kepler*, Europe contributes in kind towards its share of the operational costs of the ISS and becomes a truly autonomous space power, capable of handling more missions and exploration programmes beyond low Earth orbit.

The European push

ATV *Johannes Kepler* is the most innovative spaceship ever developed in Europe, and this mission represents a confirmation of European capabilities in the domain of space transportation. The programme is solid enough: it is not just by chance that the international space community is relying on ESA as a major partner.

The technology and experience gained with ATV are benefiting Europe and its industrial competitiveness. We are building on a firm basis for further developments to position Europe as leader in the exploitation and exploration of space, both in low Earth orbit and beyond.

We count on a highly skilled workforce, a valuable asset to the European aerospace industry. ESA and industry teams have been

working together in deploying a great effort to ensure ATV *Johannes Kepler* is ready on time. Without their team spirit and professionalism, it would not have been possible.

Dozens of companies and thousands of technicians and engineers have been involved. During the highly active phases of the ATV flight – from launch to docking, and from departure to reentry – a 60-strong mission control team will be working together in all its procedures.

Lessons learned

Nearly three years have passed since ATV's maiden flight. Although ATV *Jules Verne* was a major success, lessons learned led to several upgrades and design changes that permit ATV *Johannes Kepler* to ferry a full load of propellant – over five tonnes – to the ISS. The post-flight analysis helped us to undergo a major refurbishment of the infrastructure in order to adapt the new standards, together with a reorganisation of key persons in the operations team.

Following the qualification flight, some 30 technical recommendations were adopted and incorporated into the design of the next ATV. Thanks to that first review, ATV *Johannes Kepler* is now the most complex space vehicle ever developed in Europe.

The future

The ATV story doesn't end here. The third in line for flight already has a name, ATV *Edoardo Amaldi*, to honour the Italian physicist and space pioneer. At least two more are scheduled at regular intervals.

The unique technologies developed for the ATV are something we can build on for the future. This European space vessel is designed to be flexible, so that it can be the basis for developing new transportation systems, starting with atmospheric reentry and ISS download capabilities.

ATV technologies could also be used to develop systems for automatic missions, such as space debris mitigation, space tugs or in-orbit servicing of other spacecraft.

Further into the future, ATV's pressurised cabin could be transformed into a capsule for carrying people, making it a fully-fledged crew transport vehicle.

ESA is ready to face the challenges of space transportation. Our valuable expertise places us in the frontline of space exploration, an international endeavour in which Europe doesn't want to be a mere passenger.

→ Next up: ATV *Edoardo Amaldi*

While ATV *Johannes Kepler* starts its voyage to the ISS, the next step will be to ensure the planned launch rate of one ATV per year.

"The main challenge for ATV *Edoardo Amaldi* will be not only to perform its very complex mission as successfully as its predecessors, but also to prepare it within a much shorter interval than the previous one," says ESA's ATV-3 Mission Manager Massimo Cislaghi.

"This implies that any technical indications from the *Johannes Kepler* mission will become available only when the preparation of *Edoardo Amaldi* will be already in a very advanced stage," adds Massimo Cislaghi. So far, the only differences between the two spacecraft are their names and the cargo loading.

The launch date for ATV *Edoardo Amaldi* is currently scheduled for the end of February 2012. Massimo Cislaghi says, "Respecting this date will be of vital importance for the Space Station logistics, especially at a time when the operational life of the US Space Shuttle will have come to an end, and its replacement might not be ready by then."

←

ATV *Edoardo Amaldi*'s Integrated Cargo Carrier was flown in by a Beluga aircraft from Turin

"The main challenge for ATV *Edoardo Amaldi* will be not only to perform its very complex mission as successfully as its predecessors, but also to prepare it within a much shorter interval than the previous one."

↑

ATV *Edoardo Amaldi*'s Equipped External Bay, part of the Integrated Cargo Carrier, showing the tanks for gas and water. Behind it is the other part of the ICC, the Equipped Pressurised Module (Thales Alenia Space)

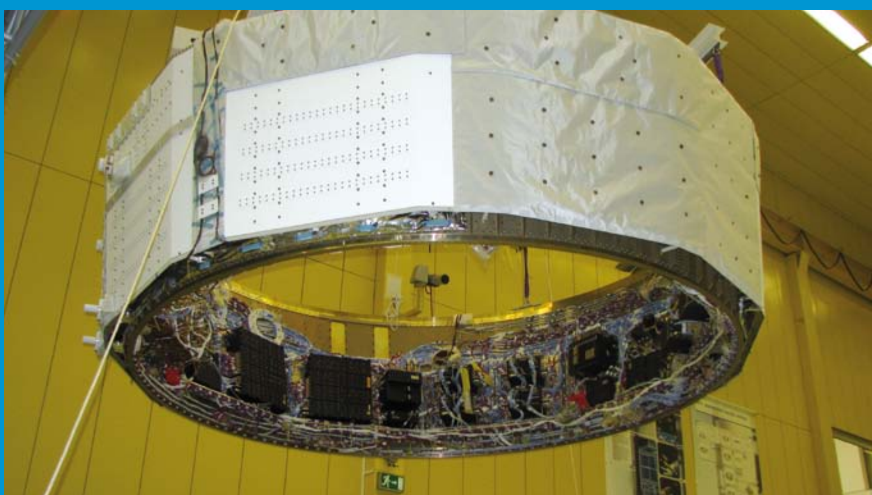
Putting all the pieces together

The three modules for Europe's third ATV, named *Edoardo Amaldi*, are finally together at Bremen, Germany, waiting to be joined and assembled as a complete spacecraft.

Coming from different parts of Europe, the regrouping of these modules took place in December at the premises of EADS Astrium, current home base for the ATV-3 team. The Integrated Cargo Carrier (ICC) is the module that will hold both dry and liquid cargoes and was flown in by a Beluga aircraft from Turin. Built by Thales Alenia Space Italy, the ICC represents about 60% of the total ATV volume.

Whereas the Equipped Propulsion Bay was already in Bremen, the Equipped Avionics Bay (EAB) had to be delivered from Toulouse, France, after completing thermal vacuum testing. The EAB is the 'brain' of the ATV and also manages a very sophisticated thermal control system.

These two modules were assembled in January in their final configuration for launch. Then the ICC will be electrically connected to them for the final subsystem testing campaign. The next stop for ATV *Edoardo Amaldi* will be French Guiana, when all the modules will be shipped to the launch site in August.

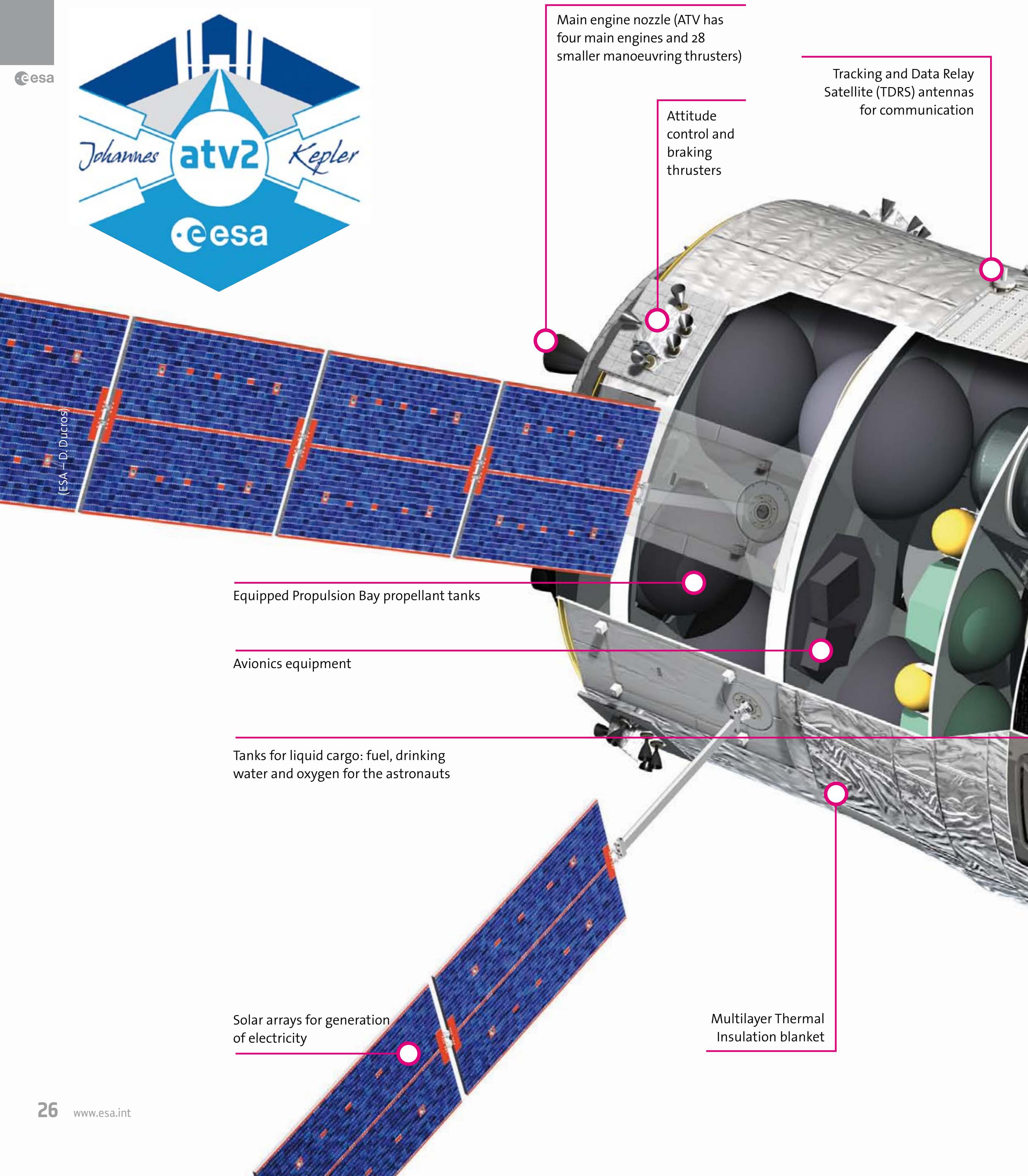


←

The Equipped Avionics Bay (EAB) is the 'brain' of the ATV, housing its Guidance, Navigation and Control systems and also managing very sophisticated thermal control system

→ AUTOMATED TRANSFER VEHICLE

ATV *Johannes Kepler*

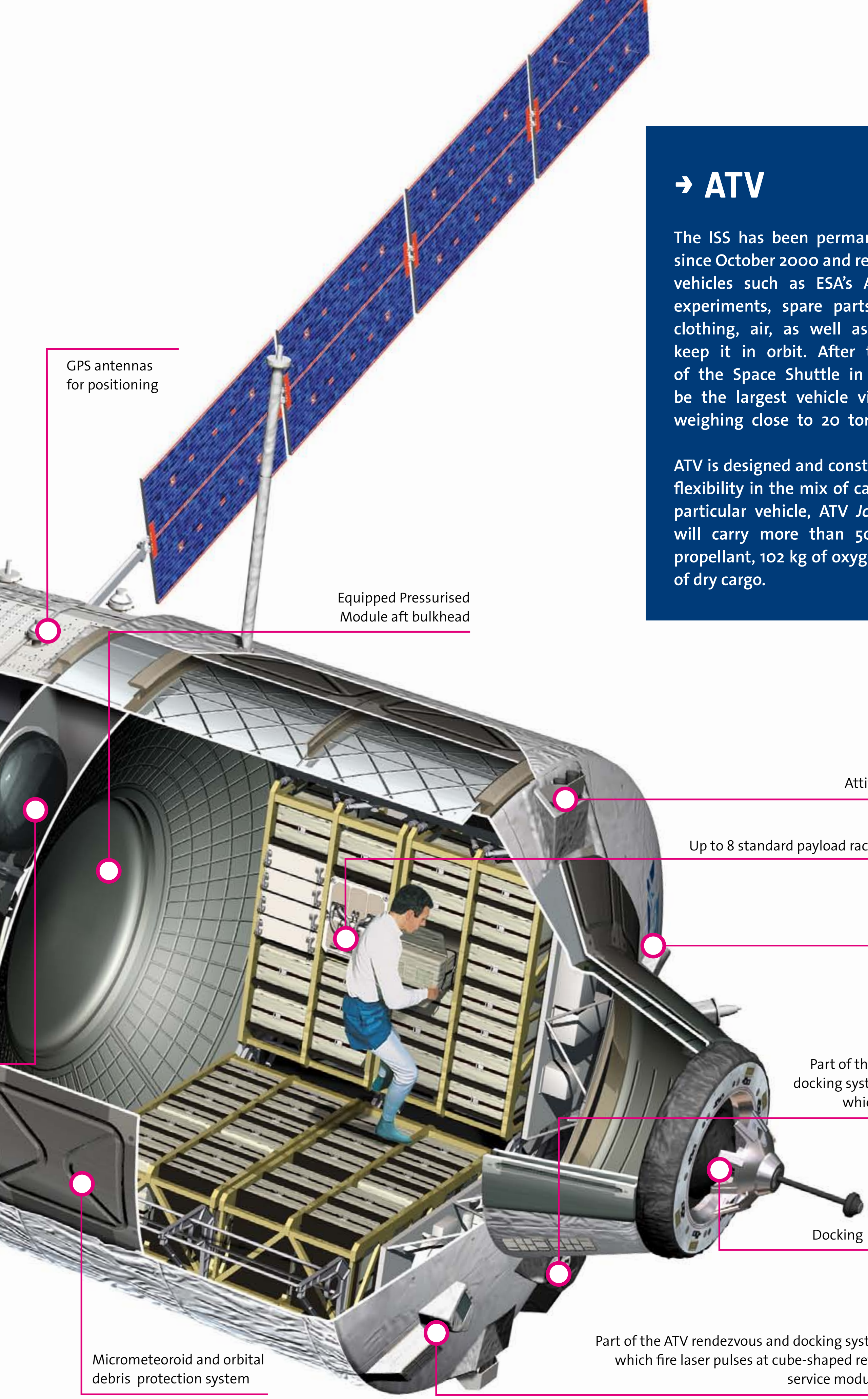


(ESA – D. Ducros)

→ ATV

The ISS has been permanently manned since October 2000 and relies on logistics vehicles such as ESA's ATV to upload experiments, spare parts, food, water, clothing, air, as well as propellant to keep it in orbit. After the retirement of the Space Shuttle in 2011, ATV will be the largest vehicle visiting the ISS, weighing close to 20 tonnes at lift-off.

ATV is designed and constructed to allow flexibility in the mix of cargoes, and this particular vehicle, ATV *Johannes Kepler*, will carry more than 5000 kg of ISS propellant, 102 kg of oxygen and 1400 kg of dry cargo.



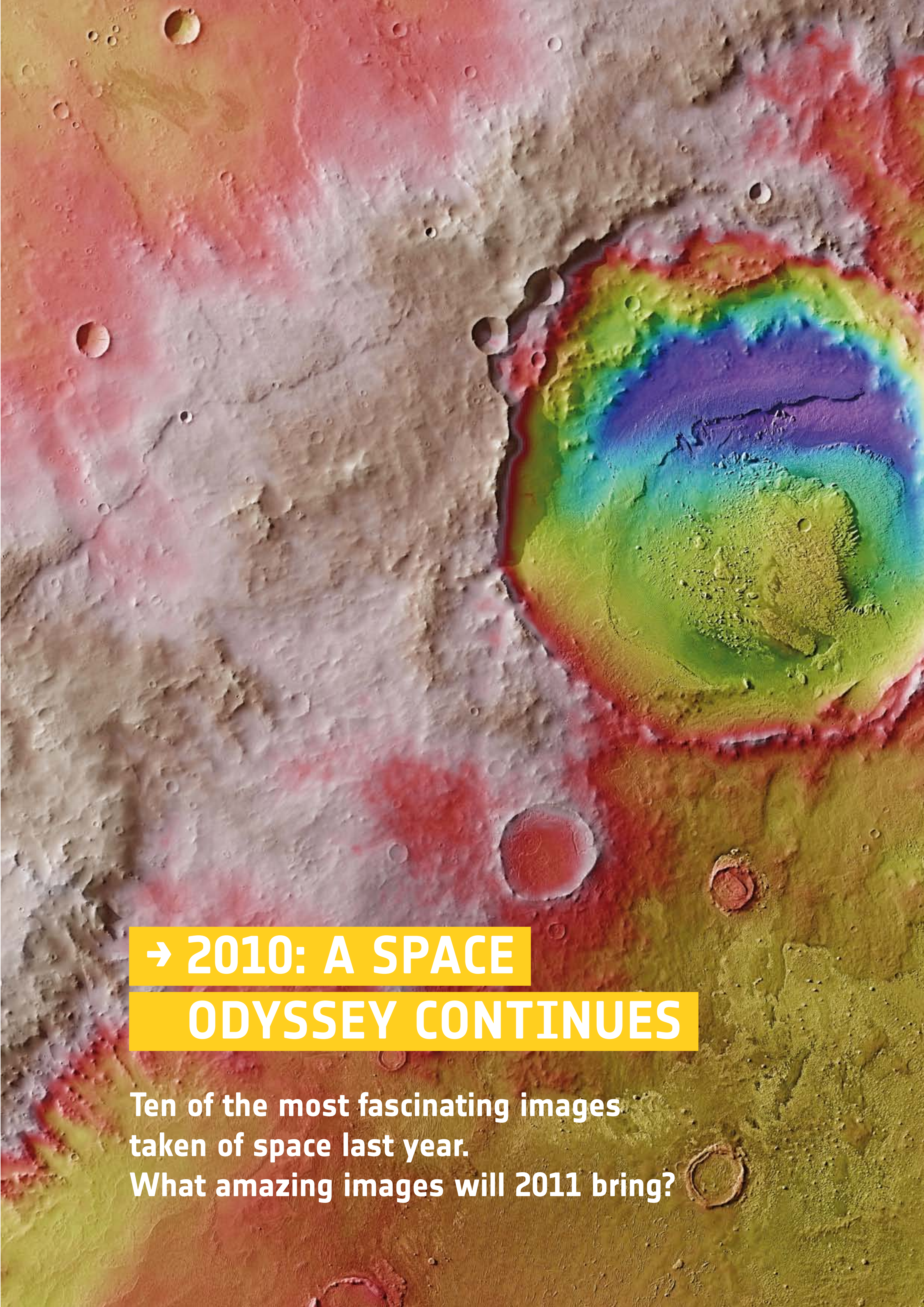
→ STOP PRESS

“We saw ATV launch!”

In Kourou, French Guiana, ESA photographer Stephane Corvaja was on hand to document the launch of ATV *Johannes Kepler* on 16 February. But another view was captured by one of the ‘photographers-in-residence’ on the International Space Station, ESA’s Paolo Nespoli.

“We actually saw the ATV launch,” said Nespoli. “Congratulations to Arianespace and ESA on the launch and Expedition 26 is looking forward to welcoming it on the ISS.” The ATV will adjust its orbit to rendezvous with the ISS and is due to dock on 24 February.

Two views of the Ariane V200 launch, carrying ATV *Johannes Kepler*
(ESA - S. Corvaja, ESA/CNES/Arianespace Photo Optique Video CSG)

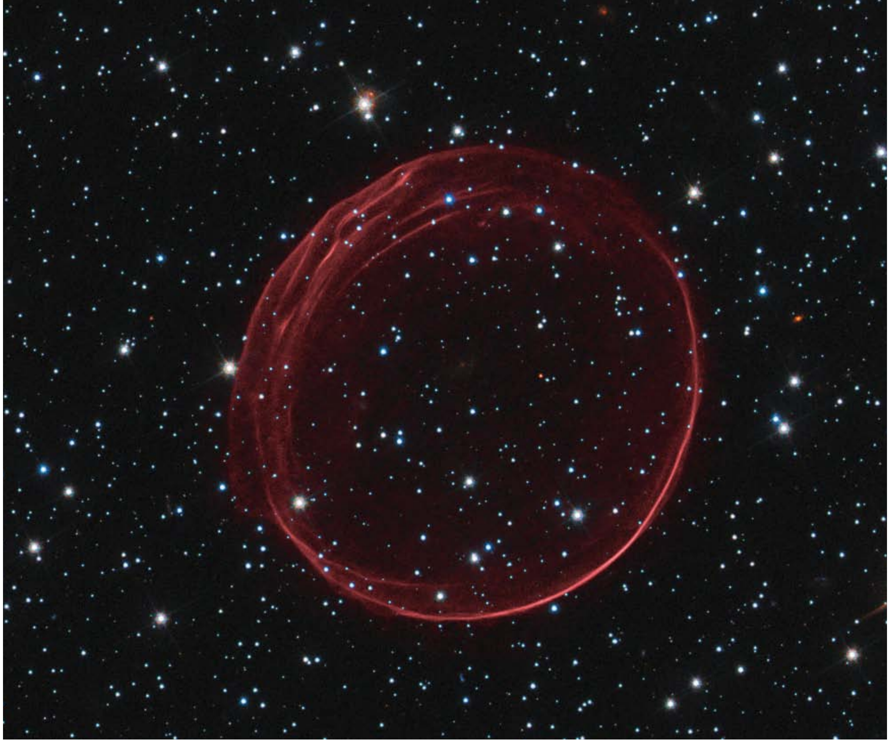


→ 2010: A SPACE ODYSSEY CONTINUES

Ten of the most fascinating images taken of space last year. What amazing images will 2011 bring?

→ **1. Celestial bauble**

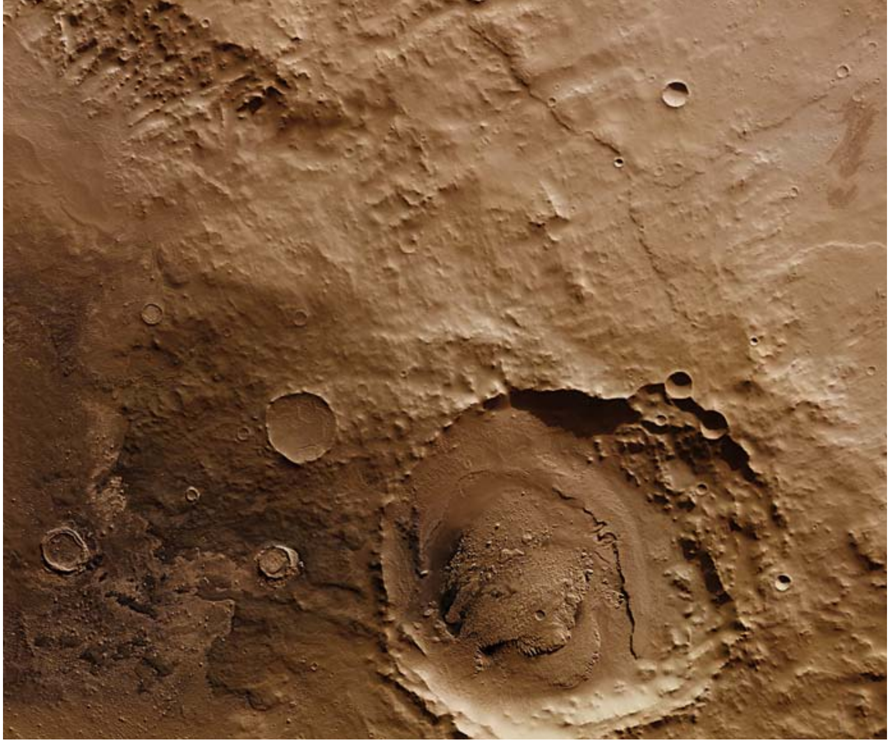
The NASA/ESA Hubble Space Telescope saw this bubble of gas being expanded by the blast wave from a supernova, 23 light-years across and is expanding at more than 5000 km per second. Called SNR 0509-67.5, the bubble is the visible remnant of a powerful stellar explosion in the Large Magellanic Cloud, a small galaxy about 160 000 light-years from Earth (NASA/ESA/Hubble Heritage Team)

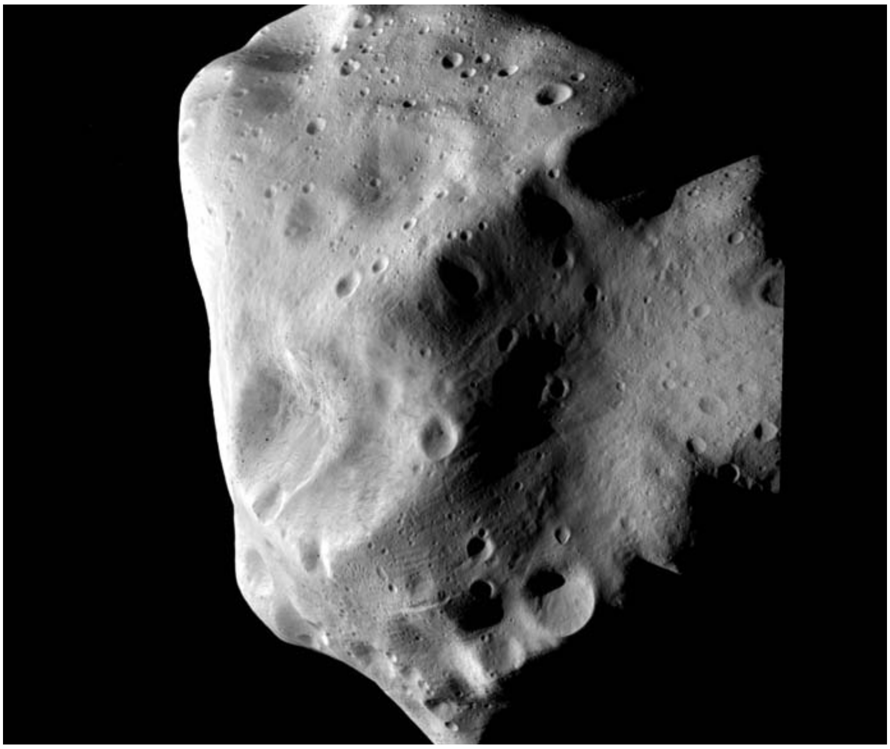


← **2. Monster star embryo**
Herschel's view of the emission nebula RCW 120, about 4300 light-years away, and formed by a star at its centre. The bright white part of the bubble is an unexpectedly large embryonic star that looks set to turn into one of the biggest and brightest stars in our galaxy in the next few hundred thousand years (ESA/PACS/SPIRE/HOBYS Consortia)

↘ **3. Vast hole in space**
NGC 1999 is the green-tinged cloud towards the top of this image. The dark spot to its right was thought to be a cloud of dense dust and gas until ESA's Herschel far-infrared observatory looked at it. In fact, it is a hole that has been blown in the side of the NGC 1999 nebula by the jets and winds of gas from the young stellar objects in this region of space (ESA/HOPS Consortium)

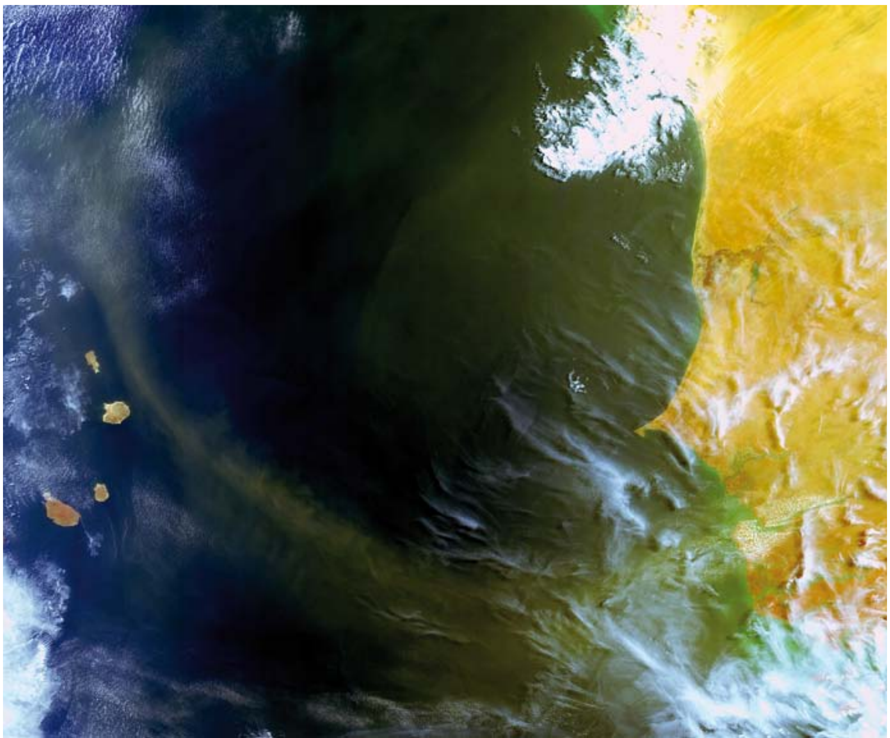
→ **4. Shaped by wind and water**
Schiaparelli is a large impact basin about 460 km wide in the Terra Meridiani region on Mars. Here we see a small part of its northwestern rim cutting diagonally across the image and a smaller crater, 42 km wide, in the rim. All around is evidence for water flowing and the high winds that periodically blow. This image was taken on 15 July by the High Resolution Stereo Camera on Mars Express (ESA/DLR/FU Berlin)





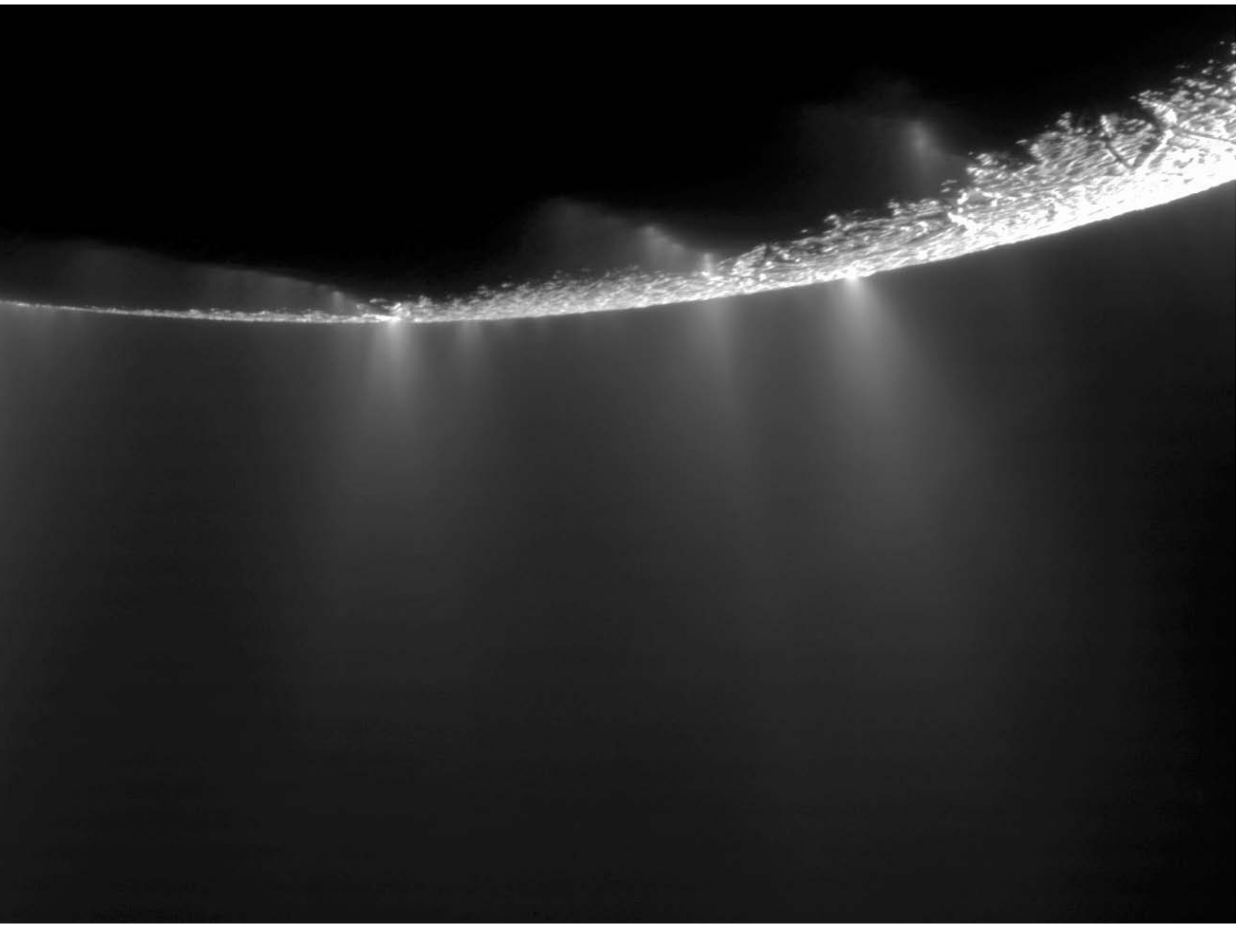
← **5. Close encounter**
The High Resolution Stereo Camera on Mars Express also took this image of martian moon Phobos during its close flyby on 7 March 2010 (ESA/DLR/FU Berlin)

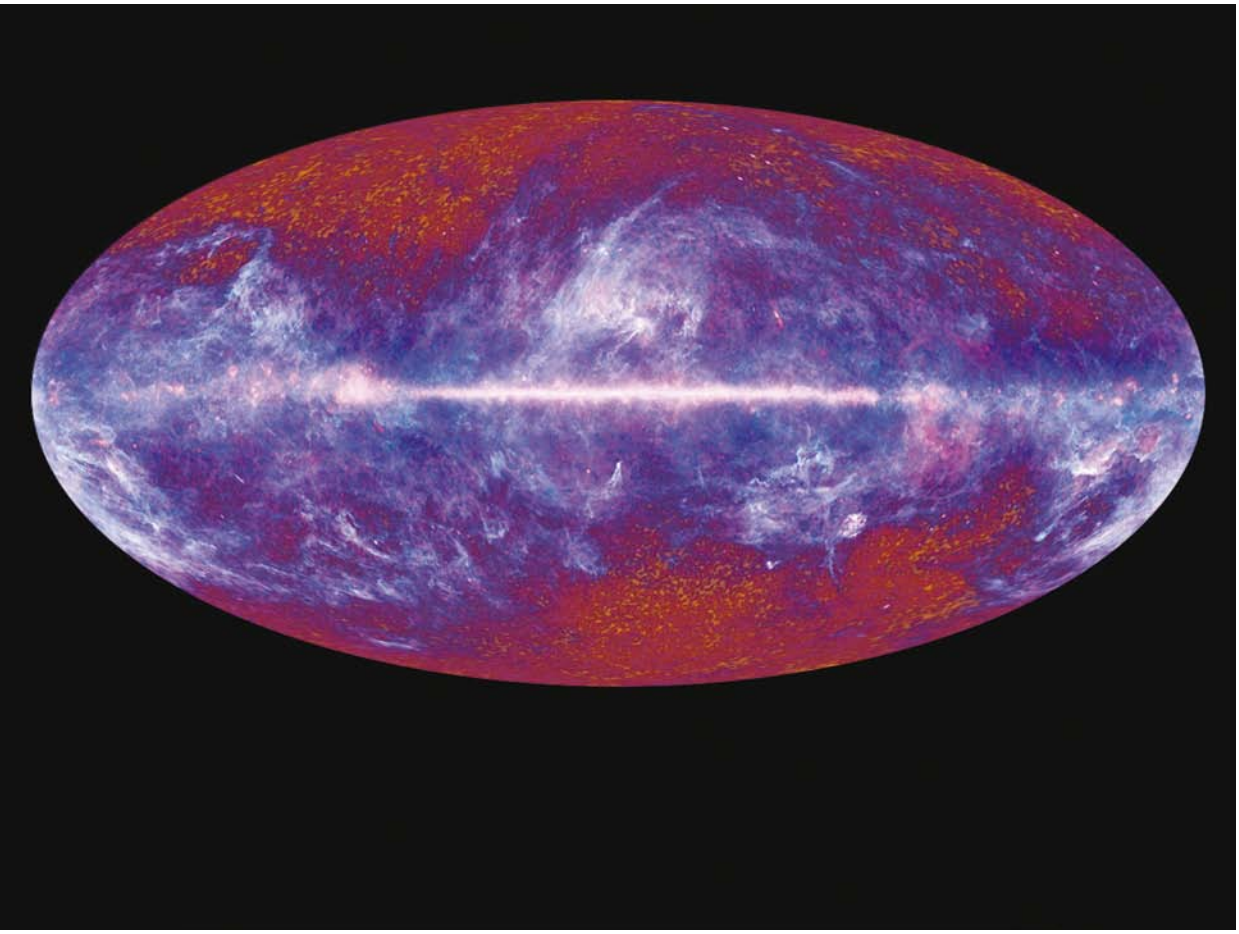
↘ **6. Duststorms seen from space**
On the third planet from the Sun in our Solar System, vast clouds of dust are blown from an equatorial land area over the surrounding liquid water mass. In other words, Earth! Envisat took this picture of sand from the Sahara Desert blowing west across Mauritania, Senegal and Guinea Bissau and over the North Atlantic Ocean in July 2010. The Cape Verde islands are at left.



→ **7. Massive stellar assembly line**
Another Herschel view, looking towards the galactic centre in the Eagle constellation. Here we see two bright star-forming regions G29.9 and W43 are clearly visible left and centre. Large newborn stars, several tens of times bigger than our Sun, are catastrophically disrupting their original gas embryos by kicking away their surroundings and excavating giant cavities in the galaxy. This is clearly visible in the 'fluffy chimney' below W43 (ESA/Hi-GAL Consortium)

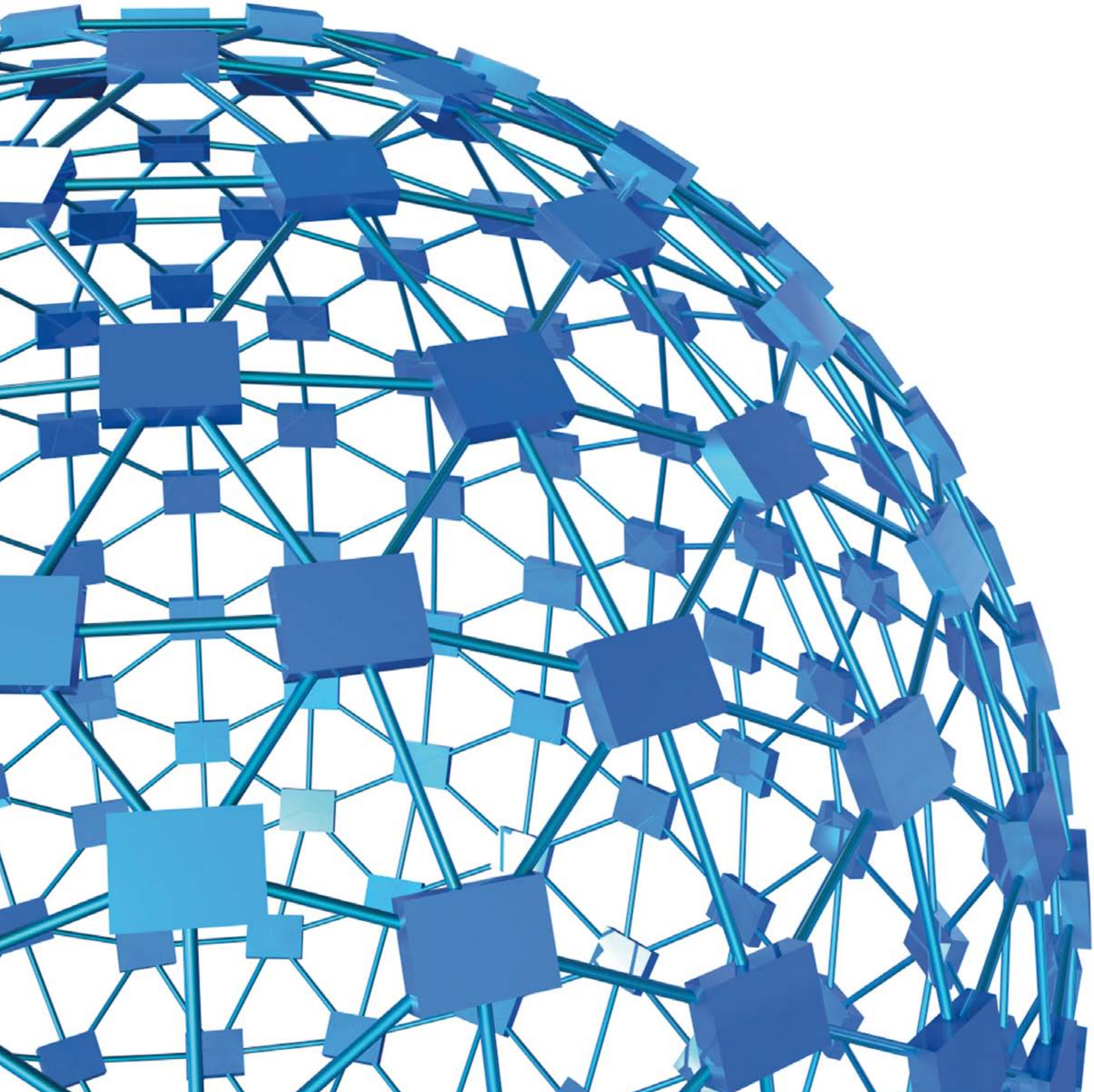
→ **8. Jupiter's missing clouds**
NASA/ESA Hubble observations of Jupiter provided scientists with a close-up of changes in its atmosphere following the disappearance several months ago of the dark cloud features known as the Southern Equatorial Belt. The last time this belt faded was in the early 1970s. In this Hubble view, a slightly higher altitude layer of white ammonia ice crystal clouds appears to obscure the deeper, darker belt clouds in the lower half of the planet (NASA/ESA/Z. Levay/STScI)





← **9. The fountains of Enceladus**
Dramatic plumes, imaged by the NASA/ESA/ASI Cassini spacecraft for the first time in 2005, are seen here erupting from the fractures (the famed 'tiger stripes') that cross the south polar region of the Saturn's moon Enceladus. The tiger stripes are fissures that spray out icy particles, water vapour and organic compounds. This image taken during the August 2010 flyby of the moon by Cassini (NASA/JPL/Space Science Institute)

↙ **10. The oldest light**
ESA's Planck mission delivered its first all-sky image, not only providing new insight into the way stars and galaxies form, but also telling us how the Universe itself came to life after the Big Bang. The main disc of our galaxy runs across the centre of the image with streamers of cold dust reaching above and below the Milky Way. Less spectacular, but more intriguing, is the mottled backdrop at the top and bottom: the 'cosmic microwave background' radiation, the oldest light in the Universe and the remains of the fireball from which our Universe sprang into existence 13.7 billion years ago (ESA/HFI/LFI consortia).



→ WELL CONNECTED

The SpaceWire on-board data-handling network

Steve Parkes
University of Dundee, Scotland, UK

Philippe Armbruster & Martin Suess
Directorate of Technical and Quality Management, ESTEC, Noordwijk, The Netherlands

In the next decade, SpaceWire-enabled missions will be monitoring our planet, exploring the distant realms of our Solar system and reaching through space and time to help understand the origins of the Universe.

The result of an extremely successful collaboration between ESA, academia and space industry, involving spacecraft engineers from around the world, SpaceWire is a standard for high-speed links and networks used on spacecraft. SpaceWire is now being used widely in the space industry, by all the major space agencies and, in particular, on many current space missions of ESA, NASA and JAXA.

SpaceWire has gained such a wide acceptance because it solved a significant problem. It replaced the collection of different data interfaces with a standard that worked well enough to meet the requirements of many space missions.

The benefits gained by the widespread adoption of SpaceWire have gone far beyond the original aspirations of its creators. SpaceWire-enabled instrumentation is being reused on new missions, standard sensors with SpaceWire interfaces are appearing in equipment supplier catalogues and many SpaceWire components and sub-systems are available.

→ What is SpaceWire?

As a data-handling network standard for use on spacecraft, connecting instruments, mass-memory and other on-board sub-systems, SpaceWire can be compared to Universal Serial Bus (USB) in personal computing, which connects memory devices, printers and so on to our computers at home or at work. SpaceWire provides similar functionality for spacecraft, but is simpler to implement and has some specific characteristics that help it support data-handling applications in space.

It offers high-speed, low-power, simplicity, relatively low implementation cost and architectural flexibility, making it ideal for many space missions. SpaceWire provides high-speed (2 Mbits/s to 200 Mbits/s), bidirectional, full-duplex data links, which connect together SpaceWire-enabled equipment. Data-handling networks can be built to suit particular applications using point-to-point data links and routing switches.

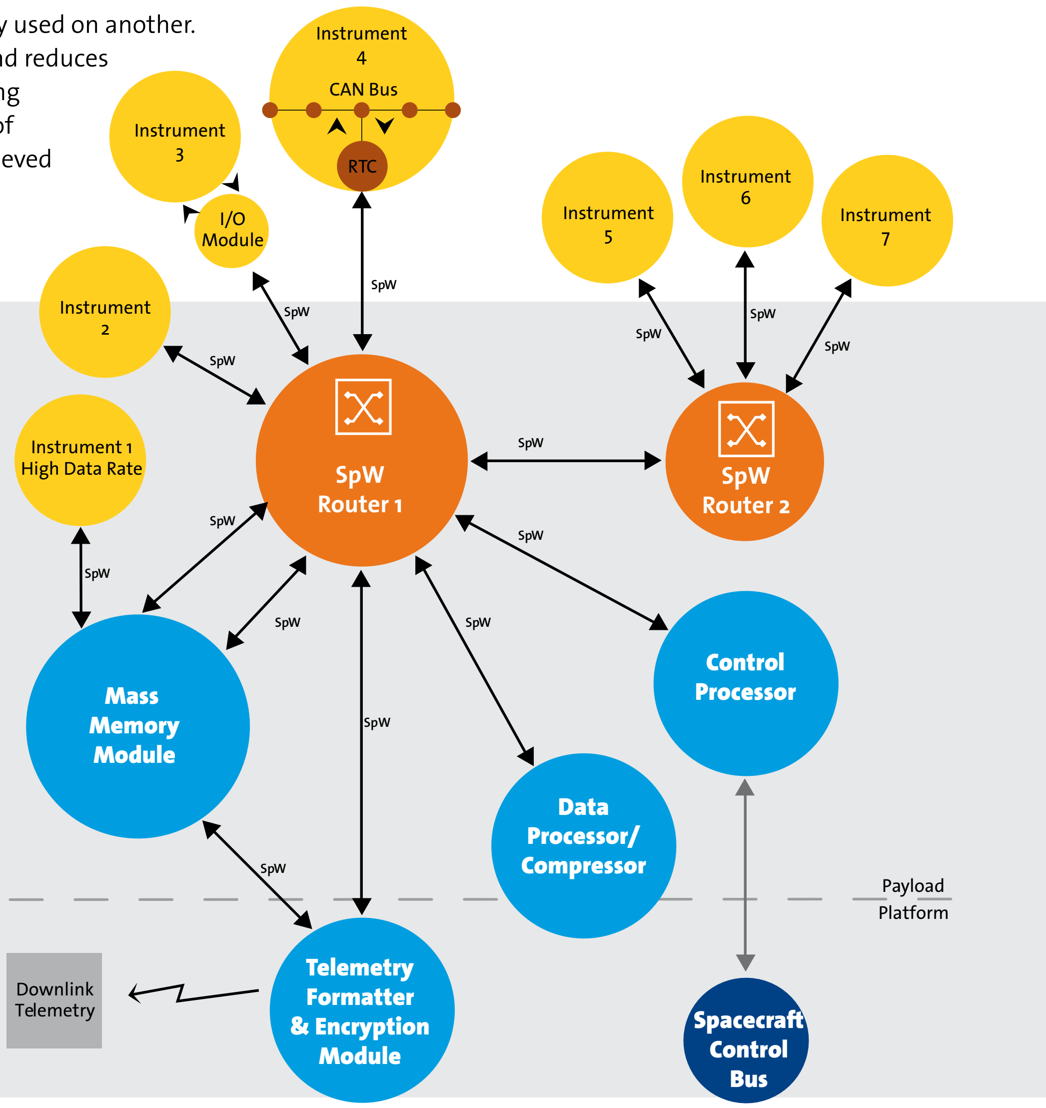
Cheaper, faster, better, more

SpaceWire was designed to facilitate the construction of high-performance, on-board data-handling systems and help reduce system integration costs. It also promotes compatibility between data-handling equipment and subsystems, and encourage reuse of data-handling equipment across several different missions.

Using the SpaceWire standard ensures that equipment is compatible at both the component and sub-system levels. Instruments, processing units, mass-memory devices and downlink telemetry systems using SpaceWire interfaces developed for one mission can be readily used on another. This reduces the cost of development and reduces development timescales, while improving reliability and maximising the amount of science and data return that can be achieved within a given budget.

Brief history of SpaceWire

Before SpaceWire became a standard, many spacecraft prime contractors and equipment manufacturers had to use ad hoc or their own interfaces for inter-unit communications, for example, connecting high data-rate instruments to mass-memory units. This resulted in several different communication links being used on a spacecraft, increasing the cost and extending the time required for spacecraft integration and testing. There was a clear need for standardising these on-board communication links that would simplify spacecraft development.

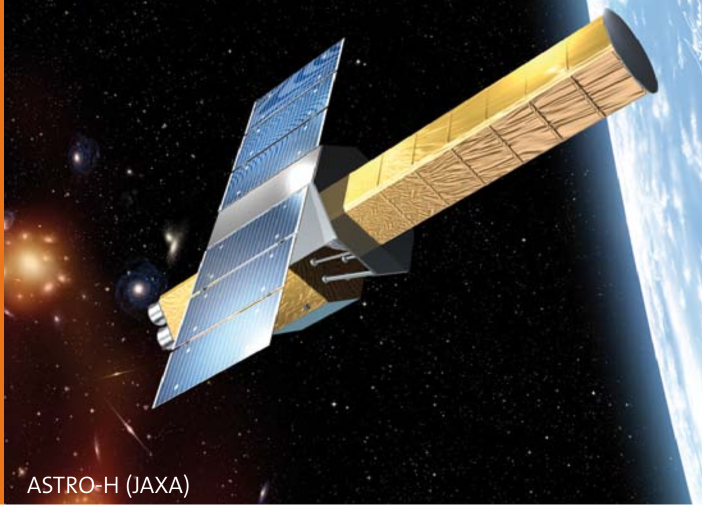


Example of SpaceWire architecture (without redundancy)

Instrument 1 on the left is a high data-rate instrument. A SpaceWire point-to-point link is used to stream data from this instrument directly into the Mass Memory Module. If a single SpaceWire link is insufficient to handle the data-rate from this instrument then two or more links may be used in parallel.

Instrument 2 is of lower average data-rate than instrument 1. Its data is passed though SpaceWire Router 1 to the Mass Memory Module. Instrument 3 does not have a SpaceWire interface so an input/output (I/O) module is

Since the SpaceWire standard was published (under the reference number ECSS-E-50-12A) by the European Cooperation for Space Standardization in January 2003, it has been adopted by ESA, NASA, JAXA and Roscosmos. It is being used today on many high-profile scientific, Earth observation and commercial missions, including Gaia, ExoMars, BepiColombo, the James Webb Space Telescope, GOES-R, Lunar Reconnaissance Orbiter and ASTRO-H.


ASTRO-H (JAXA)

In 1992, when work on what became SpaceWire started, there was also substantial interest in high-performance digital signal processing systems that were beyond the capability of the single-chip devices available at that time. The use of parallel processing was investigated and this required some form of network to interconnect the individual processing elements.

The Inmos Transputer, a microprocessor designed for parallel processing was studied, and the serial communication links being developed for the T9000 Transputer were identified as being an attractive solution for spacecraft onboard networking. This serial link technology was subsequently standardised as IEEE 1355-1995.

Several radiation-tolerant devices were developed following the IEEE 1355-1995 standard and were used on some space missions. However, there were many problems with this standard, which had to be resolved if this technology was to continue to be used for ESA spacecraft.

The University of Dundee received a contract from ESA to examine and solve these problems that resulted in the first public draft of the SpaceWire standard. After further work involving spacecraft engineers from across Europe and beyond, this matured through several more revisions into the SpaceWire standard that was eventually published in 2003.

Example of SpaceWire application

SpaceWire is able to support many different payload-processing architectures, using point-to-point links and SpaceWire routing switches. The data-handling architecture can be constructed to suit the requirements of a specific mission, rather than having to force the application onto a restricted bus or network with restricted topology.

An example SpaceWire architecture is shown here, using two SpaceWire routers to provide the interconnectivity between instruments, memory and processing modules.

used to connect the instrument to the SpaceWire router. Its data may then be sent over the SpaceWire network to the Mass Memory Module.

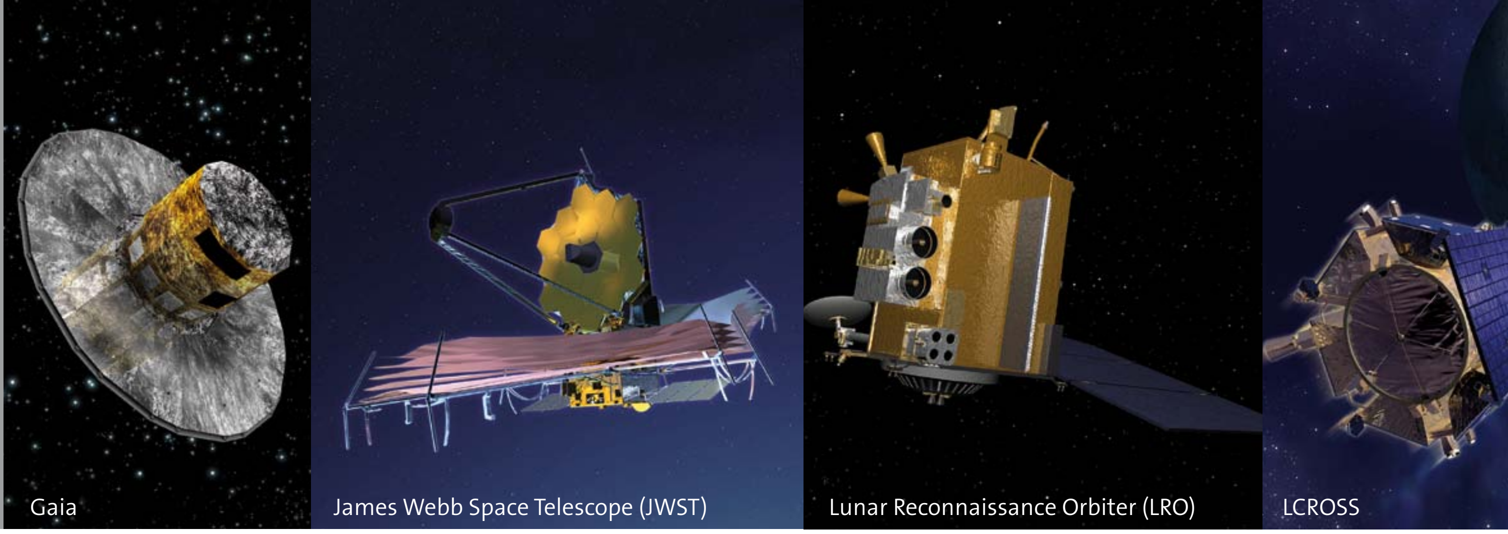
Instrument 4 is a complex instrument containing a number of sub-modules which are interconnected using the CAN bus. A Remote Terminal Controller (RTC) is used to bridge between the CAN bus and SpaceWire. Other signals from the instrument are also connected to the RTC, which contains a processor for performing the bridging and local instrument control functions.

Instruments 5, 6 and 7 are in a remote part of the spacecraft. To avoid having three SpaceWire cables running to this remote location a second router (SpaceWire Router 2) is used to concentrate the information from these three instruments and send it over a single SpaceWire link to Router 1 and then on to the Mass Memory Module.

This Mass Memory Module can receive data from any of the instruments either directly, as is the case for Instrument 1, or indirectly via Router 1. Data stored in the Mass Memory Module can be sent to the Telemetry Formatter/Encryption Module for sending to Earth, or it may first be sent to a Data Processing or Data Compression Unit. This unit may return the processed/compressed data to the Mass Memory Module or send it straight to the Telemetry Module via Router 1.

The Control Processor is responsible for controlling all the instruments, the Mass Memory Module and the Telemetry unit. Via the SpaceWire network it has access to all these modules: it can configure, control and read housekeeping and status information from all of them. The Control Processor is also attached to the spacecraft control bus, over which it can receive telecommands and forward housekeeping information.

With several instruments and the Data Processor/Compressor sending data to the Mass Memory Module via Router 1, a single link from that Router to the Mass Memory Module may be insufficient to handle all the data, so a second link has been added to provide more bandwidth. In a SpaceWire network, links can be added to provide additional bandwidth or to add fault tolerance to the system. Redundancy has not been included for clarity. In a spaceflight application, of course, another pair of routers would be included with links to redundant units. It is straightforward to support traditional cross-strapped modules using SpaceWire.



→ SpaceWire missions and architectures

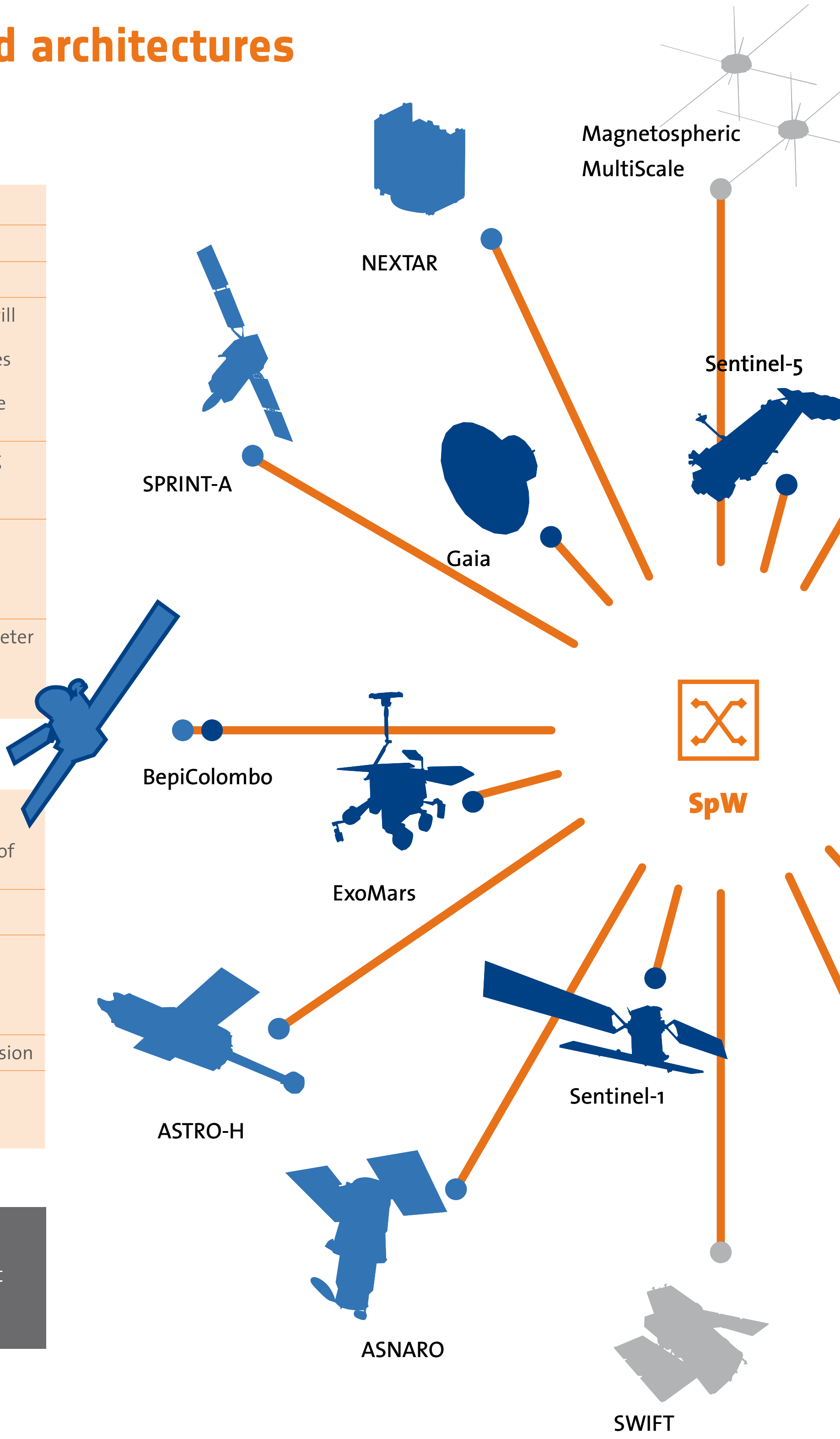
ESA missions using SpaceWire

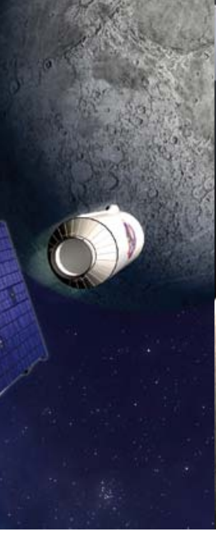
Gaia	Very-high-resolution star-mapper
ExoMars	Semi-autonomous Mars surface rover
BepiColombo	Mercury Polar Orbiter
Sentinel-1	A pair of imaging radar satellites that will provide an all-weather, day-and-night imaging capability for a range of services including, sea-ice mapping, oil-spill monitoring, ship detection, land-surface movement, and disaster management
Sentinel-2	High-resolution, multi-spectral imaging mission supporting operational land monitoring and emergency services
Sentinel-3	A pair of satellites that will provide operational marine and land Earth observation services using optical and microwave instruments
Sentinel-5 precursor	Will carry a UV/VIS/NIR/SWIR spectrometer payload to avoid a data gap between Envisat and replacement of the MetOp series of Earth observation satellites

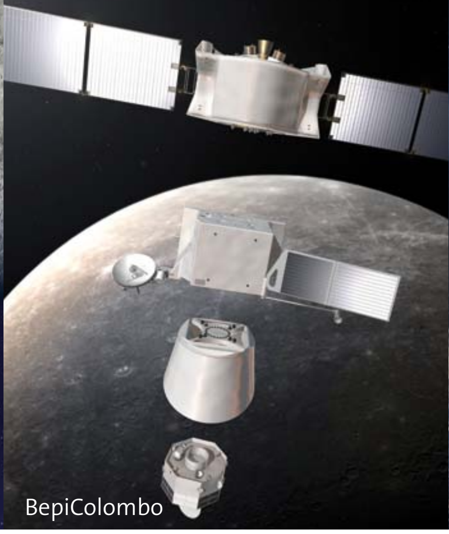
Japanese missions using SpaceWire

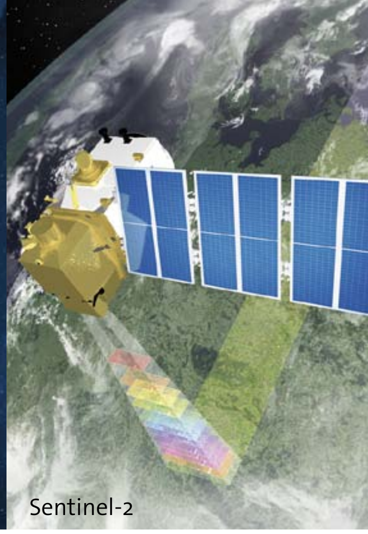
BepiColombo	Mercury Magnetospheric Orbiter, the companion of ESA's Mercury Polar Orbiter spacecraft, will study the magnetosphere of Mercury
ASTRO-H	X-ray telescope
SPRINT-A	A small satellite that will observe the atmosphere of Venus, Mars and Jupiter in extreme ultraviolet from Earth orbit, at an altitude of about 1000 km
ASNARO	High-resolution optical Earth imaging mission
NEXTAR	One of the first spacecraft to be designed using SpaceWire for all of its onboard communications and being built by NEC

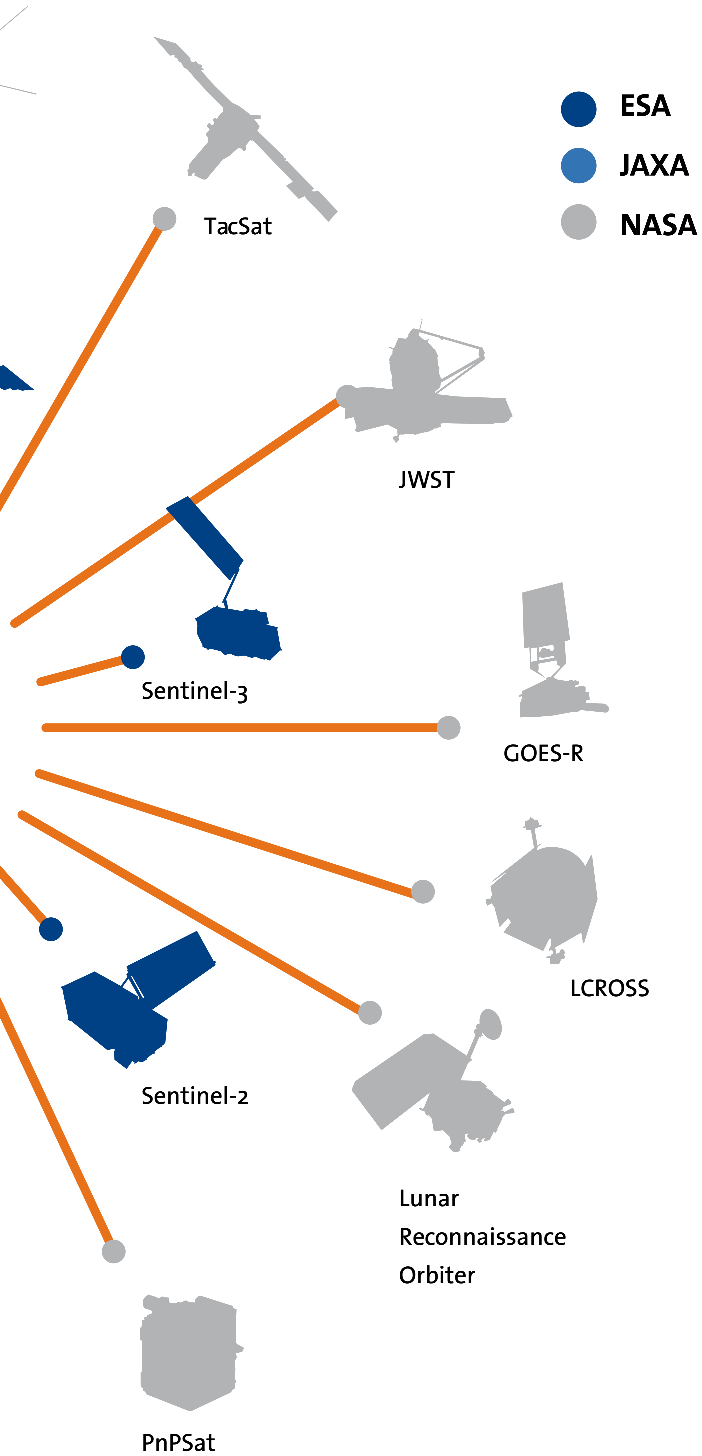
↑ The Japan Aerospace Exploration Agency (JAXA) has adopted SpaceWire for most of its spacecraft that require moderate or high data rates











NASA missions using SpaceWire

SWIFT	Gamma-ray burst observatory, in orbit and making scientific discoveries since 2004
Lunar Reconnaissance Orbiter (LRO)	In orbit around the Moon, taking very high-resolution images of the surface
LCROSS	Deliberately crashed into the south pole of the moon and discovered ice there
James Webb Space Telescope (JWST)	Infrared telescope, the biggest satellite ever launched with the exception of the ISS
Magnetospheric MultiScale	Multi-satellite mission that will explore Earth's magnetosphere
GOES-R	Series of geostationary Earth observation spacecraft, due to replace the current US weather satellites
Plug and Play Sat (PnPSat)	Pioneering rapid assembly, integration and deployment technology for tactical and disaster monitoring applications.
TacSat	Part of the US Operationally Responsive Space (ORS) programme

↑ When specifying a data-handling network for JWST, NASA made an extensive survey of suitable technologies and chose SpaceWire. Both TacSat and PnPSat projects chose SpaceWire for their onboard data-handling networks over competition of other space and terrestrial technologies

Roscosmos, the space agency of the Russian Federation, has recently approved SpaceWire for use on their spacecraft, and it regards SpaceWire as a key technology for their future space missions. SpaceWire is also being used in China, India, Korea, Thailand, Taiwan, Argentina, Canada, and by the space agencies of individual ESA Member States. A number of commercial spacecraft, including Inmarsat, are also using SpaceWire.

ExoMars SpaceWire data-handling architecture

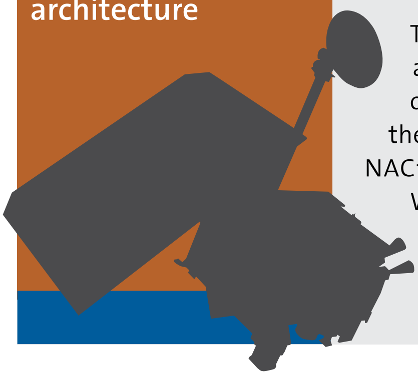
ExoMars is a series of ESA/NASA missions to Mars, the second of which in 2018 will incorporate two versatile rovers, one from ESA and one NASA.

The ESA ExoMars rover will carry a comprehensive array of scientific instruments dedicated to exobiology and geology research. The rover will travel several kilometres searching for traces of past and present signs of life, collecting and analysing samples from within surface rocks and from the subsurface, down to a depth of 2 m. The SpaceWire data-handling architecture used on ExoMars follows closely the example architecture on page 30.

ExoMars carries several cameras to support navigation: PanCam, which provides a panoramic view around the rover; NavCams, used to provide stereoscopic images from which digital elevation maps can be derived and used for navigation purposes; and LocCams, used to measure the motion of the rover relative to the surface.

The processing of this image data is very intensive so a dedicated image processor is used to support the processing. SpaceWire is used to transfer images from the cameras to mass memory and from there to the processor and image-processing chip. A SpaceWire router is used to interconnect the various SpaceWire units. The instrument arm and the Pasteur instrument are also connected to the data-handling system using SpaceWire. ExoMars makes extensive use of the RMAP protocol for passing data from cameras, to mass memory and to and from the processor and image-processing chip.

Lunar Reconnaissance Orbiter data-handling architecture



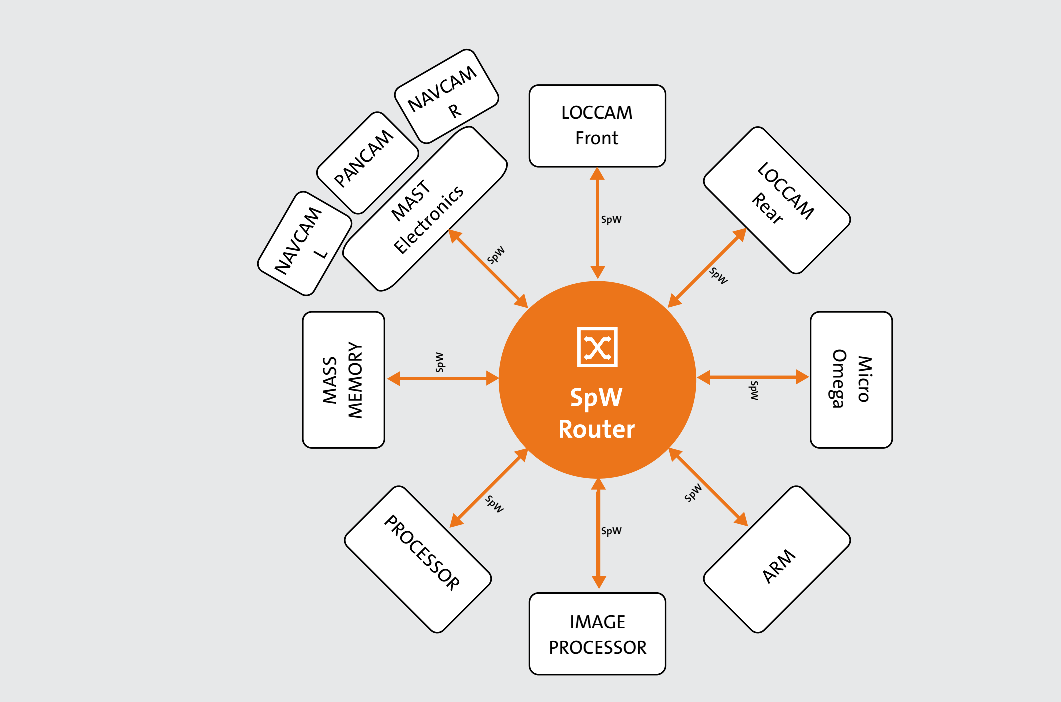
The Lunar Reconnaissance Orbiter (LRO) is a NASA mission currently in orbit around the Moon returning images and other scientific data about the lunar surface.

The data-handling architecture of LRO is also similar to the example architecture on page 30. SpaceWire is used to connect the LRO Cameras (Narrow Angle Cameras, NAC1 and NAC2, and Wide Angle Camera, WAC), and Mini-RF radar instrument, to the Command and Data-handling (C&DH) system. SpaceWire is also used to pass data from the Command and Data-handling system to the Ka and S-Band communications systems. Information from the Lyman-Alpha Mapping Project (LAMP) instrument is passed into an input/output board in the C&DH system and then sent over SpaceWire to the C&DH computer/mass memory. The C&DH computer includes a four-port SpaceWire router for handling the SpaceWire communications.

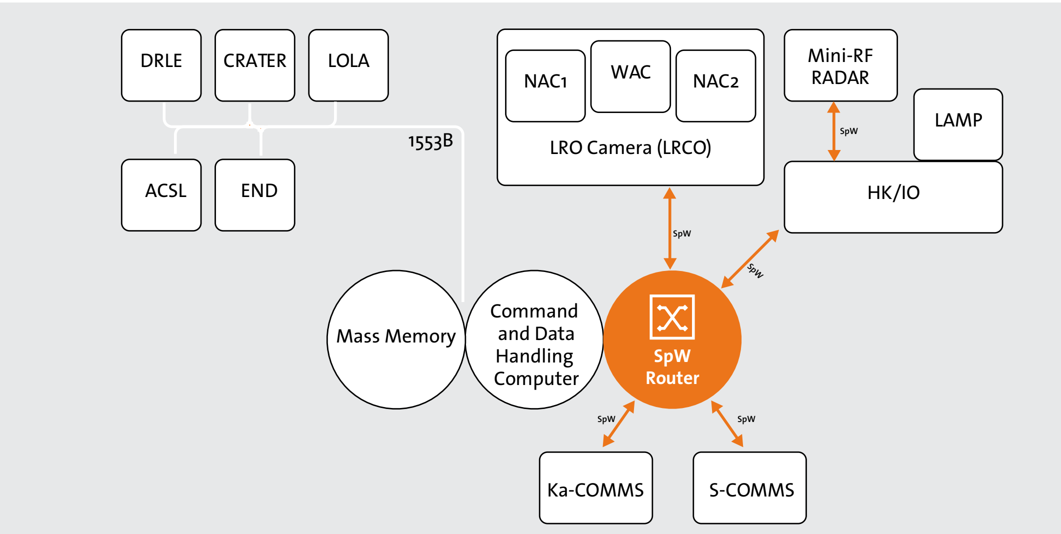
ASNARO SpaceWire networks

ASNARO is a Japanese optical high-resolution Earth-imaging mission.

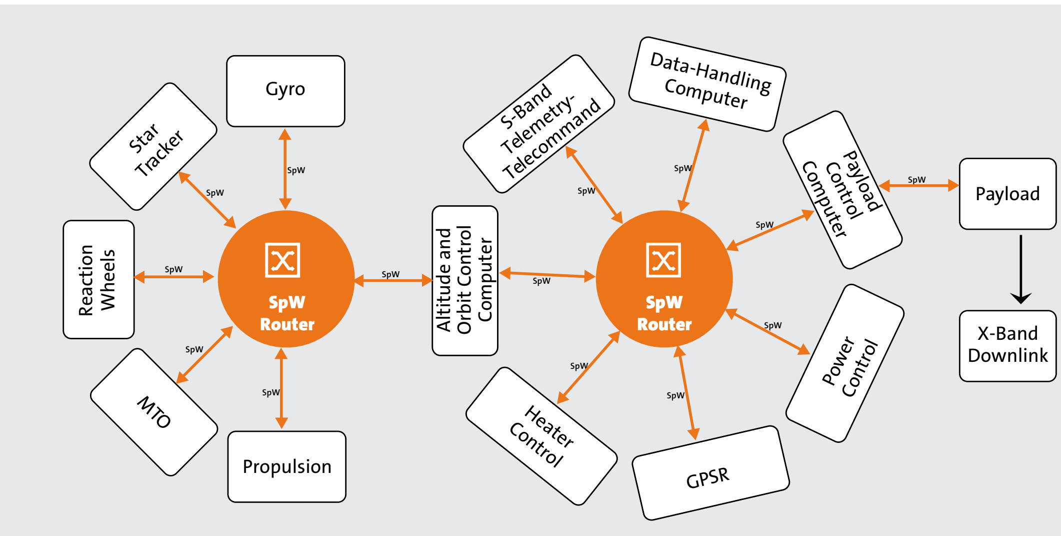
ASNARO is being developed by the NEC Corporation and the Japanese Institute for Unmanned Space Experiment Free Flyer (USEF) with funding from the Japanese Ministry of Economy, Trade and Industry. The objective of the ASNARO project is to develop a next-generation high-performance mini-satellite bus system based on open architecture techniques and manufacturing methodologies to drastically reduce the cost and the development period with adoption of up-to-date electronics technologies. SpaceWire is used on ASNARO for all the data-handling. ASNARO uses SpaceWire for platform and attitude and orbit control (AOCS) as well as for payload data-handling. The payload control computer is connected to the payload using SpaceWire. The platform electronics including the data-handling computer, payload computer, attitude and orbit control computer, heater control, GPS receiver, power control and S-band telecommand telemetry unit, are interconnected using a SpaceWire router. A separate SpaceWire network connects the AOCS sensors and actuators to the AOCS computer.



↑ ExoMars rover



↑ LRO in lunar orbit (NASA)



↑ ASNARO

How SpaceWire works

SpaceWire links

SpaceWire is a point-to-point data link that connects together one SpaceWire node (e.g. an instrument, processor or mass-memory unit) to another node or to a router. Information can be sent in both directions of the link at the same time. Each full-duplex, bidirectional, serial data link can operate at data rates from 2 Mbits/s up to 200 Mbits/s.

SpaceWire provides a simple mechanism for starting a link, keeping the link running, sending data over the link and ensuring that data are only sent when the receiver is ready for it. All data are protected by parity bits and SpaceWire automatically recovers from bit errors on the link.

SpaceWire packets

Information is transferred across a SpaceWire link in distinct packets.

The 'Destination Address' at beginning of the packet contains either the identity of the destination node or a list of characters that defines the path the SpaceWire network to reach to the destination node. The 'Cargo' is the data to be transferred. A packet can contain Cargo with an arbitrary number of data bytes. The EOP, or 'End_of_Packet' marker is the last character in a packet. The data character following an End_of_Packet is the start of the next packet. As shown the SpaceWire packet format is very simple. It is, however, also very powerful, allowing SpaceWire to be used to carry a wide range of application protocols, with minimal overhead.

SpaceWire networks

SpaceWire networks are constructed using SpaceWire point-to-point links and routing switches. SpaceWire routers connect nodes together and provide the means for routing packets from one node to any of the other nodes.

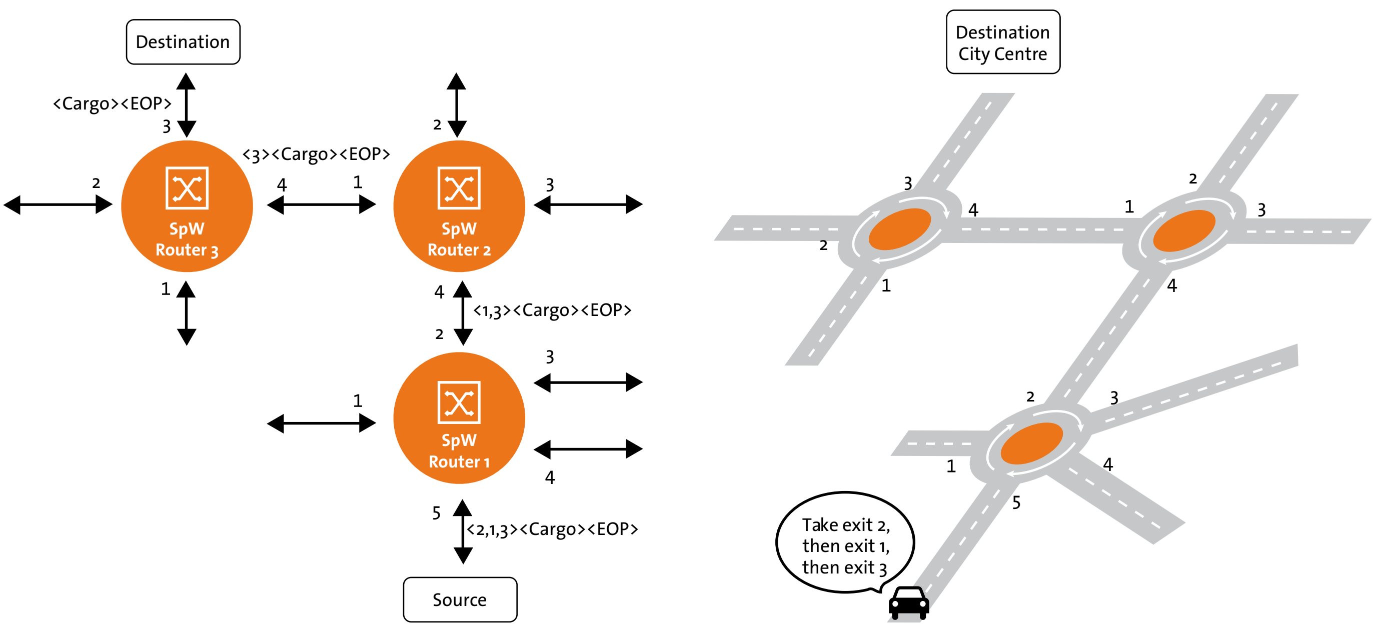
Packet addressing

There are two forms of addressing used to route the packet through a network: path addressing and logical addressing.

Path addressing can best be explained using the analogy of providing directions to someone driving a car. To reach the destination, you might suggest to the driver to take exit 2 at the first roundabout, exit 1 at the next roundabout and finally exit 3 on the third roundabout. There is one direction to follow at each roundabout (take a particular exit). Together these directions describe the path from the initial position to the required destination. Once a direction has been followed it can be dropped from the list.

In a SpaceWire network, the 'roundabouts' are routers and the 'roads' connecting the roundabouts are the links. The list of directions is provided as the destination address. The first direction is followed when the first

↓ Path addressing, with the analogy of a series of roundabouts, and how the path address at the start of the packet is modified as the packet goes through the network. Since a router can have a maximum of 31 ports along with an internal configuration port, each data character forming a path address is in the range 0 to 31



router is encountered. This direction is given in the first data character that specifies through which port of the router the packet should be forwarded. For instance, if the leading data character is 3, the packet will be forwarded to port 3 of the router. Once the leading data character has been used it is removed because it is no longer needed. This reveals the next data character in the path address to be used at the next router.

Explained using the same analogy of giving directions to a car driver, logical addressing is like saying to the driver, “Follow the signs to City Centre at each of the roundabouts.” This, of course, requires appropriate signs to be placed at each roundabout and each destination has to have a name or identifier so that it can be recognised on the signs.

In a SpaceWire network using logical addressing, each node is given an identifier in the range 32 to 254 (e.g. 44 for City Centre). Each router has a routeing table (like the sign at a roundabout) specifying the correct port to be taken to reach a destination.

The leading data character is used to look up the appropriate directions from the routeing table and the packet is forwarded accordingly. For logical addressing the leading data character is not discarded at each router, since it will be needed again at the next router.

Logical addressing has the advantage that only a single address byte is required, but it does require the routing tables to be configured before it can be used.

Path addressing requires one byte for each router and does not depend on routing tables in the routers.

Time-codes

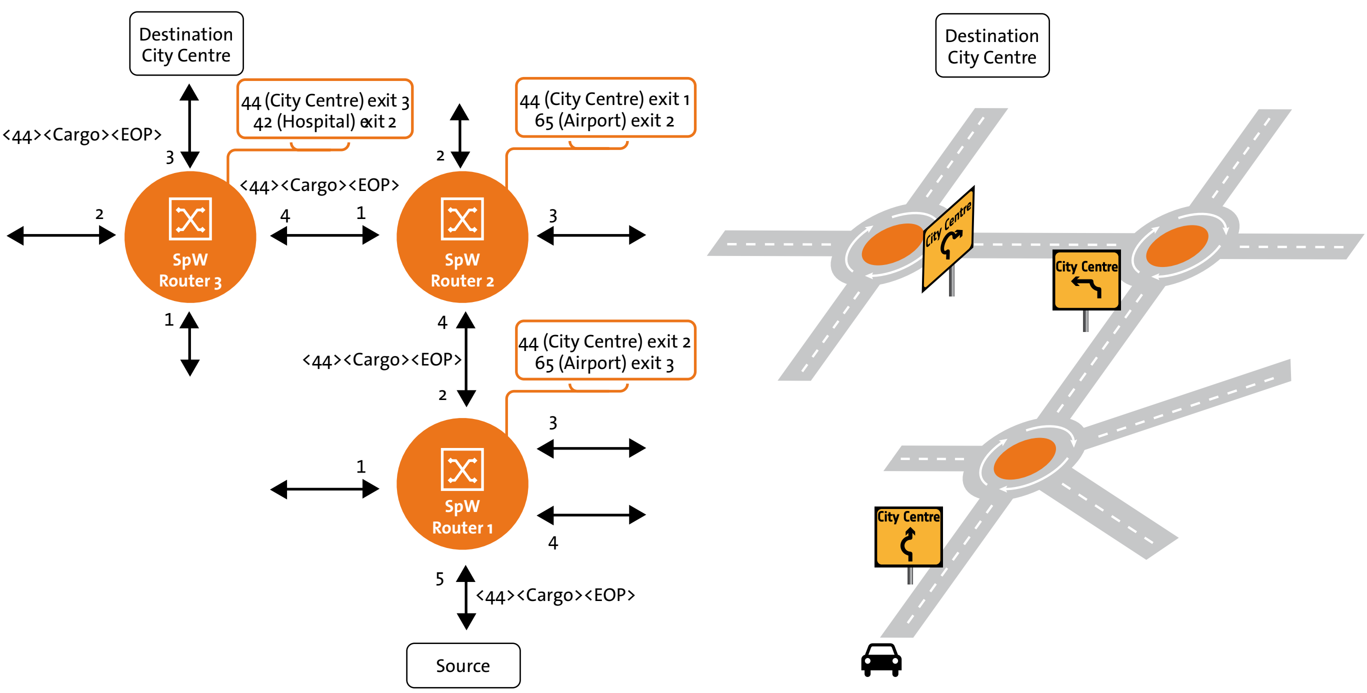
Time-codes are one additional feature of SpaceWire. They provide a means of synchronising units across a SpaceWire system to spacecraft time. The time-codes are broadcast rapidly to all nodes over the SpaceWire network, alleviating the possible need for a separate time distribution network.

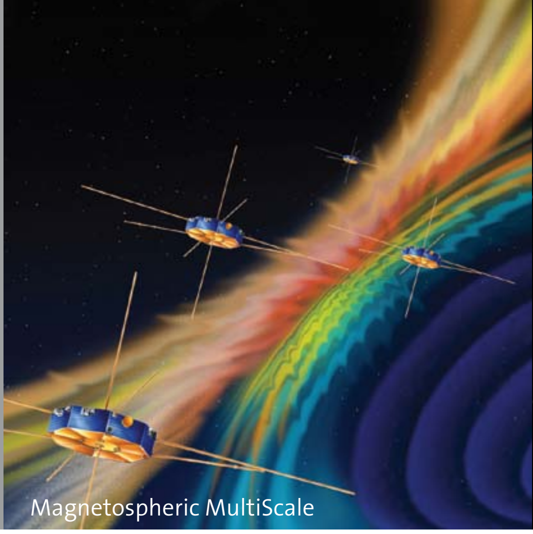
Remote Memory Access Protocol

The flexibility of SpaceWire means that it can be used in many different ways to transfer data between nodes and to support other needs such as configuring and controlling an instrument or another type of unit plugged on the network. To avoid unnecessary duplication of effort the SpaceWire Working Group examined common applications of SpaceWire and specified some additional protocols, enabling further standardisation of the on-board data-handing system. The SpaceWire Remote Memory Access Protocol (RMAP), which is specified in ECSS-E-ST-50-52C, is a particularly effective example of one of these protocols operating over SpaceWire.

RMAP provides a common mechanism for reading and writing to registers and memory in a remote device through a SpaceWire network. It can be used to configure devices, read housekeeping information, read data from an instrument or mass-memory, as well as writing data from an instrument into a mass-memory. Together RMAP and SpaceWire provide a powerful and versatile combination for spacecraft data-handling.

↓ Logical addressing uses just a single data character in the range 32 to 254 so that it does not get confused with path addresses




Magnetospheric MultiScale


Sentinel-1


Sentinel-3

ESA SpaceWire components and IP cores

To support the development of SpaceWire systems on ESA spacecraft, ESTEC, in Noordwijk (NL), has developed several radiation-tolerant SpaceWire chips and related intellectual property (IP) cores. The IP cores are available from ESA for use on ESA missions and from STAR-Dundee Ltd for other applications. The SpaceWire chips are available from Atmel (FR).

The ESA SpaceWire Interface IP core provides a complete interface to SpaceWire that can be readily implemented in a field-programmable gate array (FPGA) or other chip technology. Fully compliant to the SpaceWire standard, the IP core can be configured to meet the requirements of a wide range of applications. It has a simple interface to a host system, which provides for data input and output, time-code transmission and reception, and link status and error reporting. This IP core is being used in several ESA missions.

SpaceWire RMAP IP Core

There are two ESA SpaceWire Remote Memory Access Protocol (RMAP) IP cores available: one, known as the Initiator, which is used to send RMAP commands and receive replies, and the other, the Target, which receives the RMAP command, reads or writes data from and to memory, and send the result back to the Initiator. The RMAP Target IP core has a highly configurable memory interface so that it can be used in various applications from very simple instruments with registers for control and data access, to complex instruments controlled by a microprocessor.

SpaceWire Router ASIC

The ESA SpW-10X is a complete SpaceWire router in a single chip. It has eight SpaceWire ports each capable of 200 Mbits/s bidirectional data transfer, two bidirectional FIFO ports for connecting to other electronics (e.g. an FPGA or host computer), and an internal configuration port. The SpW-10X supports path and logical addressing, and has several advanced features designed to make the device easy to use in many applications. The SpW-10X was designed for ESA by the University of Dundee, Astrium GmbH and Austrian Aerospace. It is available from Atmel as the AT7910E.

SpaceWire RTC ASIC

The SpaceWire Remote Terminal Controller (RTC) chip is designed to be an instrument controller or a bridge between SpaceWire and the CAN bus. It contains a LEON2-FT SPARC V8 RISC processor with floating-point unit, 64 kB on-chip memory, two SpaceWire interfaces, two CAN bus controllers and various other interfaces. It was designed for ESA by Saab Ericsson Space and Gaisler Research and is available from Atmel as the AT7913E device.

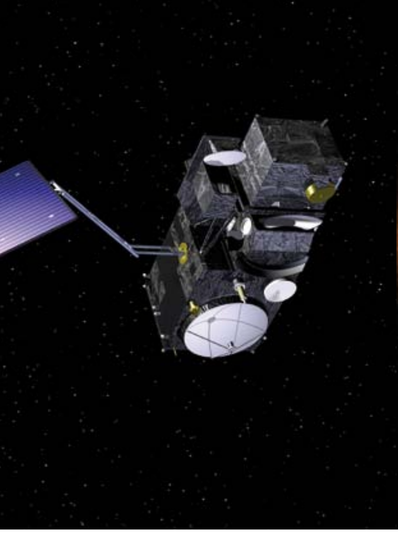
SpaceWire-compliant devices and IP cores are available from numerous suppliers worldwide, demonstrating the popularity of the standard.

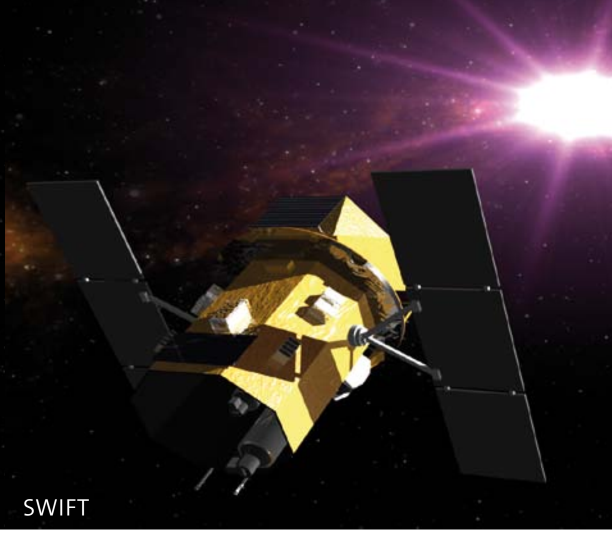
International collaboration

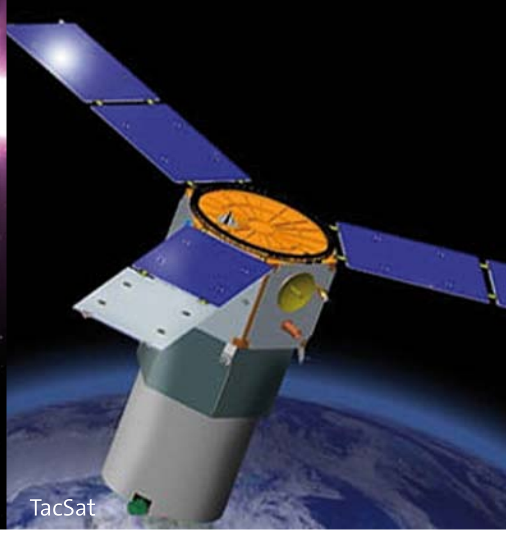
SpaceWire has both encouraged international collaboration and, in turn, benefited from that collaboration. The SpaceWire Working Group has been a major vehicle for the development and adoption of SpaceWire. The working group is open to engineers across the world who deal with spacecraft data-handling technology. Current participation includes European, Japanese, Russian and American representatives.

In line with ESA's mandate to promote cooperation in space research and technology, the SpaceWire Working Group is a truly international collaborative body, developing technology, not just for the European states, but also for the benefit of the whole space community. International technical experts meet typically twice a year to develop and review SpaceWire-related standards and trade experience on its application in space systems.

The SpaceWire standard is an open standard developed for anyone to use. It was authored by Steve Parkes, of the University of Dundee, with contributions from many individuals within the SpaceWire Working Group and from the international space agencies and space industry. To ensure the formal nature of the document and its appropriate maintenance, the SpaceWire standard was published by the European Cooperation for Space Standardization (ECSS). A series of standards related to SpaceWire including RMAP have been and are being







→ SpaceWire Conference 2011

The fourth SpaceWire conference will be hosted by NASA and held in San Antonio, USA, in 8–10 November 2011.

SpaceWire conferences bring together product designers, hardware engineers, software engineers, system developers and mission specialists, interested in and working with SpaceWire, to share the latest ideas and developments. Conferences are targeted at the whole SpaceWire community including both academics and industrialists. To support international collaboration and the exchange of ideas, experiences and technologies, the first International SpaceWire Conference was held in Dundee in 2007. Building on the success of this initial conference, SpaceWire 2008 was hosted by JAXA in Nara, Japan, and SpaceWire 2010 by Roscosmos in St Petersburg, Russia.

http://2011.spacewire-conference.org

written and incorporated in the body of space standards from the ECSS. While the ECSS is a European organisation, it provides standards that support international cooperation, of which the SpaceWire standard (ECSS-E-ST-50-12C) is a prime example.

Future

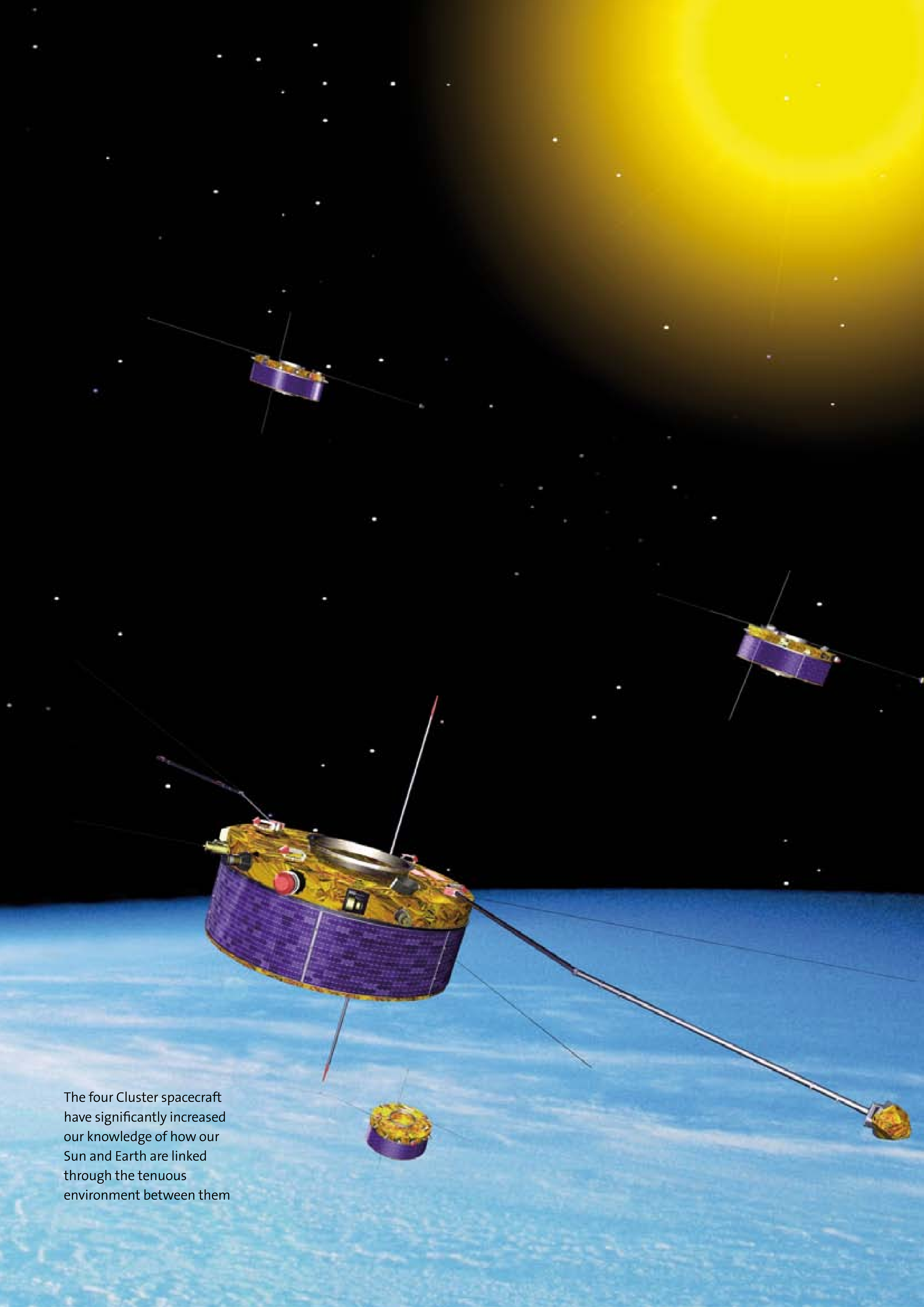
The SpaceWire Working Group is working on two new protocols for SpaceWire. The first is SpaceWire-D, which will provide deterministic data delivery over SpaceWire, making it suitable for AOCS-type applications. The second is SpaceWire-PnP, which will provide a common mechanism for configuring SpaceWire units and for automatic detection when a device is connected to the SpaceWire network. The standard specifies a very robust and therefore high-mass cable. ESA is developing a low-mass SpaceWire cable which aims to be around half of the mass of the existing cable, without a significant change in performance.

Research and technology development has also started on the next generation of SpaceWire technology. SpaceFibre is the spearhead of this development. While being fully compatible to SpaceWire on packet level, it will provide data rates of at least ten times that of SpaceWire, reduce the cable mass by a factor of four and provide galvanic isolation. SpaceFibre will be able to operate over fibre-optic and copper cable and support data rates of at least 2.5 Gbit/s. ■

↑ Attendees of the first SpaceWire conference in Dundee, including many members of the SpaceWire Working Group

Acknowledgements

The authors would like to acknowledge the contributions to SpaceWire from many individuals and organisations across the world. In particular, we would like to express our thanks to the members of the SpaceWire Working Group, who have reviewed and commented on the various SpaceWire standards as they were developed. This extends as well to an even larger community of users and suppliers of SpaceWire technologies.



The four Cluster spacecraft have significantly increased our knowledge of how our Sun and Earth are linked through the tenuous environment between them

→ THE LEGENDARY CLUSTER QUARTET

Celebrating ten years flying in formation

Matt Taylor, Arnaud Masson, Philippe Escoubet & Harri Laakso
Directorate of Science and Robotic Exploration, ESTEC, Noordwijk, The Netherlands

Jürgen Volpp
Directorate of Operations and Infrastructure, ESOC, Darmstadt, Germany

Mike Hapgood
Rutherford Appleton Laboratory, Didcot, Oxfordshire, UK

February 2011 marks the tenth anniversary of the start of the science phase of the four ESA Cluster satellites, in one of the most successful scientific missions ever launched.

The ESA/NASA Cluster mission has spent a decade revealing previously hidden interactions between the Sun and Earth. Its studies have uncovered secrets of the aurora and solar storms, and given us insight into fundamental processes occurring across the Universe.

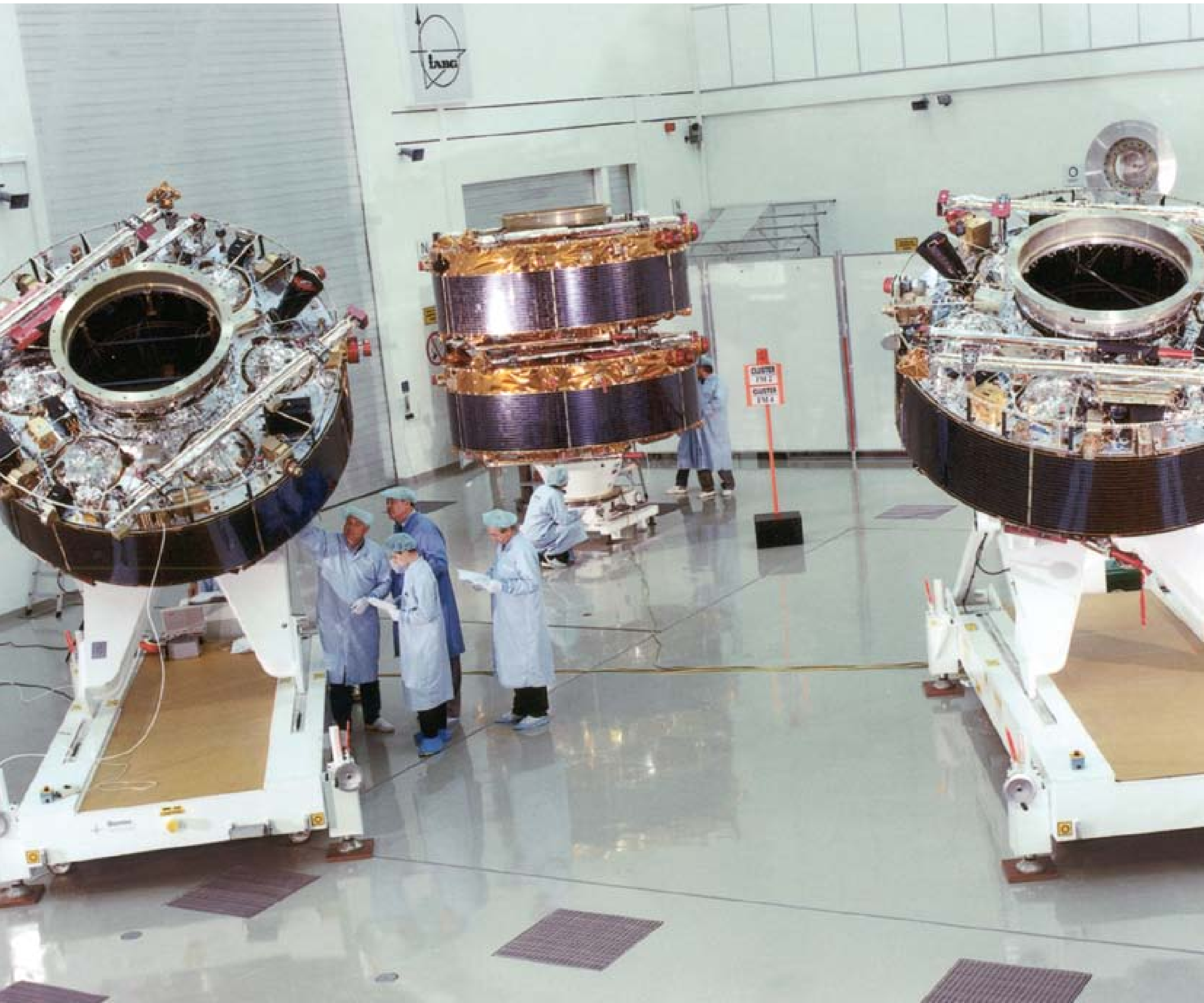
In September 2000, just a few weeks after launch, the four satellites, Cluster 1, 2, 3 and 4 – dubbed Rumba, Salsa, Samba and Tango – began flying in formation.

They have gone on to collect some of the most detailed data ever on the physical properties of space between Earth and the Sun, and on the interactions between the charged particles of the solar wind and Earth's atmosphere. In all, over 2.6 terabytes of data – enough to fill 3300 CD-ROMS – have been delivered from space.

"We are doing astrophysics close to home," said Prof. David Southwood, ESA's Director of Science and Robotic Exploration, at a press conference celebrating 10 years of the Cluster mission held in September 2010. "In fact, we are looking at important parts that astrophysicists cannot see directly. Beyond the Solar System is an enormous Universe, filled with uncountable stars. The space between them is full of electromagnetic fields that transmit forces and guide and control the behaviour of matter there. Other missions study the objects – the 'islands' in the universal 'ocean' – but Cluster studies the very ocean itself," he added.

The scientific rationale of the Cluster mission is to understand better the impact of the Sun on Earth's space environment. But to achieve this goal, physical processes, ubiquitous across the Universe, need to be understood.

This includes magnetic reconnection, shock physics, plasma turbulence and particle acceleration. The local space environment around Earth is the closest natural laboratory in which to study these phenomena *in situ*, a place where the direct measurement of the magnetic field, electric field and particle distributions, the core ingredients of these processes, is possible.



↑ The four original Cluster spacecraft at the test and integration facilities at IABG near Munich, Germany

→ Cluster history

The Cluster mission was first proposed to ESA in November 1982, in response to a Call of Opportunity for new science missions. After feasibility studies, the mission was approved in 1986 as part of the first 'cornerstones' of the Horizon 2000 long-term programme.

By 1995, after long years of work and preparation, Cluster was ready for launch. Ever sensitive to cost saving, it was decided to take advantage of a 'free' launch on the maiden flight of the new Ariane 5 rocket. Ariane 501 lifted off from Kourou, French Guiana, on 4 June 1996, carrying its payload of the four Cluster satellites. Catastrophe followed. Within a minute, as the rocket rose, an inappropriate setting of a software module led to intense aerodynamic loads on the rocket. The immediate result was a break-up of the launcher and the initiation of the automatic destruct system. The launcher, the four Cluster satellites and ten years of work were destroyed in less than a minute.

> **"Ten years is a long time in the severe conditions of space."**

Phoenix from the ashes...

After this disastrous setback, perhaps against the odds and after a tremendous effort, finance was found for the mission to be revived. Only one year later, in 1997, thanks to the support of ESA Member States and NASA, Cluster II was approved. To recover the unique science promised by the mission, ESA tasked industry to build one new Cluster satellite from spare parts prepared as part of the original Cluster mission. A further three satellites and their instruments were then commissioned from industry and the scientific community. Impressively, in less than four years, a new set of Cluster satellites was ready to be launched.

↑ Soyuz rocket carrying a pair of Cluster satellites is ready for launch at Baikonur, Kazakhstan, in 2000

The Sun–Earth connection in three dimensions

The four Cluster satellites work together, collecting three-dimensional information on how the solar wind, the perpetual stream of subatomic particles expelled by the Sun, interacts with the magnetosphere, Earth's natural cloak of magnetism. The great strength of Cluster is its multi-satellite nature. The magnetosphere is a complex time varying system, governed by the dynamic interplay of the charged particles together with electric and magnetic fields which act on different length and time scales. As a result it is difficult to fully disentangle any dynamic change in measurements with a single spacecraft.

Cluster's four identical satellites allow us to distinguish between spatial and temporal changes in the magnetosphere: if all four satellites register the same change in the plasma at the same time, then a temporal change that is uniform on at least the scale of the satellite separation has been observed, whereas if the satellites observe a change at different times it is more likely that a localised structure has propagated across the satellites. The tetrahedron (triangular pyramid) formation of the four Cluster satellites allows the velocity vector of these propagating features to be determined in three dimensions.

Another unique capability of Cluster is its ability to measure the spatial gradients of quantities by comparing measurements made by the four satellites. For example, Cluster can examine changes in the magnetic field and derive electric current densities flowing in the local plasma. Such currents at high altitude not only shape and mould the magnetosphere, but also during solar storms can affect everyday life by causing damage by inducing excess current in electrical power grids on the ground.

Mission and science operations

The first pair of Cluster satellites lifted off on 16 July 2000, and the second pair three weeks later on 9 August 2000, on Soyuz rockets from Baikonur, Kazakhstan. At each launch, two Cluster satellites were placed in an elliptical orbit whose height varied from 200 km to 18 000 km above Earth by the Fregat upper stage. After separation, each satellite used its own propulsion system to reach the final operational orbit: 19 000 km to 119 000 km, about a third of the Earth-to-Moon distance. Routine mission operations then began for the Cluster Flight Control Team at the European Space Operations Centre (ESOC) in Darmstadt, Germany.

ESOC's Cluster team controls the satellites and their payloads, and carries out all activities related to mission planning and scheduling. Supported by flight dynamics specialists, mission planning engineers and ground station controllers, Cluster operations engineers keep contact with and control over the satellites. The team is responsible for operating and manoeuvring the satellites in their precise orbits, commanding the satellites and instruments as well as retrieving the scientific data.

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Separation of the Tango (C4) satellite seen from the Rumba (C1) spacecraft about three hours after launch

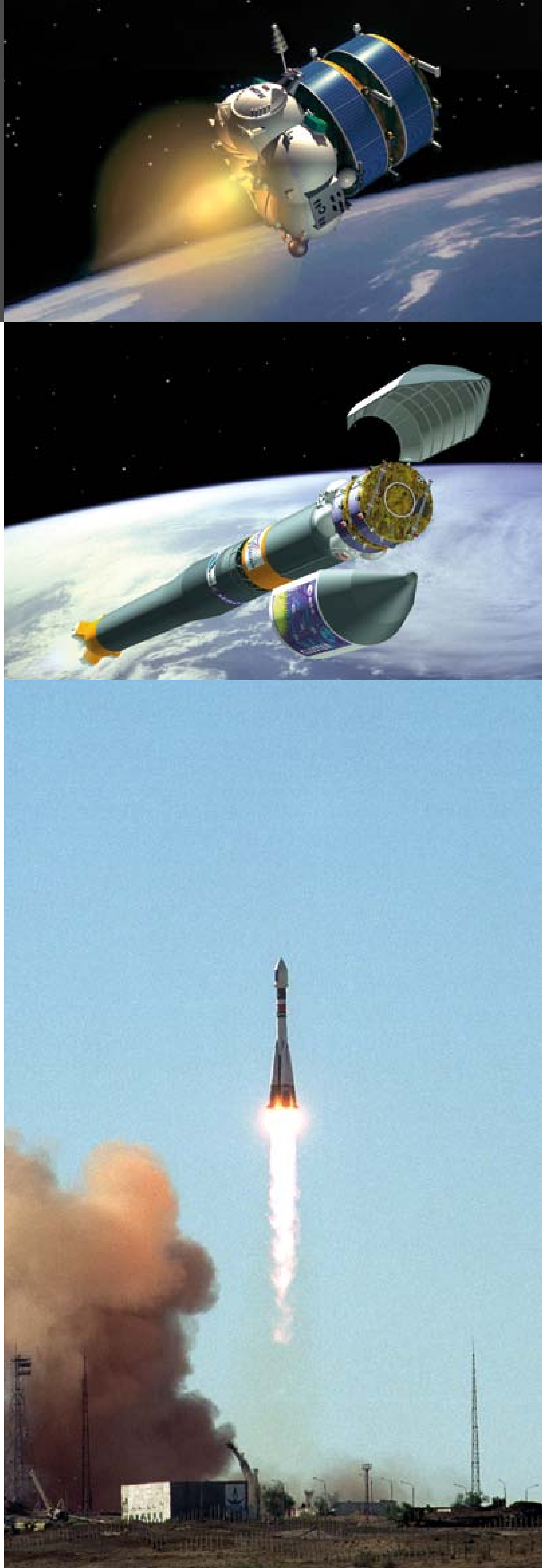
The critical task of co-ordinating the Cluster's science operations, planning the complex operation of scientific instruments and generating the consolidated payload command set every week is carried out by the Joint Science Operations Centre (JSOC), located at the Rutherford Appleton Laboratory, Didcot, UK. This coordination is a particularly demanding task.

Cluster is a 'Principal Investigator'-class mission, meaning the Principal Investigators (PIs) of the 11 instruments on board each of the four Cluster satellites retain a major role in instrument operation throughout the mission. These PI teams have worked very hard to ensure optimum science is returned from their instruments. JSOC is the interface through which the Principal Investigators submit inputs to take into account in the payload command schedule and receive feedback on the status of their inputs. JSOC carries out Cluster science operations under the direction of the Cluster Project Scientist.

During the course of the mission, the distance between the Cluster satellites has changed numerous times. Varying the size of the Cluster 'constellation' has allowed Cluster to examine Earth's magnetosphere at different scales, targeting the tetrahedron in various regions around the orbit.

In 2005, a new 'asymmetric' flying formation allowed the satellites to make measurements of medium and large-scale phenomena simultaneously, transforming Cluster into the first ever 'multiscale' mission. Such an orbital configuration facilitates study of the link between medium-scale kinetic processes of the plasma around Earth and the large-scale morphology of the magnetosphere.

In one of the most complex manoeuvres ever conducted by ESA to date, Cluster 1, 2 and 3 became separated by 10 000 km to form a triangular shape with Cluster 4 at 1000 km from Cluster 3 in a direction perpendicular to the large triangle. In 2007, Cluster 3 and 4 were orbiting just



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A sequence showing the launch of two Cluster satellites: the Soyuz rocket ascending just after launch, an artist's impression of fairing jettison and lastly the Fregat upper stage putting Cluster into a parking orbit

17 km apart – the closest distance that two ESA spacecraft have achieved in routine operations. To date, these satellites have been commanded through around 800 orbital manoeuvres – an enormous number in spacecraft navigation terms.

Ten years is a long time in the severe conditions of space. The four Cluster satellites are all showing their age and the operations team faces a daily challenge to keep the fleet operational. Perhaps the biggest task is to make sure the power keeps flowing. The solar panels no longer generate as much electricity as they did, and the batteries are gradually breaking down in a dramatic way: a series of minor explosions.

The batteries are made of non-magnetic silver-cadmium to avoid interfering with Cluster's instruments. But over time, such batteries generate oxy-hydrogen, an explosive gas. To date, seven batteries have cracked across the four satellites, two of which were more like small explosions. Ground controllers saw the satellites lurch each time this happened. From 20 batteries, just seven remain (November 2010).

Engineers have devised ingenious workarounds to account for these battery issues and the normal reduction in electrical power as the solar panels degrade. The ESOC team has implemented creative scenarios for operations so that the satellites remain almost fully functional despite the loss of battery power. In particular, new strategies ensure the satellite health, even during long eclipses, and enable a fast restart of science measurements after a complete power-down.

Earth's space environment

Earth's magnetic field is generated deep inside our planet but the domain over which it has influence, the magnetosphere, extends far into space, forming an obstacle in the solar wind many times bigger than Earth.

As the solar wind is supersonic, a shock wave is formed upstream of Earth, similar to the shock formed by a supersonic aircraft. However, whereas in ordinary gases or liquids shocks are formed due to collisions between particles, the rarefied nature of space plasma implies that the plasma is essentially 'collisionless'. In such a medium, electromagnetic fields and waves play the role of collisions in the formation of a 'collisionless shock'.

Earth's bow shock slows the solar wind and forms a 'magnetosheath' around the magnetospheric bubble bounded by the magnetopause. The magnetosphere has a tail like a comet extending hundreds of thousands of kilometres behind Earth (in the direction away from the Sun), called the 'magnetotail'.

Unfortunately, the magnetosphere is only partially protective. Gusts and storms in the solar wind are known as 'space weather' and can penetrate the shield and cause a variety of disruptive effects.

Cluster's orbit was designed to investigate these regions, including the cusps, the high-altitude regions above the magnetic poles where solar wind plasma enters and interacts with the atmosphere to form the aurora.

During the 'dayside' season in winter/spring Cluster samples the solar wind, bowshock, magnetopause and magnetosphere. During the night-side season, six months later, the magnetotail and related regions are sampled.

Securing Cluster science for the future

The Cluster Active Archive (CAA) has been specially set up to give free access to Cluster high-resolution data. It will ensure the greatest scientific output possible from Cluster and provide its data for future generations of scientists. The CAA is a database containing the highest temporal and spatial resolution data and other allied products and services. A small team, led by the Archive Project Manager, is conducting the programme at ESTEC.

In view of the shortage of manpower in most institutes processing Cluster data, ESA is supporting teams deployed in institutes where the relevant expertise exists, to assist in

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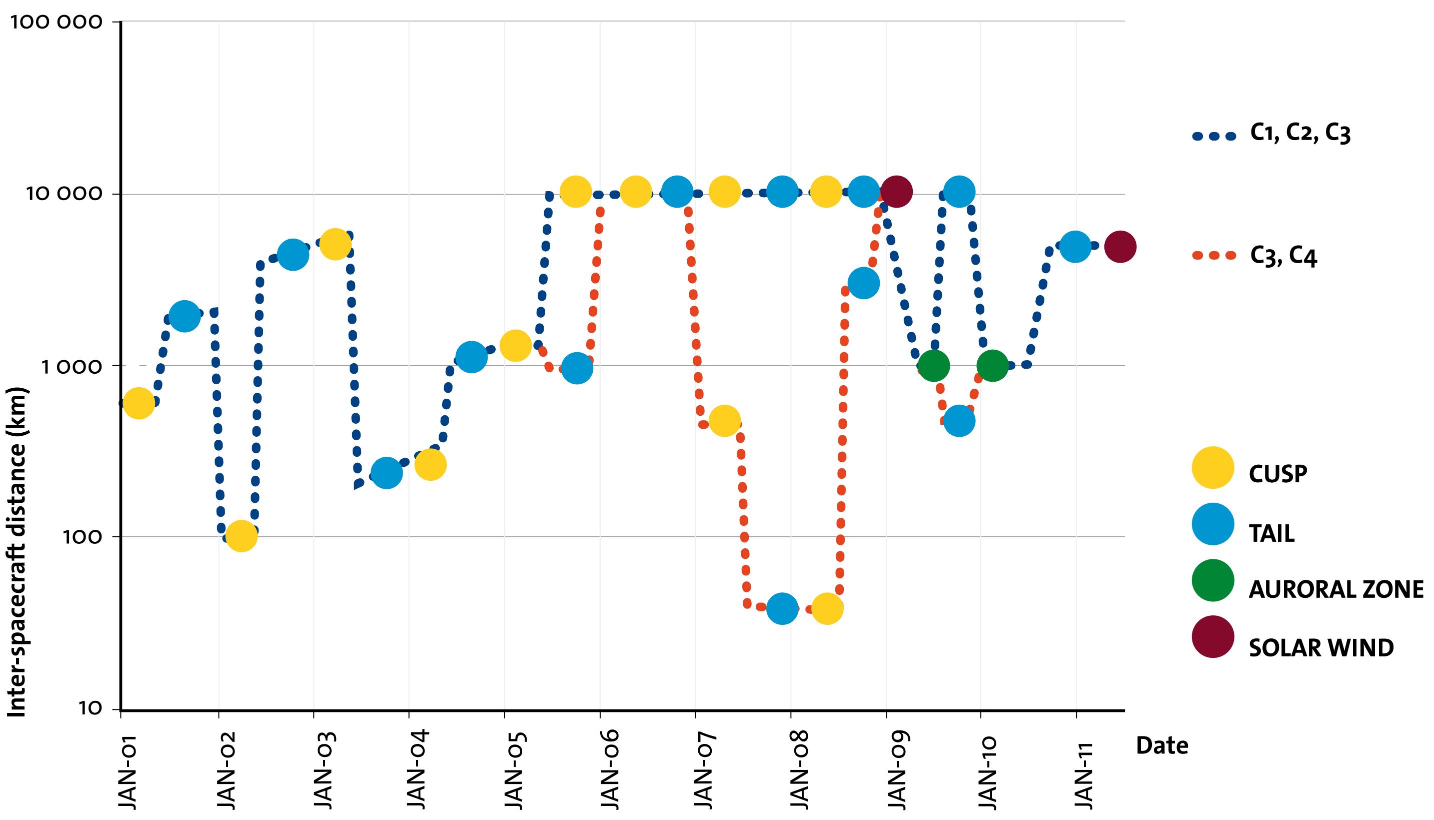
The inter-satellite separation during the mission, indicating target regions of the magnetosphere: the region high above the magnetic poles known as the cusp, the magnetic tail on the night side of Earth, the auroral zone and the solar wind. Since 2005 Cluster has made several multi-scale investigations, separating three satellites in a triangle by thousands of kilometres while having the fourth satellite at tens to hundreds of kilometres from this triangle



the calibration, preparation, validation and documentation of the high-resolution data deposited in the archive.

Routine activities include yearly CAA operations reviews, where the CAA infrastructure is reviewed by an external advisory board. Inter-calibration meetings are held every six months, where all teams attend and present the status of their inter-calibration efforts, both inter-satellite and across different instruments measuring the same physical quantities. This unique activity has greatly improved the quality and accuracy of the datasets, as well as building expertise in the instrument teams.

This activity would not have been possible without the CAA. Routine peer reviews of the data products, documentation and the archive itself are carried out. Also, monthly reports from the teams are collected, reviewed and redistributed to all CAA teams to allow them to have visibility of all activities. Yearly meetings with teams are an important aspect of the CAA activities, where the core CAA team is able to address the progress of each team individually.

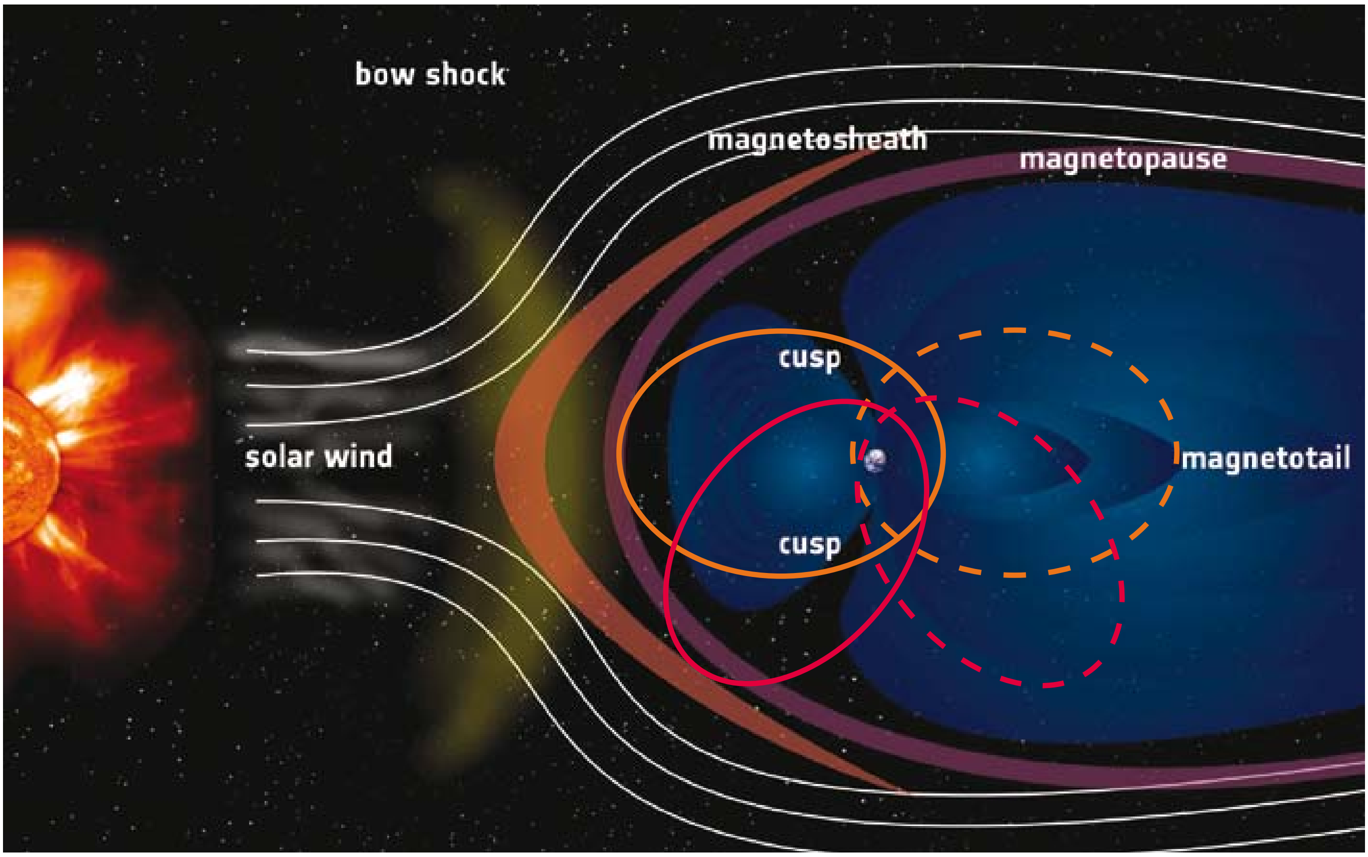
The CAA was opened to the public on 1 February 2006. The database currently contains data from 2001 to 2009 and the following years will be added in turn. The CAA currently has over 1110 registered users with an average of 20 new users every month. During 2010, the average data download rate was around 1 terabyte per month.

Cluster's global community

There is a global science community working on Cluster. Every other day, a science team somewhere in the world has a paper accepted for publication that relies on Cluster data. After 10 years in space, the data collected by Cluster satellites have already enabled the publication of 1360 refereed publications (and counting).

↓

The magnetosphere of Earth, indicating a number of regions where Cluster has been able to investigate: the magnetopause, magnetosheath, cusps, magnetotail, solar wind and bow shock. The orbits of the Cluster satellites are indicated, where solid represents the winter/spring season and dashed the summer/autumn season. To demonstrate the evolution of the orbit due to lunar-solar gravitational perturbations, we have indicated the orbit during 2001 in yellow and 2010/11 in red. This drift has allowed for even greater coverage of the magnetosphere



The Cluster Active Archive will ensure that this excellent science output will continue even after the mission itself comes to an end and the CAA already has over a thousand users worldwide.

The operational lifetime of the Cluster mission has been extended four times: first to 2005, then 2009, then to 2012 and very recently up to 2014 (a review will confirm the last extension in two years' time). Thanks to the latest extension, Cluster scientists and engineers will now be able to study the rise and peak of the Sun's current 11-year cycle of activity, solar cycle 24, which should peak in 2014.

Cycle 23 was unusually long, presenting the deepest and longest minimum of solar activity since the start of the Space Age, its unusual nature giving the potential for a cornucopia of new insights in the analyses under way. Cluster will continue to observe the magnetosphere as

→ Science highlights

Earth's bow shock

Collisionless shocks are ubiquitous in the Universe. They can be found mediating the interaction between planets and ordinary stars' stellar winds, in supernova remnants, space jets and gamma-ray bursts. These shocks are efficient accelerators of particles, capable of accelerating cosmic-ray particles to extreme energies. Multi-spacecraft *in situ* observations provide the best way to examine collisionless shocks in detail and are only available for the terrestrial bow shock.

Observations made by Cluster have underpinned major breakthroughs in the understanding of the physical processes responsible for the formation of the bow shock. The multipoint measurements at the shock front enable the separation between temporal and spatial changes and study of the spatial scales of the shock front. The spatial scales are closely related to the type of physical process that is responsible for shock formation.

Magnetic reconnection

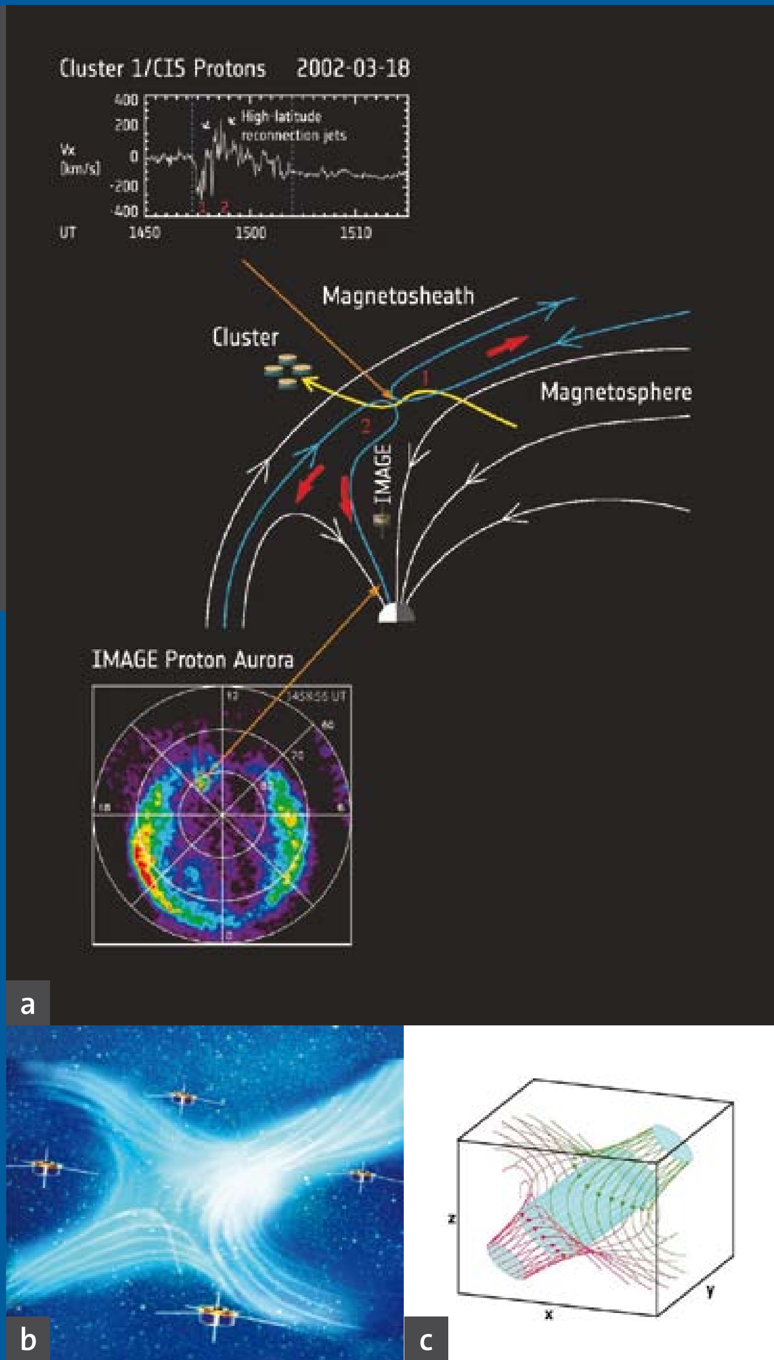
Understanding magnetic reconnection is a major quest in physics. It is responsible for tremendous solar explosions, known as 'solar flares' that can be a billion times more powerful than an atomic bomb. In Earth's magnetotail, magnetic reconnection can funnel particles towards Earth, leading to increased auroral activity. Although reconnection releases energy from plasma in Earth-based laboratories, unwanted reconnection frustrates efforts to contain plasma and its suppression is of major interest for the design of possible fusion reactors.

Magnetic reconnection can take place when plasmas with embedded magnetic fields collide. When this happens, the shape of the 'magnetic landscape' changes, allowing previously separated plasmas to mix, enabling for instance solar plasma to enter the magnetosphere along reconnected field lines. Moreover, in the process the plasma is heated and individual particles are accelerated. However, certain fundamental properties of this phenomenon remain unknown. One key issue is what happens at the heart of the process, known as a magnetic 'null' point. Cluster data have led to the first 3D picture of a null, the magnetic heart of reconnection. Vital new insights include showing that the magnetic field can be twisted into tubes 500 km wide around the complex reconnection null region.

← The bow shock around the very young star LL Ori, located in the intense star-forming region known as the Great Nebula in Orion. Cluster is able to directly sample the nature of shocks at Earth's bow shock (NASA/STScI/AURA) cycle 24 builds up, providing us with full coverage of the unusual transition and, hopefully, its implications.

Cluster has revealed the effectiveness of measurements at multiple points and different scales in space plasma environments. It was coordinated for part of its time with the Chinese satellite pair, Double Star, and has paved the way for more recent and future space plasma missions (NASA's five-satellite THEMIS mission, the dual-satellite Radiation Belt Storm Probes mission and the four-satellite Magnetospheric Multiscale mission).

Cluster was the pioneer, but it has set the agenda for the future. New mission concepts being discussed and proposed involve collections of spacecraft at varying scale sizes – clusters within clusters – which will bring us even closer to understanding not only how the Sun and the terrestrial magnetosphere interact, but how the plasma universe behaves. ■



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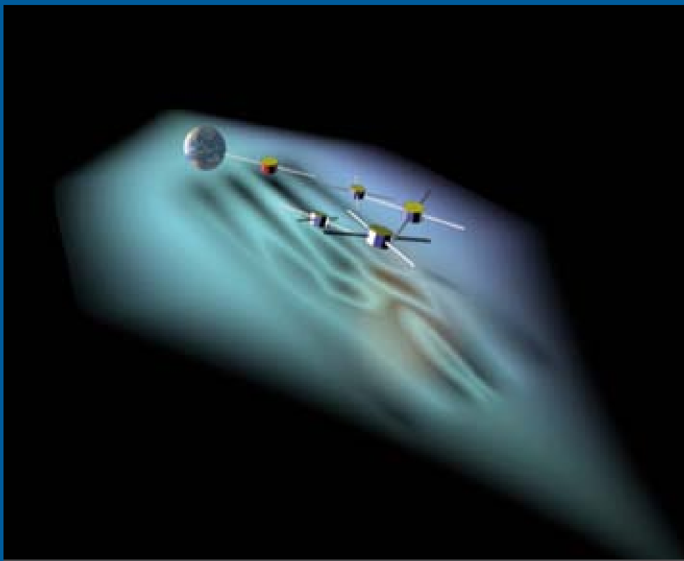
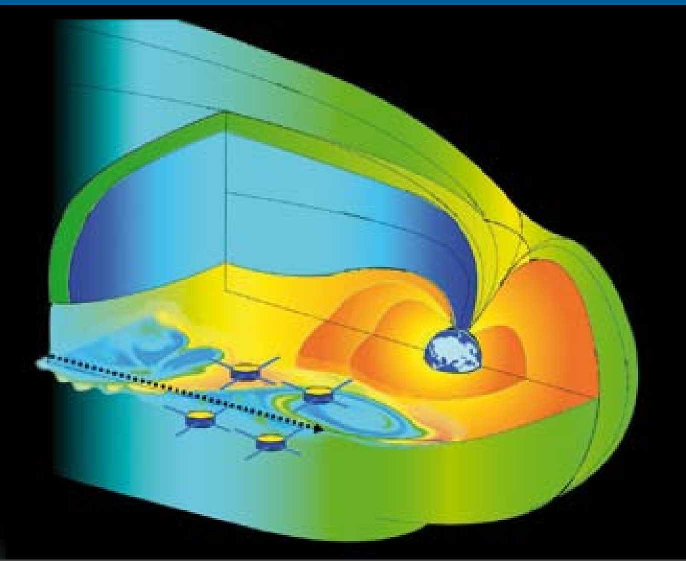
a) A composite image showing an event where Cluster flew close by a magnetic reconnection region and observed characteristic 'jets' of ions expelled from the null. These particles spiral down the field lines into the auroral region and were detected by the NASA IMAGE satellites, showing up as a spot on the auroral oval. b) Artist's impression of the four Cluster spacecraft spanning a reconnection null region observed in the magnetotail. The set of reconnecting magnetic field lines form a spiralling tube structure around 500 km wide, as shown in (c). This characteristic size had never been reported before in observations, theory or simulations until the observations by Cluster.

Extent of magnetotail oscillations

In mid-2004, Cluster's four satellites and one from the Chinese/ESA Double Star mission were coasting through the night-side magnetosphere at a time when Earth's magnetotail was quivering, and took detailed measurements. Though it is still unknown exactly what triggers these fluctuations in the magnetotail, the satellites revealed that they take place across scales larger than 30 000 km.

A wave motion begins in the centre of the magnetotail and moves outward like the waves created by a boat travelling across a lake. This suggests that the oscillations are generated in the tail itself, rather than imposed on it from outside by a gusty solar wind. Because of the geometrical arrangement of the satellites at the time of the observation, the oscillation was detected closer to Earth than ever before – only 70 000 km. At such proximity, oscillations like these direct particles into Earth's atmosphere where they create the colourful auroras.





↑ Artist's impression of the oscillations observed in the magnetotail by Cluster (blue) and Double Star TC-1 (red)

↗ A three-dimensional cutaway view of Earth's magnetosphere. The wavy features sketched on the boundary layer are the Kelvin-Helmholtz vortices on the dawnside of the magnetosphere revealed by Cluster. They originate where two adjacent flows travel with different speed. In this case, one of the flows is the heated gas inside the boundary layer of the magnetosphere, the other the solar wind just outside it (black dashed arrow is Cluster's trajectory)

Giant swirls at the edge of the magnetosphere

Earth's magnetosphere protects the planet from most of the electrically charged particles pouring from the Sun. However, it is only partially effective. Giant whirlpools of plasma can form along the flanks of our magnetic shield, boring into it. These whirlpools are generated by the solar wind sliding past Earth's magnetic field in roughly the same way as wind blows across the surface of an ocean. Thanks to multi-point measurements by Cluster, the size of these vortices has been established and found to be huge: around 40 000 km across, nearly six times Earth's radius.

Computer reconstructions show that these whirlpools inject electrified gas into Earth's magnetic environment by forcing magnetic reconnection to take place within these swirls. This opens passageways that allow the plasma to cross the usually impenetrable boundary. This discovery has solved a long-known mystery: how the outer layer of Earth's magnetosphere can be constantly topped up with electrified gas, when it had been thought that it should rather act as a shield.

Auroras

Anyone living near the Arctic or Antarctic Circle will be familiar with the aurora, the red and green curtains of light in the upper atmosphere or 'ionosphere' that illuminate the long winter nights. Much less familiar is the mysterious 'black aurora', which produces dark, empty regions within the visible northern and southern lights. The black aurora takes on various guises: dark rings, curls or blobs that punctuate the glowing colours. Cluster has shown that these peculiar patches occur where there are 'holes' in the ionosphere. From these holes, negatively charged ionospheric particles have been pulled upwards into space. This is the opposite of what happens in the bright coloured aurora, where electrons spiral down from space into the atmosphere, collide with ionospheric particles and make them fluoresce.

Thus, the black aurora is, in fact, an 'anti-aurora', a hole in the visible one. Indeed, Cluster has shown that after a few minutes, all available electrons are 'sucked' out of the ionosphere, and the black anti-aurora is filled in by the normal colour one. In the course of the last five years, Cluster's closest approach to Earth has lowered due to the influence of the Sun and Moon, from 19 000 km to just a few hundred kilometres. This swept Cluster through the regions responsible for the final acceleration of particles before reaching the upper atmosphere and triggering auroral arcs, giving scientists an unparalleled view of this behaviour.

Shocking recipe for 'killer' electrons

Our planet is surrounded by two belts of trapped high-energy particles, held in place by Earth's magnetic field, called the Van Allen radiation belts. Killer electrons in the outermost Van Allen belt move close to the speed of light and carry a lot of energy. These can penetrate satellite shielding and cause microscopic 'lightning' strikes that damage and sometimes destroy vital electronic components.

↑ The dark bands separating the arcs in the green aurora pictured here are an example of a black aurora. A black aurora isn't an aurora at all; rather it is a lack of auroral activity. The black aurora is only visible to the naked eye if it is embedded in a region of diffuse (faint) aurora. Auroras are caused by the precipitation of particles accelerated at thousands of kilometres above the upper atmosphere, known as the auroral acceleration (AAR) region. Thanks to the extension of the Cluster mission, the AAR was crossed for the first time by multiple spacecraft in 2009 (J. Curtis, Fairbanks, Alaska)

↑

Data from Cluster, and other spacecraft monitoring the magnetosphere, have shown that interplanetary shocks – caused by coronal mass ejections from the Sun – can create 'killer electrons' in the near-Earth space environment within 15 minutes of the shock reaching Earth's protective magnetic bubble. Killer electrons are highly energetic particles trapped in Earth's outer radiation belt (right, a zoom of the near-Earth magnetosphere, with radiation belts as the blue torus)

Even before the Space Age, the behaviour of Earth's magnetic field during solar storms suggested that Earth is surrounded by a variable ring current, generated by electrically charged particles from the Sun. Such particles were indeed found in the Van Allen belts, but it was only some 40 years after their discovery that Cluster was able to make an accurate determination of the permanent ring current around Earth through its detailed measurement of the magnetic field in this region.

Intense solar activity can disrupt the Van Allen belts, and Cluster made another vital discovery when it was on hand to observe directly the effects of a particularly strong solar storm hitting the magnetosphere in 2004. It saw the creation of killer electrons through what turns out to be a two-step process. The electrons are initially accelerated by the storm compressing Earth's magnetic field. Then Earth's magnetic lines wobble, making something like a very large-scale, low-frequency laser that accelerates the electrons even more to these 'killer' energies. Cluster showed that this transition, from normal to killer intensities, can happen in just 15 minutes.

As well as advancing our understanding of plasma physics, Cluster has a practical side: it unveils the environment that spacecraft such as navigation and communications satellites are expected to work in. Solar particles can damage spacecraft electronics, sometimes critically, so Cluster's characterisation of this danger can lead to more robust satellite design.

→ FIRST SCIENTIFIC RESULTS FROM PLANCK

Following the publication of the first full-sky Planck image in July last year, the first scientific results from the mission were released in January, focusing on the coldest objects in the Universe, from within our galaxy to the distant reaches of space.

The basis of many of these results is Planck's 'Early Release Compact Source Catalogue' (ERCSC). Drawn from Planck's continuing survey of the entire sky at millimetre and submillimetre wavelengths, the catalogue contains thousands of very cold, individual sources which the scientific community is now free to explore

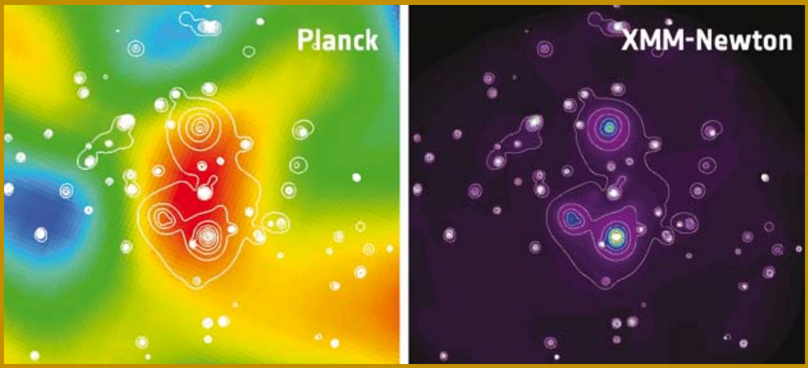
> **Planck will reveal the Cosmic Microwave Background in unprecedented detail, the opening act of the cosmic drama, a picture of the beginning of everything.**

Early Release Compact Source Catalogue

Launched on 14 May 2009, ESA's Planck satellite has been surveying the sky in nine frequencies, covering the spectral range 30–857 GHz, since 13 August 2009. Its main goal is to measure tiny fluctuations in the Cosmic Microwave Background (CMB), the oldest source of light in the Universe, the relic radiation of the Big Bang.

This radiation is, however, 'contaminated' by foreground emission from cosmic structures of all sizes located between the CMB and us – galaxies, galaxy clusters and, within the Milky Way, gas and dust spread small over small as well as large scales. So the first step before the rich cosmological information concealed in the CMB can be accessed is to carefully characterise and separate out this foreground emission.

As a byproduct, the study of this foreground delivers an extensive list of individual compact sources as well as a series of maps of the galactic diffuse emission – both of these are valuable resources for a variety of studies in the fields of galactic and extragalactic astrophysics alike. The individual sources detected during Planck's first all-sky survey that are classed as highly reliable are catalogued in the ERCSC, which is the first scientific product based on Planck data to be made publicly available. The public release of the ERCSC, which consists of nine lists of foreground sources detected in each of Planck's frequency channels, provides astronomers with an extremely valuable resource. The catalogue has a number of unique features: it has the widest frequency coverage of any catalogue produced by a single telescope scanning the whole sky and it contains the first all-sky inventory of sources at submillimetre wavelengths. Optimised to detect the coldest galactic and extragalactic objects, it is also the first catalogue to cover the complete 'zoo' of extragalactic sources, all the way from radio and infrared-luminous galaxies to clusters of galaxies.



← One of the newly discovered superclusters of galaxies detected by Planck and confirmed by XMM-Newton. This is the first supercluster to be discovered through its Sunyaev-Zel'dovich effect (ESA/Planck Collaboration)

The ERCSC was released early to give the astronomical community a timely opportunity to follow up these sources using ground- or space-based observatories, in particular ESA's Herschel observatory, which has a limited lifetime.

Continuing to survey the Universe

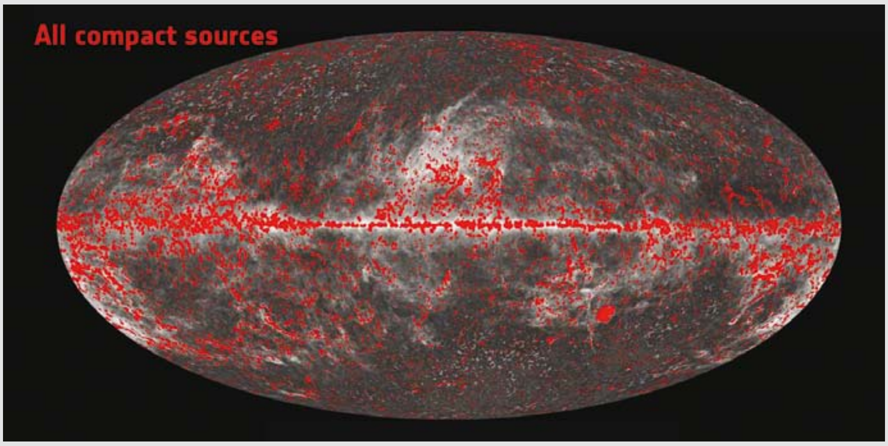
The catalogue has enormous scientific potential, and two of its highlights are 'Cold Cores', cold and dense locations in the interstellar medium of the Milky Way, with temperatures cooler than 14 Kelvin (the ambient dust temperature in the galaxy) and new clusters of galaxies, detected using the spectral signature of the Sunyaev-Zeldovich effect (an interaction of light from the CMB with the energetic electrons which fill the intracluster medium).

Planck has identified 189 such clusters so far, including 20 previously unknown clusters that are being confirmed by ESA's XMM-Newton X-ray observatory. By surveying the whole sky, Planck stands the best chance of finding the most massive examples of these clusters. They are rare and their number is a sensitive probe of the kind of Universe we live in, how fast it is expanding, and how much matter it contains.

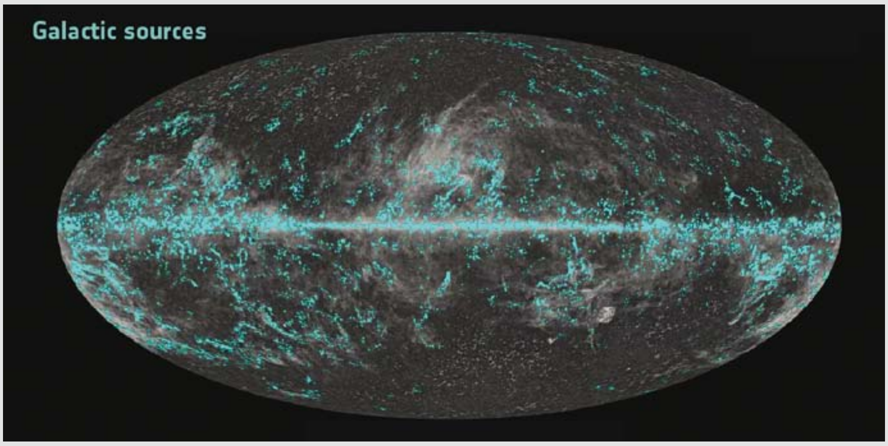
"These results are the tip of the scientific iceberg. Planck is exceeding expectations thanks to the dedication of everyone involved in the project. However, this catalogue contains the raw material for many more discoveries. Even then, we haven't got to the real treasure yet, the Cosmic Microwave Background itself," said Prof. David Southwood, ESA's Director of Science and Robotic Exploration.

Planck's next data release is scheduled for January 2013, covering data acquired up to November 2010. This will include cleaned and calibrated data timelines for each detector, all-sky maps at all Planck frequencies, catalogues of compact sources extracted from the frequency maps, maps of the main diffuse components separated from the maps, including the CMB, and scientific results based on the data released.

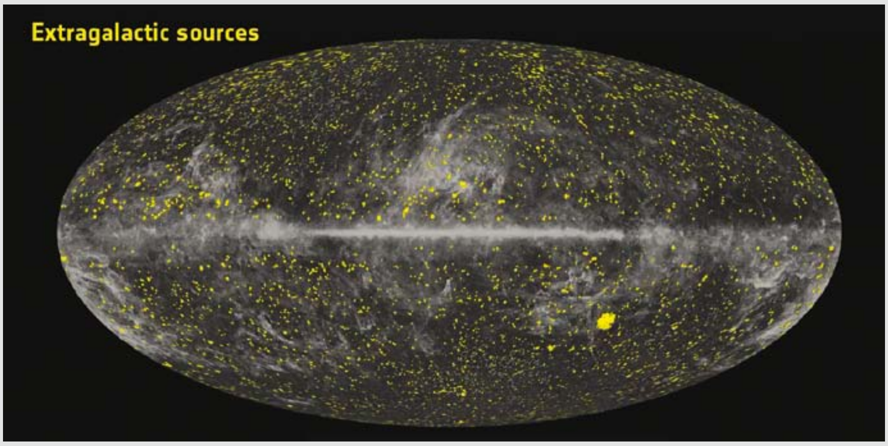
→ Planck Early Release Compact Source Catalogue



↑ The position on the sky of more than 15,000 unique compact sources detected by Planck during its first all-sky survey and listed in the ERCSC. The ERCSC contains a wide variety of astronomical objects, both galactic (features in the galactic interstellar medium, cold molecular cloud cores, stars with dust shells) and extragalactic (radio galaxies, 'blazars', infrared-luminous galaxies, and galaxy clusters), and it represents a rich database for the entire astronomical community (ESA/Planck Collaboration)



↑ Galactic sources detected by Planck during its first all-sky survey and listed in the ERCSC, showing features in the galactic interstellar medium, cold molecular cloud cores, stars with dust shells, HII regions, etc. (ESA/Planck Collaboration)



↑ Extragalactic sources detected by Planck during its first all-sky survey and listed in the ERCSC, including both radio galaxies and infrared galaxies (ESA/Planck Collaboration)

→ 2011: THE YEAR OF SOYUZ AND VEGA

Later this year, a Soyuz rocket will lift off from Europe's Spaceport in Kourou, French Guiana – a historic event because it will be the first time that a Soyuz is launched from a spaceport other than Baikonur in Kazakhstan or Plesetsk in Russia.

↑ The launcher for first Soyuz flight has already been assembled in the launcher assembly and testing building (MIK)

It will also be a milestone in the strategic cooperation between Europe and Russia on launchers. The Soyuz launch site at Europe's Spaceport is in the final phase of preparations, with qualification tests of the new facilities under way.

The Soyuz launch site is located in the northwest part of the Guiana Space Centre (CSG), 13 km from the Ariane launch site. It consists of three main zones: the launch platform, made up of a five-level reinforced concrete structure, the preparation area, where the three stages will be assembled horizontally and checked, and the launch control centre.

Geological and topographic surveys began at the site selected for Soyuz in 2003. Construction of the flame trench, the launch platform, the preparation area and the control centre was completed at the end of 2008.

The site is almost identical to the other Soyuz facilities in Kazakhstan and Russia, with the most visible difference of the mobile gantry, which allows payloads to be installed on the launcher vertically. The structure of the mobile gantry is now complete with the metal side panels installed.

Vega

There has been growing interest in smaller satellites, in particular for scientific and Earth observation missions. In order to provide an affordable response to European needs and to maintain its competitiveness in the world's launcher market, Europe has developed Vega.

Vega will inject payloads into a low polar orbit (300 km to 1500 km). With a height of 30 m and a diameter of 3 m, it will be able to place a 1.5-tonne payload into orbit. Its three solid-propellant stages (P80, Zefiro-23 and Zefiro-9) are topped by the AVUM liquid-propellant stage. Unlike most small launchers, it will be able to place multiple payloads into orbit.

Seven ESA Member States (Italy, France, Spain, Belgium, the Netherlands, Switzerland and Sweden) are contributing to the programme. The industrial prime contractor is ELV SpA, 70% of which is owned by Avio SpA and 30% by the Italian space agency ASI.

→ Artist impression of Vega on the launch pad (CNES/ESA)

↑ View of the Soyuz launch platform and mobile gantry

↑ Soyuz MIK launcher assembly and testing building

↑ Soyuz launch control centre

To the top of its curved roof, the gantry is 52 m high, and its internal movable work platforms provide access to the launcher at various levels up to a height of 36 m. The gantry provides a protected environment for the installation of payloads, as well as for the checkout of fully-integrated vehicles. Its parked position is 80 m from the launch platform.

The launcher assembly and testing building (MIK) is where the preparation activities for the three-stage Soyuz launcher and the Fregat upper stage will take place. A 700 m length of railway leads to the launch platform and will be used for the horizontal rollout of Soyuz launch vehicles on their erector.

Behind the assembly building, one kilometre from the launch pad, is the 'Launch Control Centre', the only building in the Soyuz launch zone that is occupied during final countdown and lift-off. This three-storey facility houses equipment, consoles and offices for the mission control team.

Soyuz

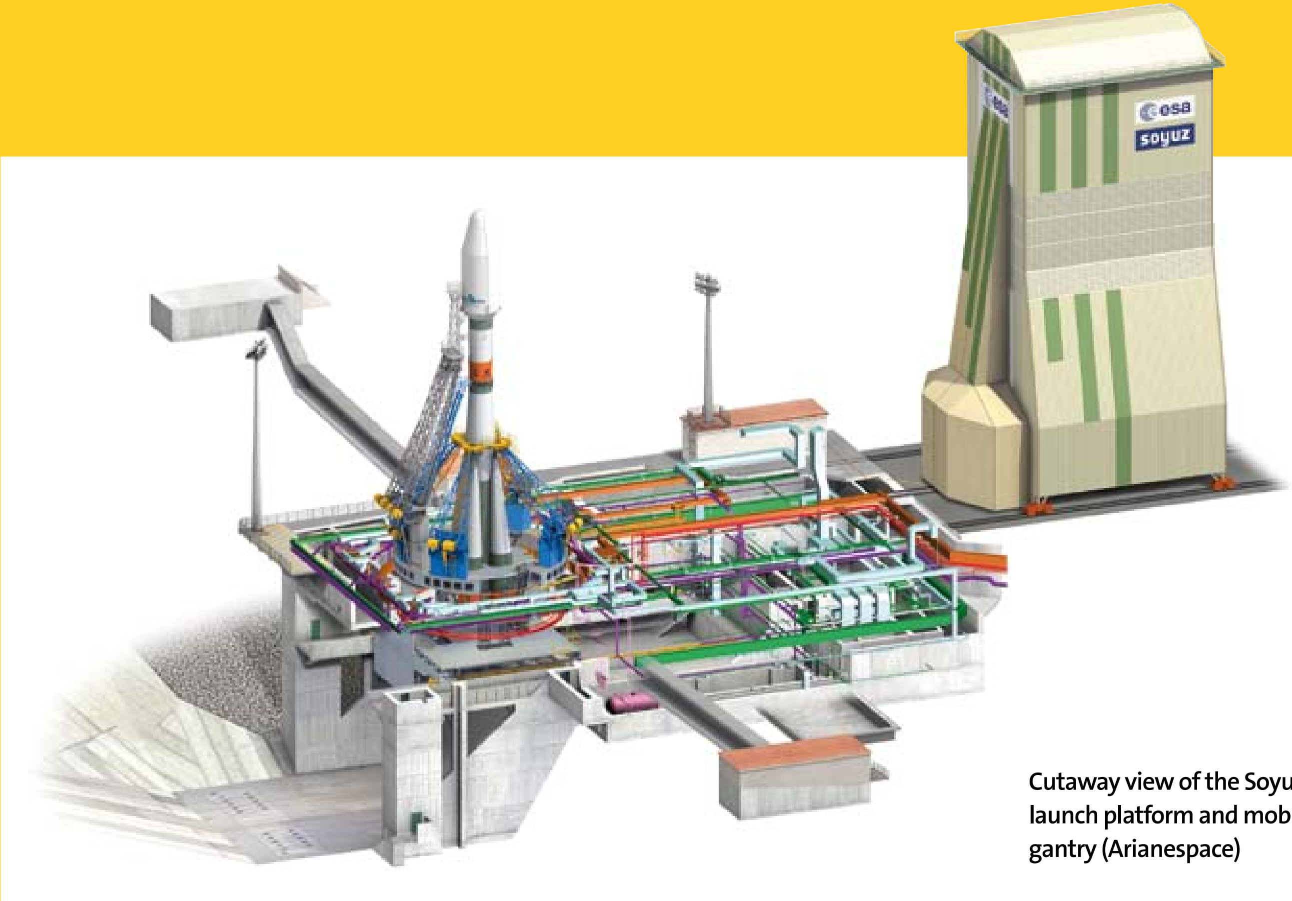
The Soyuz rocket is the workhorse of Russian human spaceflights and has been used for that purpose longer than any other vehicle. In the 1950s, it began carrying cosmonauts into space and then to the Soviet Salyut and Mir space stations. Together with the US Space Shuttle, it has ensured the transport of crews to and from the International Space Station.

The Soyuz launch vehicle that will be used at Europe's Spaceport is the Soyuz-2 version, also called Soyuz-ST. This includes the Fregat upper stage and the ST fairing.

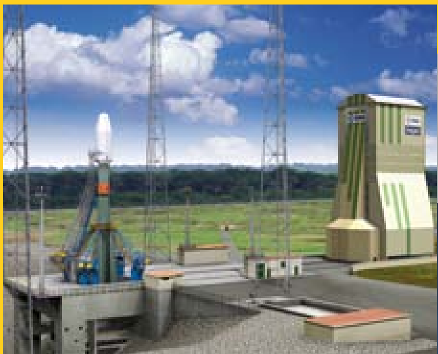
Soyuz-2 is the most recent version of the renowned family of Russian launchers that began the space race more than 50 years ago, when earlier versions launched Sputnik and then sent the first man into space on Vostok 1.

Soyuz-2 will have improved performance and be able to carry up to three tonnes into geostationary transfer orbit, compared to the 1.7 tonnes that can be launched from Baikonur, Kazakhstan. The Fregat extends the launcher's access to a full range of orbits, including medium-Earth orbit, Sun-synchronous orbit, geostationary transfer orbit and Earth-escape trajectories.

To ensure that Soyuz will be able to carry out missions of this type from Europe's Spaceport, the launch infrastructure has been designed so that it can be smoothly adapted for human spaceflight, should this be decided.



Cutaway view of the Soyuz launch platform and mobile gantry (Arianespace)



The launcher for first Soyuz flight has already been assembled in the MIK. The vehicle will then be transferred to the launch pad in the horizontal position on a rail-mounted erector. At the pad, the erector will raise the Soyuz into the upright position.

The decision to develop the launch infrastructure to enable Soyuz to be launched from French Guiana is of mutual interest to both Europe and Russia, and benefits from funding from the European Community.

Soyuz is a medium-class launcher and its performance will complement that of the ESA Ariane and Vega launchers, and increase the competitiveness and flexibility of the exploitation of Ariane in the commercial market.

← These views show how the launcher is raised upright on its erector transport wagon and how the mobile gantry can be moved in place for working on payloads while the launcher is upright (Arianespace/ESA/CNES)

Europe's Spaceport ready for Vega

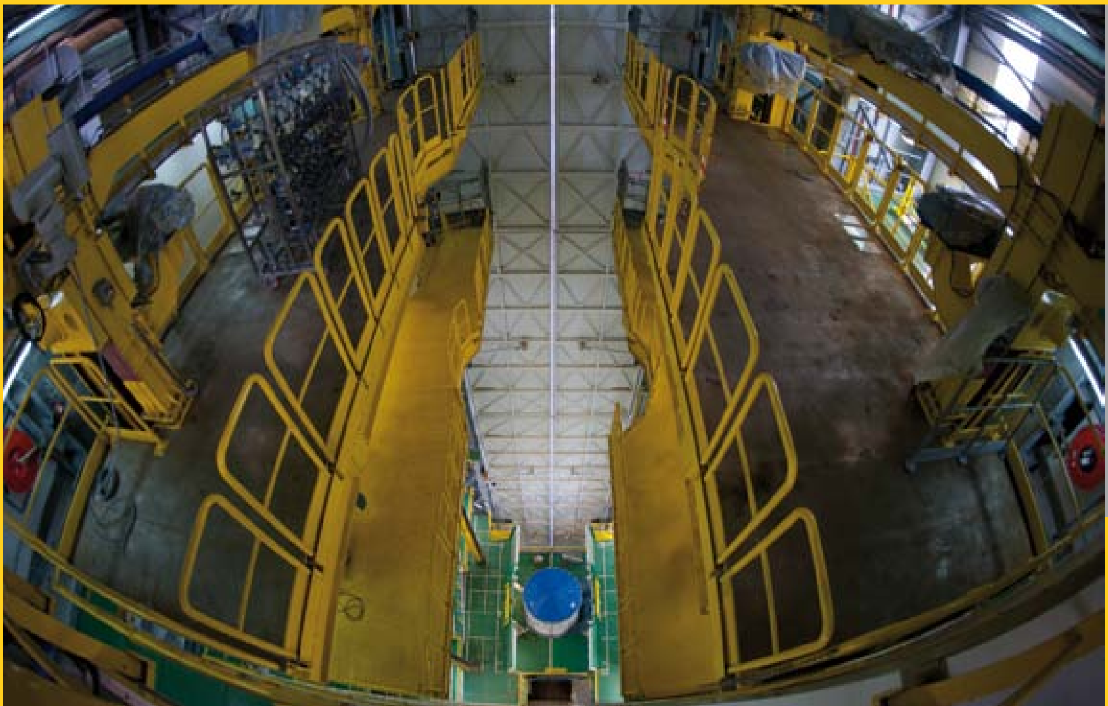
A mock-up of Europe's Vega launcher first stage was transferred on 26 October from the Booster Integration Building to the Vega Launch Zone, marking the first step towards the operational readiness of the Vega launch system and paving the way for this year's qualification flight.

The start of the combined testing phase involved the mechanical validation of several elements of the launch vehicle and the ground segment. The model of the first stage includes the P80 solid-propellant rocket motor and the Interstage-0/1 structure that attaches to pad. The stack, with a total mass of 135 tonnes and a height of about 15 m, was transferred to Vega's mobile gantry, where launch preparations take place.

After rolling out the first stage in the launch position on the lower pallet, the operations were completed with the upper pallet safely anchored to the launch table. The Flight Readiness Review will give the final green light for Vega's qualification flight.

"The mechanical combined tests have started with this transfer. This is a first step in the operational qualification of the Vega launch system and an important milestone towards the qualification flight," said Stefano Bianchi, ESA's Vega project manager.

↑ Vega launcher first stage mock-up arrives at the Vega Launch Zone in October 2010



← View from inside the Vega mobile gantry, looking down to the first stage mock-up

→ NEWS IN BRIEF

NASA astronaut Tracy Caldwell-Dyson in the European-built Cupola module of the International Space Station looking at Earth below during Expedition 24

←

Alexander Gerst, Timothy Peake, Samantha Cristoforetti, Thomas Pesquet, Andreas Mogensen and Luca Parmitano, pictured after completion of their EVA pre-familiarisation training course, with the Neutral Buoyancy Facility team at EAC

Europe's new astronauts qualify

ESA's six latest astronaut candidates are officially 'astronauts'. Their graduation ceremony was held at the European Astronaut Centre (EAC) near Cologne, Germany, in November.

The new astronauts were presented with their diplomas by Jean-Jacques Dordain, ESA Director General, Simonetta Di Pippo, Director of Human Spaceflight, and Michel Tognini, Head of the Astronaut Group, marking a milestone in their astronaut careers: the official end of Basic Training, the first phase of astronaut education.

"When we introduced these six new astronauts, the most important part was not that there were six individuals representing five member countries, but a team of six persons representing Europe," said Mr Dordain at the ceremony.

"ESA has three new astronaut flight opportunities to the ISS before 2015, so half of the new astronauts will have an opportunity to fly in space very soon. The first will head into orbit in 2013. I think this is important, especially now when we see the utilisation of the Station continuing to 2020 and hopefully also beyond," said Mrs Di Pippo.

The new astronauts are continuing with Advanced Training and taking part in public relations activities. Once assigned to a mission, they will concentrate on specialised training specific to that mission.

Arianespace to launch ESA's Sentinel-1

The first Earth observation satellite for Europe's Global Monitoring for Environment and Security programme, Sentinel-1A, is scheduled for launch in December 2012 by a Soyuz rocket from Europe's Spaceport in French Guiana.

The contract for the launch of Sentinel-1A was signed by ESA and Arianespace in December. The satellite is being built by an industrial team led by Thales Alenia Space, Italy.

The Sentinels are a family of satellites being developed by ESA to meet the needs of the services provided through the EU's Global Monitoring for Environment and Security (GMES) initiative. Sentinel-1 is a radar mission that will provide an all-weather, day-and-night supply of imagery for GMES ocean and land-monitoring services, including mapping forests, ground movement, sea ice and oil spills.

New Earth observation missions chosen for further study

↑

A representation of the main parts of the complex Earth system investigated by ESA's Earth Explorers

Vying to be ESA's eighth Earth Explorer, two new mission proposals have been selected for further development.

As with all Earth Explorers, the missions respond to issues raised by the scientific community to further our understanding of how Earth works as a system and how human activity is affecting natural Earth processes. Called FLEX and CarbonSat, both aim to provide key information on different aspects of the carbon cycle.

The CarbonSat mission would quantify and monitor the distribution of the two most important greenhouse gases in the atmosphere, also released through human activity: carbon dioxide and methane. Data from the mission would lead to a better understanding of the sources and sinks of these two gases and how they are linked to climate change.

The FLEX mission aims to provide global maps of vegetation fluorescence, which can be converted into an indicator of photosynthetic activity. These data would improve our understanding of how much carbon is stored in plants and their role in the carbon and water cycles.

The next step in the development of these two mission concepts is to begin the definition studies in the second quarter of 2011. Currently there are three Earth Explorers in orbit: GOCE, SMOS and CryoSat-2; a further three being built: Swarm, ADM-Aeolus and EarthCARE; and three undergoing feasibility studies competing for selection as ESA's seventh EarthExplorer: BIOMASS, PREMIER and CoReH2O.

World record for zero-g parabolas

↓

Vladimir Pletser, seen here passing the 5000th parabola mark during one of his zero-g flights

ESA's Vladimir Pletser has set a Guinness World Record as the person who has flown in the most aircraft performing zero-g parabolas.

Vladimir is a physicist and engineer in ESA's Human Spaceflight Unmanned Microgravity Platforms Office. Has worked on several payloads and instruments flown on Spacelab, Spacehab and ISS missions. From 1986 to date, he has organised and led 52 ESA campaigns and participated in another 17 campaigns being invited by different national space agencies and, in doing so, flew parabolas in nine types of aircraft.

Aircraft parabolic flights provide up to 20 seconds of reduced gravity during each ballistic flight manoeuvre, which are used to conduct short microgravity investigations in life sciences and technology, or testing experiments before and after they are flown in space to improve their quality and success rate.

The nine aircraft in which Vladimir has flown are the ESA/CNES Airbus A300, the CNES Caravelle 'Zero-G', the NASA KC-135/930, KC-135/931 and DC-9/30, the Russian Ilyushin IL-76-MDK, the Austrian Short Skyvan, the NLR Cessna Citation II and the Belgian air force Fouga Magister. In total, he has logged 5569 parabolas with a cumulative time of 30 hours 55 minutes of zero-g equivalent to 20.6 Earth orbits.

"The feeling of weightlessness is always extraordinary, even after nearly 25 years of flying zero-g parabolas, it is always a rediscovery during each parabola; the reaction, the feeling and the adaptation to zero-g is always a truly 'out of this world' experience," said Vladimir.

Paolo Nespoli on the ISS

ESA astronaut Paolo Nespoli (IT) arrived at the International Space Station in December for ESA's six-month 'MagISStra' mission.

↑

Paolo Nespoli and Catherine 'Cady' Coleman give a thumbs-up sign at the start of their six-month stay on the ISS

Following a launch from the Baikonur Cosmodrome in Kazakhstan, the Soyuz TMA-20 spacecraft carrying Nespoli and his crewmates Dmitri Kondratyev and Catherine Coleman docked with the ISS on 17 December, marking the start of ESA's third long-duration mission on the ISS, code-named MagISStra.

A very challenging mission now awaits Nespoli and his crewmates, with resupply missions planned, in particular the arrival of the second Japanese HII Transfer Vehicle (HTV) in January and that of Europe's second Automated Transfer Vehicle, ATV *Johannes Kepler*. The crew will oversee the deployment of a major scientific experiment to the ISS – the Alpha Magnetic Spectrometer (AMS-02) – scheduled for launch with Space Shuttle *Endeavour* in April. Nespoli will participate in the docking operations to receive both the ATV and HTV cargo spacecraft, and he will be the prime operator for berthing the HTV to the ISS after the free-flying vehicle has been captured by Catherine Coleman.

From now until his return in May, Nespoli will also undertake an intensive programme of experiments in different research fields, ranging from radiation monitoring to measurements that could improve oil recovery in petroleum reservoirs. He will conduct more than 30 experiments, not only for European scientists, but also for US, Japanese and Canadian space agencies.

He will be a test subject for various human physiology experiments covering neuroscience, cardiovascular, metabolism and fitness evaluation, and will also act as the main operator in complex biological experiments. On 20 December, for example, Nespoli set up the hardware for the NeuroSpat experiment studying spatial cognition, novelty processing and sensorimotor

Romania becomes 19th Member State

←

Romania signed the Accession Agreement to the ESA Convention on 20 January 2011, to become ESA's 19th Member State. ESA Director General Jean-Jacques Dordain and Marius-Ioan Piso, President and CEO of the Romanian Space Agency, signed the agreement at the Romanian Ministry of Foreign Affairs in Bucharest, in the presence of Teodor Baconschi, Minister of Foreign Affairs, and former cosmonaut Dumitru Dorin Prunariu.

integration, involving two main experimental tasks: visual orientation and visuomotor tracking, plus additional, standardised electroencephalogram (EEG) tasks performed to assess general effects of the space station environment on EEG signals. The following day, he was assisted by Coleman in donning and setting up the EEG cap and carrying out his first session of the experiment.

During his mission, Nespoli will also carry out public relations activities and perform an educational programme that includes the international 'Mission X: Train Like an Astronaut' initiative built around health, well-being and nutrition, and 'Greenhouse in Space', an experiment aimed to grow plants and observe the life cycle of a flowering plant in space, with school children using a similar unit and the same species of plant to monitor the same phenomena on ground.

Commenting on the launch, Simonetta Di Pippo, ESA Director of Human Spaceflight said, "We can be proud of the level of integration and importance Europe has reached in the ISS partnership, also thanks to a regular presence of European astronauts on board the ISS."

ISS breaks record

While ISS partner agencies celebrated ten years of humans living and working continuously aboard the ISS in November, the ISS also quietly broke the record on 25 October for being the longest continuously inhabited spacecraft, eclipsing the previous record of 3644 days set by the Russian Mir Space Station.

Since the crew of Expedition 1 boarded the ISS in November 2000, more than 196 people have visited the complex, and more than 600 different research and technology development experiments have been conducted on board, many of which have produced advances in medicine, technology and our fundamental understanding of the Universe.

↑

The first Expedition crew to fly to the ISS, Sergei Krikalev, Bill Shepherd and Yuri Gidzenko

Canada partnership extended

Jean-Jacques Dordain, Director General of ESA, and Steve MacLean, President of the Canadian Space Agency, signed a new Cooperation Agreement between ESA and Canada that will extend their partnership for a further 10 years, until 2020. Marc Lortie, Canadian Ambassador to France, also witnessed the signature.

Israel signs Cooperation Agreement

→

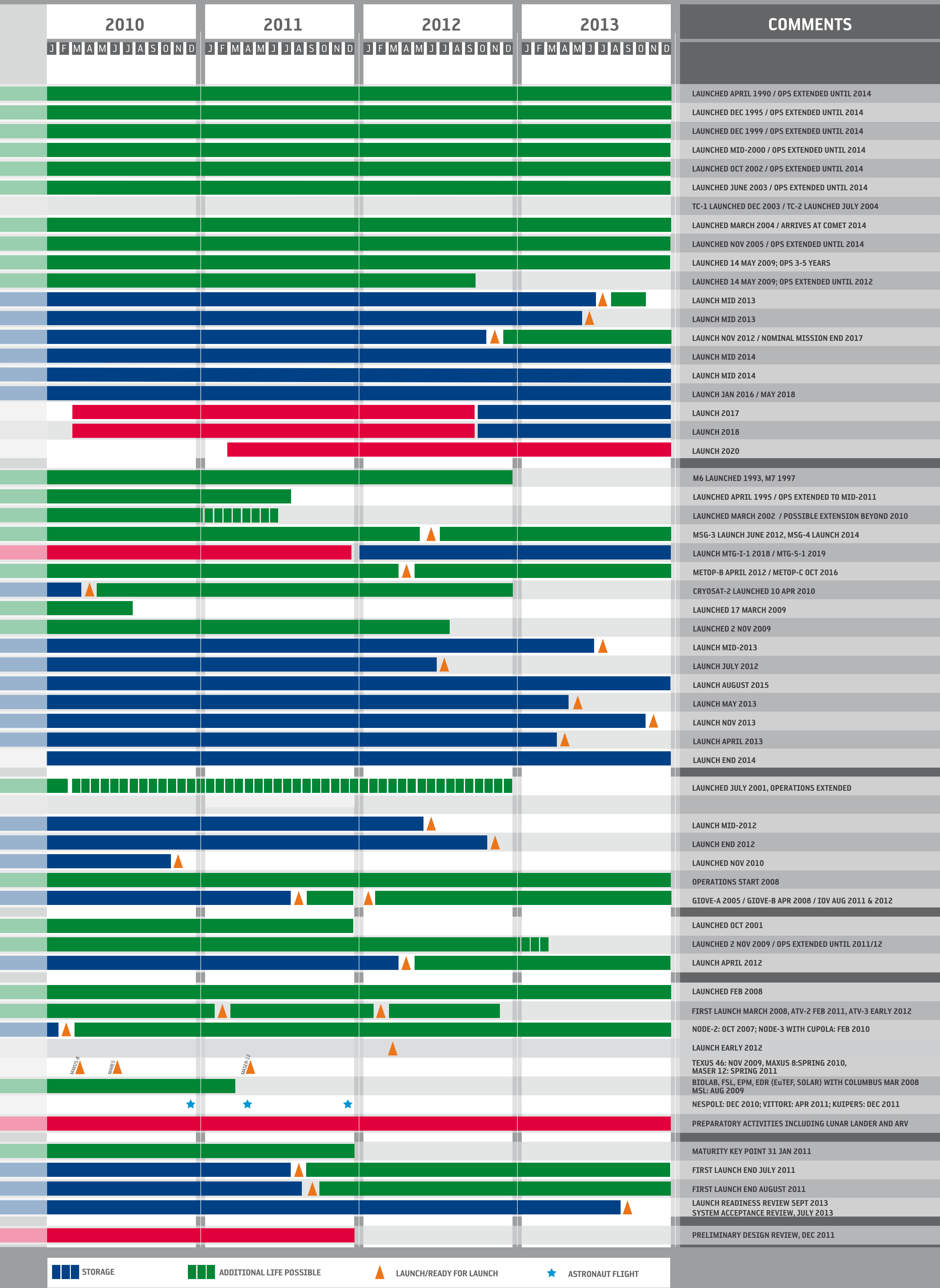
Israel signed a Cooperation Agreement with ESA on 30 January, to create the framework for more-intensive cooperation in ESA projects in the future. ESA's Director General Jean-Jacques Dordain signed the agreement in Tel Aviv with the Director General of the Israel Space Agency (ISA), Dr Zvi Kaplan (right), on 30 January 2011. Back row from right, Mr Ben Israel, Chairman of the Israeli Space Committee, Prof. Daniel Hershkowitz, the Israeli Minister of Science and Technology, Mr Menachem Greenblum, Director General of the Ministry of Science and Technology, and ESA's Karl Bergquist (ISA)

→ PROGRAMMES IN PROGRESS

Status at end December 2010

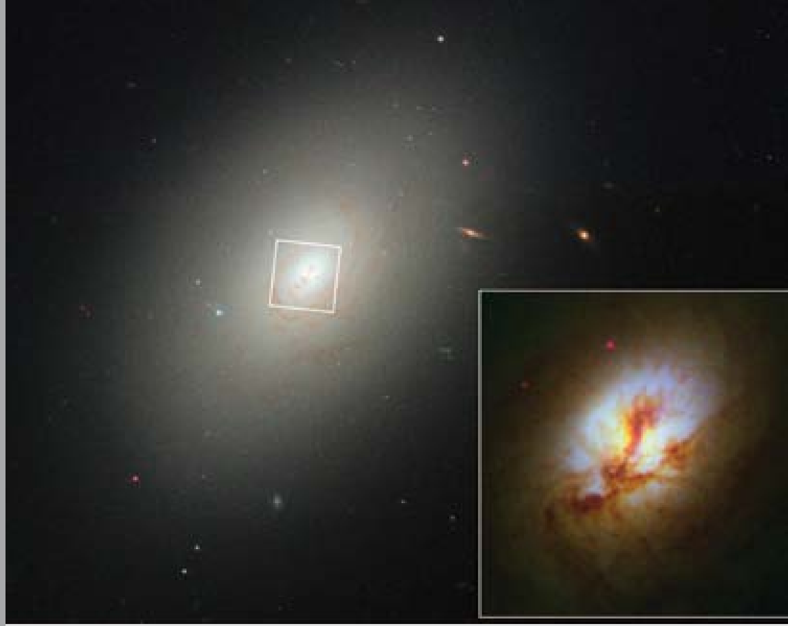
On 26 November 2010, Ariane 5 flight V198 lifted off from Europe's Spaceport in French Guiana on its mission to place two telecommunications satellites, Hylas-1 and Intelsat 17, into their planned transfer orbits. This was the 54th Ariane 5 flight (ESA/CNES/Arianespace - Optique Video CSG)

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


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

KEY TO ACRONYMS

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



This image from the Hubble Space Telescope combines observations in visible and near-ultraviolet light and reveals fresh star birth in the ancient elliptical galaxy NGC 4150. These observations support the view that old elliptical galaxies like NGC 4150 are home to a significant amount of recent merger-driven star formation (NASA/ESA/Univ. Oxford, UK/Imperial College London/STSci/Univ. Virginia, Charlottesville/WFC3)

→ HUBBLE SPACE TELESCOPE

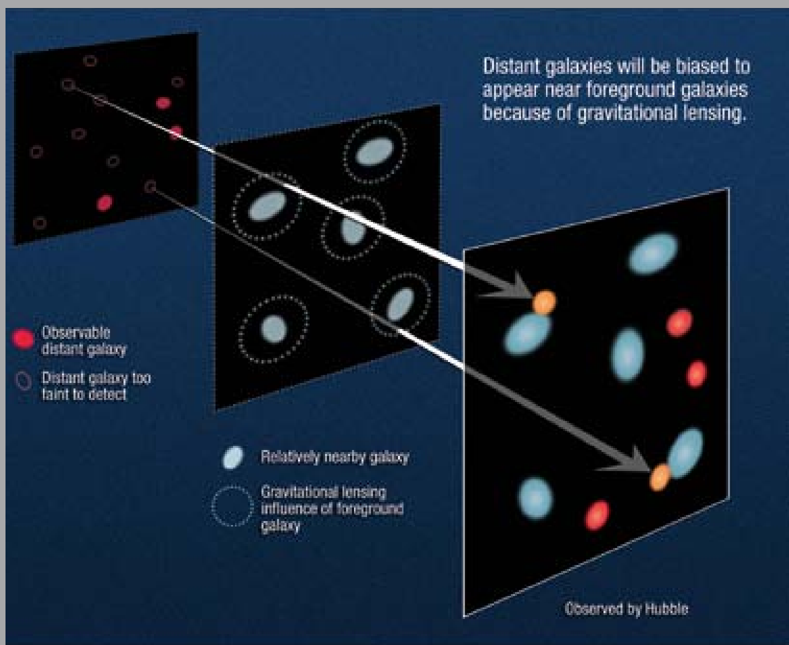
Hubble has found direct observational evidence for a star-formation episode in elliptical galaxy NGC 4150. Elliptical galaxies were thought to have ceased forming stars billions of years ago, but new Hubble observations are helping to show that galaxy mergers might have a role in continuing star formation in elliptical galaxies.

Ultraviolet images of NGC 4150 reveal streamers of dust and gas and clusters of young stars. Photometric data confirmed that the star-formation episode occurred about a billion years ago and that the star-formation rate declined afterward. There is strong evidence that this episode was triggered by a merging with a dwarf metal-rich galaxy that supplied NGC 4150 with the fuel necessary to make new stars. These observations support the theory that galaxies have been gradually assembled over billions of years by collisions with smaller galaxies.

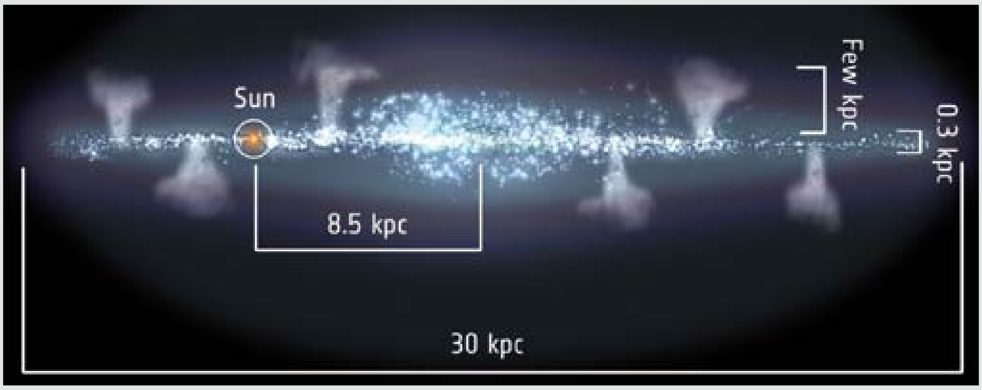
Astronomers have also claimed that as much as 20% of the most distant galaxies currently detected appear brighter than they actually are, because of strong 'gravitational lensing'. This conclusion has been made by analysing images from the Hubble Ultra Deep Field (HUDF) survey, a collection of images of the farthest reaches of the Universe taken by Hubble.

The survey looks back in time 13 billion years, to when the Universe was less than a billion years old. Astronomers were interested to know how many galaxies were bright or faint when the Universe was still in the early phases of its evolution, and they were puzzled by why so many of the far galaxies observed in the HUDF images appeared to be located near the line of sight to galaxies in the foreground. Through a statistical analysis, they found that gravitational lensing was the most likely explanation.

Astronomers have long known about gravitational lensing, but it was believed to be such a rare phenomenon that it would not have any real impact on galaxy surveys. This 20% effect is just an estimate and could change as the result is refined. Astronomers now predict that many galaxies in the most remote Universe are visible to us only because they are magnified in this way.



This is how gravitational lensing by foreground galaxies influences the appearance of more distant background galaxies. As many as 20% of the most distant galaxies currently detected appear brighter because their light is being amplified by the effects of intense gravitational fields in the foreground (NASA/ESA/A. Feild (STScI)



The Milky Way and the 'galactic fountain' scenario. The number of fountains in the Milky Way is not known, but the image shows the rough scale of the fountains compared to the size of the galaxy and the position of our Sun. Distances are in kiloparsecs (kpc)

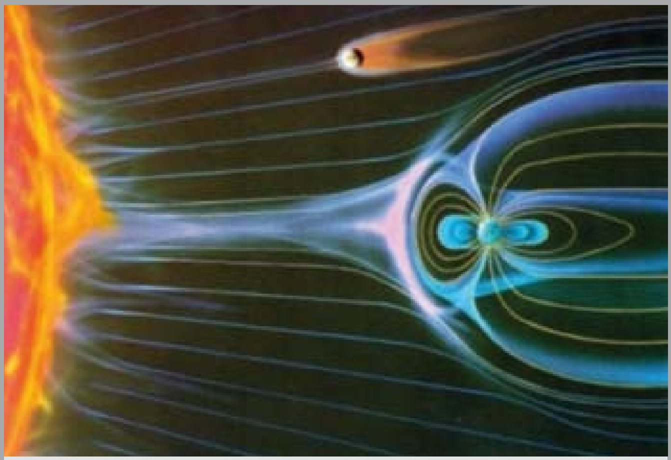
→ XMM-NEWTON

Observing the X-ray-bright gas in the halo of the Milky Way, XMM-Newton has new evidence for supernova-driven 'galactic fountains' of hot gas. Supernova explosions in the galactic disc heat the interstellar medium and drive hot gas out of the disc, creating these fountains that contribute to the formation of a gas halo around the galaxy. As the gas rises above and below the disc, reaching heights of a few kiloparsecs, it emits radiation and cools, condensing into clouds that then fall back into the disc. Such a scenario confirms the importance of supernova explosions in forging the evolution of the interstellar medium and the galaxy as whole.

→ CLUSTER

The four Cluster satellites are now deep into the long eclipse season, which will last until July. During each orbit, for the duration of the eclipse (up to an hour), the satellites are fully powered down, waking up once they see the Sun again. These eclipse power-downs are now routine for Cluster. During the next few months, Cluster will be examining the dayside magnetosphere and the solar wind flying in a tetrahedral formation at scales of around 5000 km.

A recent Cluster science highlight incorporates data from Venus Express, investigating the interaction of planetary bodies with the solar wind. Earth and Venus are similar in terms of size, mass and internal structure but differ magnetically. Earth has an internal magnetic field and Venus does not. Near-simultaneous joint observations by Venus Express and Cluster enabled scientists to make a study of the solar wind interaction with the outer magnetospheric layers of Venus and Earth. The scientists compared the observations to a model of the plasma interface or magnetopause, the first time such a comparison of two very different plasma environments has been made. The study demonstrates the broad applicability of Cluster science, which can be transferred to other plasma and planetary environments, even those with no intrinsic magnetic field. The comparative study of planetary plasma environments contributes to a better understanding of the general principles that govern magnetospheric configuration and dynamics, in particular the role of the solar wind state and of the planetary plasma environment.



The solar wind shaping the magnetospheres of Venus (brown tail, closer to the Sun) and Earth (blue). The planets are roughly the same size but, unlike Venus, Earth has an internal magnetic field that makes its magnetosphere bigger. The lines coming out of the Sun represent the propagation direction of the solar wind

→ INTEGRAL

Operations continue with the spacecraft, instruments and ground segment all performing normally. Observations approved in the Eighth Announcement of Opportunity began on 1 January.

One of Integral's latest discoveries is that the interstellar medium in our solar vicinity has been shaped by very nearby massive stars. Just like archaeologists who rely on radioactive carbon to date the organic remains from past epochs, astronomers have exploited the radioactive decay of an isotope of aluminium, Al 26, to estimate the age of stars in the nearby

Mars Express returned this image as it passed within 100 km of the martian moon Phobos on 9 January (ESA/DLR/FU Berlin)

Scorpius–Centaurus association, the closest group of young and massive stars to the Sun. The new observations by Integral provide evidence for recent ejections of matter from massive stars that took place only a few million years ago in our cosmic neighbourhood.

→ MARS EXPRESS

Mars Express continues to work well and deliver excellent results. Another Phobos flyby campaign was completed, with a close pass of the moon's surface made on 9 January. The solar superior conjunction started on 19 January, which means that contact with Mars Express was reduced for five weeks. A solar corona experiment was to be performed at conjunction entry and exit. The December 2010 issue of *Science* includes special sections on 'Breakthroughs of the Year' and 'Insights of the Decade'. In the top ten was 'Water on Mars'. The past decade's half-dozen Mars missions, including ESA's Mars Express, have made it clear that early in martian history, liquid water on or just inside the planet's surface did indeed persist long enough to alter rock and, possibly, sustain the creation of life.

→ ROSETTA

The Rosetta Hibernation Readiness Review was completed in November. The spacecraft and ground segment are ready for the 19-month deep-space hibernation phase starting

Taken by Mars Express on 15 December 2004, this image shows a relatively thin cover of what is likely to be water snow over smooth plains. A small impact crater is visible in the centre-right of the image. Snow over dark areas has probably been blown away by strong winds, as the numerous dune-layered deposits seem to indicate (ESA/DLR/FU Berlin)

in June. The scientific payload had its final active checkout in December in preparation for the hibernation phase. All orbiter instruments, as well as the Philae lander, were tested and are ready for hibernation.

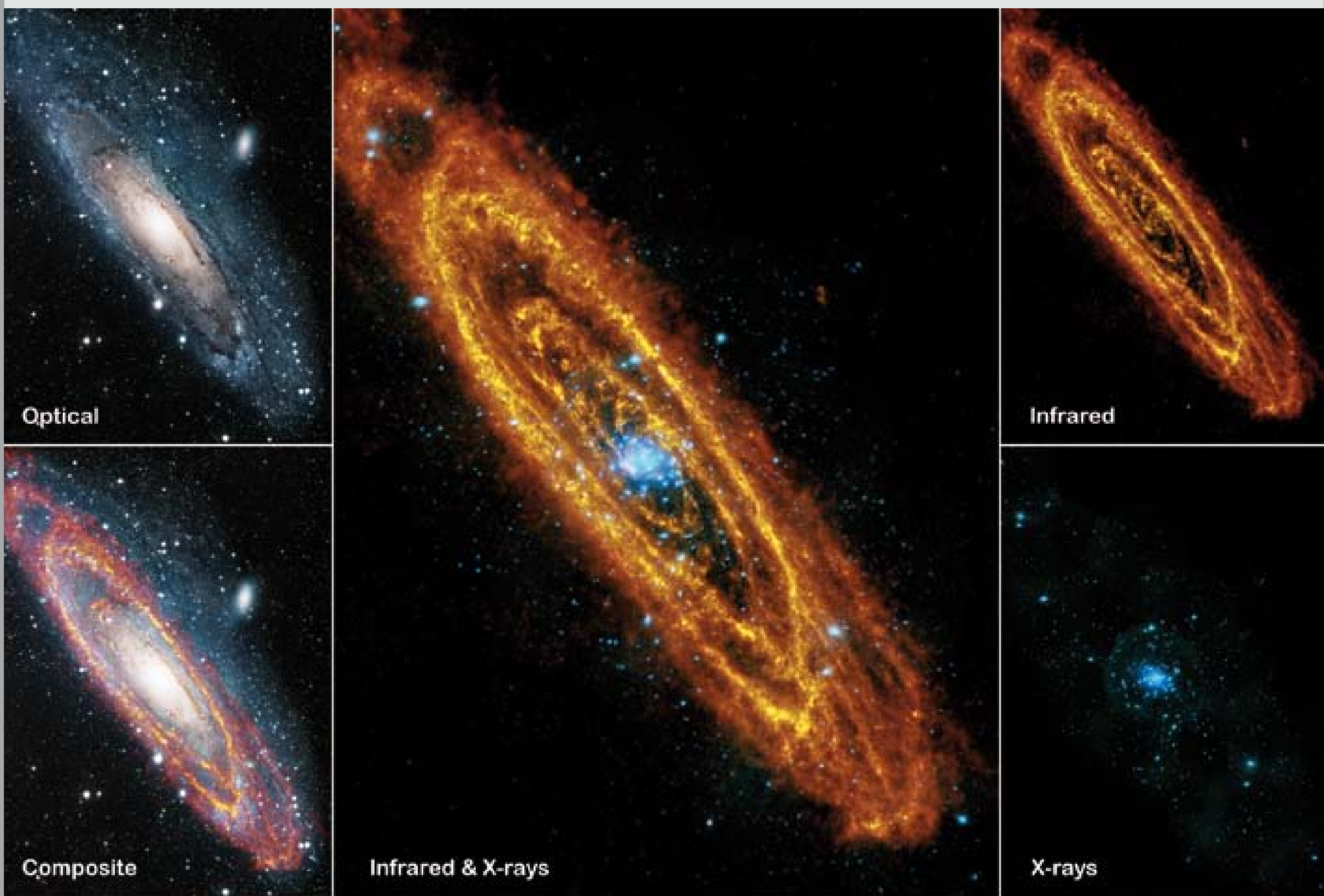
The spacecraft was configured for the manoeuvre in January to direct Rosetta onto the right path for rendezvous with its target, Comet 67P/Churyumov–Gerasimenko, in 2014. This last manoeuvre before hibernation is the first of two rendezvous manoeuvres to prepare for approaching the comet nucleus, going into orbit and deploying the lander on its surface.

→ VENUS EXPRESS

Owing to the relatively large angular distance between Venus and the Sun as seen from Earth from December to January, Venus could be observed well by ground-based observatories and spacecraft in Earth orbit. A dedicated campaign for coordinated Venus Express and ground-based observations took place during this period. Similar observations were made during the three last opportunities with maximum solar elongations. Such observations are useful for studies of the global dynamics on both large and small scales. This time, a set of three observations by the Hubble Space telescope was coordinated with spectroscopic observations by Venus Express, concentrating on the atmospheric distribution of sulphur dioxide. A new generic model of planetary magnetospheres (Echim *et al.*) was also tested by using data collected simultaneously at Venus and Earth, by Venus Express and Cluster respectively (see Cluster).

The surprisingly high concentration of sulphur dioxide at around 100 km altitude, as discovered earlier by Venus Express, has been explained using a new model (Zhang *et al.*) including the effect of photolysis of sulphuric acid. Interesting parallels can be drawn with Earth, because it has been proposed that such sulphuric acid layers, artificially created by injecting sulphur dioxide into the stratosphere, could be very efficient for mitigating global warming. Sulphuric acid droplets at high altitude could increase the albedo of Earth and reflect sunlight efficiently, reducing the global temperature. A natural manifestation of this effect is noticeable after large volcanic eruptions that inject sulphur dioxide high up into the atmosphere.

Herschel, XMM-Newton and optical views of M31, showing how observations in the three spectral regions complement each other. In the optical, mainly starlight is seen with dark lanes where the stars are obscured. These dark lanes, filled with dust that traces the gas where new stars will be born, are glowing in the far-infrared. Finally, the X-rays provide a view of stars having reached their evolution endpoints as compact objects accreting material from their surroundings



→ HERSCHEL

Herschel is carrying out routine science observations with its three instruments (PACS, SPIRE and HIFI) and continues to generate excellent science data. Well over half of the observing time allocated to the 42 Key Programmes before the launch has been used. In the first 'in-flight' call to the worldwide astronomical community for open time proposals, 241 proposals were given observing time on the recommendation of the Herschel Observing Time Allocation Committee in October.

Herschel results were featured in many conferences last year, but on 4 January, just as Herschel reached 600 days since the launch, a special public event took place. Herschel, together with XMM-Newton, was featured in the UK's BBC 'Stargazing Live' TV show where the two ESA space observatories joined forces observing M31, the Andromeda galaxy. The observations provided very different views of M31, convincingly demonstrating the importance of having access to multiple spectral regions that can only be observed from space, each one providing unique and complementary information. The show reportedly had more than four million viewers.

→ COROT

COROT continues its mission and has to date recorded 25 new planets and 'brown dwarf' stars (objects intermediate to stars and planets) orbiting stars other than our Sun. With several hundred candidate objects already on the list, the follow-up procedure on the ground is a large effort, taking on average one year per candidate. This is including the vetting of 'false positives', such as eclipsing binary stars mimicking the transit signature of a planet passing in front of its star, as well as background objects injecting a 'false signature' into the COROT observation.

The most important ground-based observation after a candidate has been proven genuine is to measure the 'radial velocity' of the star as a function of the orbital period of the planet. The radial velocity is the component of the stellar velocity along the line of sight to the star/planet system that shows the gravitational influence of the planet on its host star and allows the determination of the planetary mass. With a very exact radius determination of the planet, coming from the transit light curve recorded by COROT, the average density of the planet can be calculated. This is the most important physical parameter that can be obtained with current methods, allowing true comparative planetology to be carried out on exoplanets.

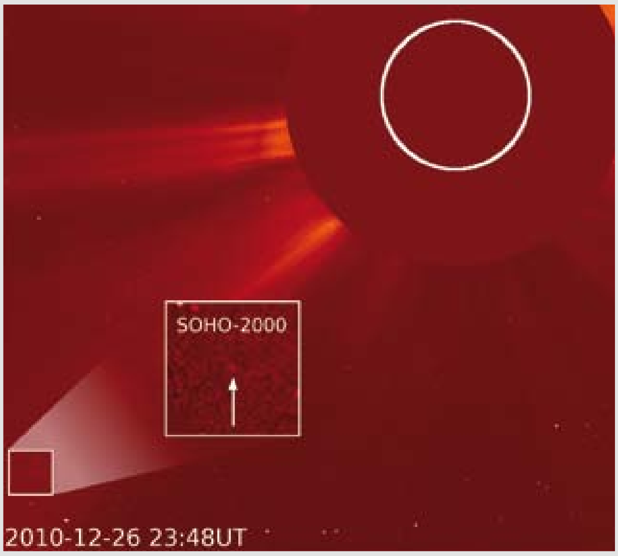
The first terrestrial-type exoplanet detected over a year ago by COROT (COROT-7b) has been joined by a second object (Kepler-10b) detected by NASA's Kepler spacecraft. The new object is almost identical to COROT-7b (orbiting same solar type of star, similar mass and radius, identical distance from the central star), showing that COROT-7b is the first object of a new type of planet, namely planets very similar to Earth in composition, but larger (about five times more massive), and orbiting just a few million kilometres from their star and having surface temperatures around 2000°C.

→ SOHO

SOHO discovered its 2000th comet on 26 December. Drawing on help from citizen scientists around the world, SOHO became the single greatest comet-finder of all time. This is impressive, since SOHO was not specifically designed to find comets, but to monitor the Sun. Of course, it is not the SOHO spacecraft itself that discovers the comets, but the dozens of amateur astronomer volunteers who study daily the pictures produced by SOHO's LASCO cameras.

Over 70 people from 18 different countries have helped to spot comets over the last 15 years, by searching through the publicly available SOHO images online. The 1999th and 2000th comet were both discovered on 26 December

Michal Kusiak, discoverer of SOHO's 2000th comet (M. Kusiak)



SOHO's view of its 2000th comet on 26 December (ESA/NASA) by Michal Kusiak, an astronomy student at Jagiellonian University in Krakow, Poland. Kusiak found his first SOHO comet in November 2007 and has since found more than 100. It took SOHO ten years to spot its first thousand comets, but only five more to find the next thousand. This is partly because of increased participation from comet hunters and work done to optimise the images for comet spotting, but also because of an unexplained systematic increase in the number of comets around the Sun. Indeed, December alone saw an unprecedented 37 new comets spotted, a number high enough to qualify as a 'comet storm'.

→ GAIA

Integration of the Payload Module FM is proceeding. The first mirror has been mounted on the optical bench. Nine of the ten FM mirrors have been delivered and the last one is expected in February. All flight CCDs, including the flight spares, have been delivered.

Mechanical testing of the Focal Plane SM was completed at Intespace. The SM has been disassembled and most of the hardware is now being refurbished for flight. Additional tests on the Focal Plane Assembly EM were completed and the hardware is now in storage. The Service Module FM is now at Astrium SAS (Toulouse). The integration and test of the first electronic units is under way. The large Deployable Sun Shield and Phased Array Antenna FMs are being manufactured.

The spacecraft CDR was completed in October. The development of the operation and science ground segments continues. The first System Validation Test, with the spacecraft AM commanded from ESOC using flight procedures, was conducted. The activities on the launcher side with Arianespace are going as planned.

A Gaia mirror being prepared for integration on the Payload Module optical bench

→ LISA PATHFINDER

The Science Module (SCM) FM is almost fully integrated with all platform units and most of the payload electronic boxes. The Propulsion Module (PRM) is completely integrated.

The two modules were mated for the system mechanical test campaign in February. This will be the third system test (after the magnetic system test and the transfer orbit thermal test in 2010) and will prove system compatibility with the load induced by the launcher. In parallel, the SCM FM is in integrated system testing, where all the functions of the platform are being checked to demonstrate their performance for all mission phases.

LISA Pathfinder Propulsion Module and Science Module Flight Models mated at the Astrium integration facilities, Stevenage, UK (Astrium Ltd)

Functional verification of the spacecraft is continuing, both at Real-time Test Bench and Software Verification Facility level. The three Power Control Unit FMs and the Neutraliser units of the micro-propulsion system have been integrated and tested on the spacecraft. The FEEP thrusters had a technical problem during the second lifetime test in October, which should have confirmed the performance obtained in the first lifetime test of two years ago. The test failure is under investigation.

All units of the LISA Technology Package (LTP) have been delivered for integration in the SCM, except the LTP Core Assembly (LCA), where a redesign of the caging mechanism was needed. With the remaining activities on the micro-propulsion system and the LCA, the launch of LISA Pathfinder is expected no earlier than the second half of 2013.

→ MICROSCOPE

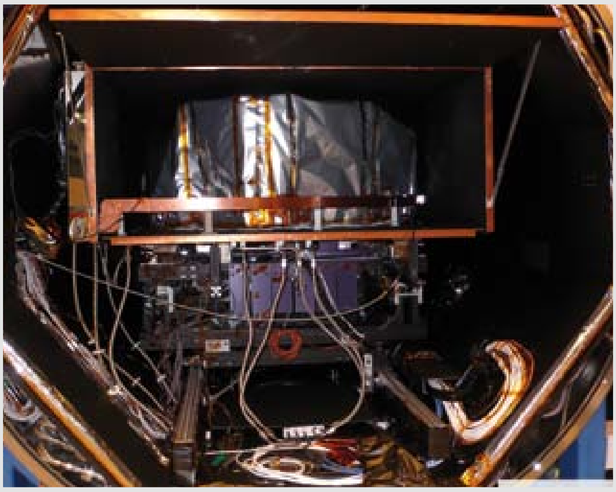
The Microscope schedule has been consolidated by CNES, with key milestones being the PDR in March and the move to Phase-C/D in June. CNES is implementing a new baseline design for the micro-propulsion system (cold gas is now replacing electrical propulsion). The intention is to use, as far as possible, the system qualified for Gaia. The system will be provided by ESA and the ITT for the industrial phase will be released by the middle of February.

→ JAMES WEBB SPACE TELESCOPE

Significant technical progress has been achieved on the NASA side. All the primary mirror segments (PMSs) have had their initial polishing completed and undergone initial wavefront error testing at cryogenic temperatures. The final polishing of six PMSs has been completed and two have already been gold-coated. The Integrated Science Instrument Module FM has passed cryo-proof load testing and the ambient proof load testing is ongoing.

The acceptance review of the NIRSpec FM detectors was not successful and it is likely that these integrated detectors will have to be replaced with the flight spare detectors. The NIRSpec instrument vibration test, post-test alignment and functional tests have been completed.

The NIRSpec Flight Model inside the thermal vacuum chamber completely integrated



The fully integrated MIRI Flight Model on rotator table during its final inspection before covering with multi-layer insulation

The micro-shutter assembly has been inspected and no damage has been identified. The acceptance test programme is going ahead with the first cryogenic cycle. The second cryogenic cycle will take place after detector exchange and the final cleaning of the micro-shutter assembly.

The MIRI vibration test, post-test alignment and functional tests have been completed. The detector modules were delivered from JPL after end-to-end detector system performance tests. They are now integrated and the MIRI optical system is ready for the cryogenic test. The detector electronics are in the final stages of acceptance testing at JPL, with delivery expected at the end of January.

→ BEPICOLOMBO

The Mercury Magnetospheric Orbiter (MMO) and its Sunshield STM passed the 10 Solar Constant thermal test, and the shield demonstrated adequate protection from the Sun for the six-year cruise phase. The Mercury Planetary Orbiter (MPO) structure was delivered for integration in Turin and the system-level assembly activities are under way for the propulsion system and the equipment. The Mercury Transfer Module primary structure was completed and transported to the static load test facility. The solar array design is now ready for its PDR and the data packages were delivered. The electric propulsion twin-engine firing test was completed. Manufacturing of FM equipment is under way. The MPO instrument STMs were delivered for integration to the spacecraft. Deliveries of the instrument EMs started in October and four instruments passed the initial functional compatibility tests on the Spacecraft Engineering Test Bench. Remaining instrument EMs should be completed by early 2011.

BepiColombo's Mercury Magnetospheric Orbiter and its sunshield in the Large Space Simulator at ESTEC, Noordwijk

The first spacecraft-level thermal balance test at 10 Solar Constants for the MMO TM was completed. After refurbishment into the Mechanical Test Model, this MMO module will come back to ESTEC in the summer for the mechanical test of the BepiColombo composite in launch configuration.

The Mission Control System Software Requirements Review was completed. Launch is planned in the Mercury launch opportunity in mid-2014.

→ EXOMARS

The ExoMars programme achieved the very important milestone of the System PDR. This is crucial for moving ahead into the implementation phase. The PDR began on time with the delivery by industry of the data package on 25 October. Teams of engineers from ESA, CNES and NASA/JPL, as well as independent reviewers and specialist experts from various backgrounds, were assembled to review the data over four weeks. Then the designs and requirements of ExoMars for the 2016 and 2018 missions were discussed in detail. Top-level ESA and NASA/JPL managers reviewed the findings and concluded that the project could proceed with evaluation of the Phase-C/D industrial proposal and begin Phase-C/D in April.

The Phase-C/D/E1 Price Proposal is due in February and will contain the industrial prices for both the 2016 and 2018 missions to evaluate the total costs for the programme, including the international cooperation elements.

Work on the Trace Gas Orbiter (TGO) instruments has started at JPL. JPL will manage the development of the TGO instruments, with the exception of NOMAD (a Belgian-led instrument that is subject to ESA science instrument funding and development arrangements). For NOMAD, ESA will take a direct monitoring role in the instrument's development. The AO for the Entry, Descent and Landing Demonstrator Module Science Sensors was released in November and allows proposals for individual science sensors, or lead responsibility including the Central Electronics Unit of the science sensors.

In the 2018 mission, discussions with JPL continue in order agree interfaces for the ESA-assumed baseline NASA/JPL architecture. ESA is attempting to maintain the investments associated with the existing Rover design by maintaining the boundaries of the present design. NASA/JPL announced an architecture review for the 2018 mission that will consider two main approaches. One approach is to land two Rovers individually mounted on a platform. This architecture has been the ESA baseline and the basis of discussions in the international cooperation to this point. The other approach being considered by JPL is a single Rover landing with separation into two vehicles after landing. This architecture maximises the use of the NASA/JPL Mars Science Laboratory designs, due for launch in 2011, but may require ESA to adapt significantly to the new approach. The impacts on the ESA Rover are not yet quantified for this latter approach.

→ ERS-2

ERS-2 will cease its operations in mid-2011, after 16 years of successful activity. Preparations for the subsequent decommissioning and deorbiting have started. Before the end of its mission, ERS-2 is being exploited to the maximum of its capabilities, within the constraints of its ageing equipment. Until the Envisat orbital change of October 2010, ERS-2 was used for specific SAR Interferometry (InSAR) campaigns in tandem with Envisat. A new ERS-2 mission phase, with a three-day repeat cycle, is being prepared for the few months before the end of the mission. This phase will repeat the ERS-1 Ice Phases of 1992 and 1994, almost 20 years later, taking advantage of the availability of GPS network supporting atmospheric corrections for InSAR applications.

→ ENVISAT

Envisat changed orbit in October 2010, to move into an orbit requiring much lower hydrazine consumption, so that the satellite could be operated until mid-2014. Without the orbit change, the mission would have to end during 2011. After lowering the satellite orbit by 17.4 km in

Flood-inundated areas in Australia's northeastern state of Queensland, as seen by Envisat on 2 January. The image shows an area measuring approximately 450 km from east to west and about 350 km north to south. Although much of the ground is shrouded by cloud, the murky brown river floodwater can be clearly seen

successive steps starting on 22 October, a reconfiguration of the ground segment allowed the data flow to users to resume in November. This major reconfiguration included only a short interruption of service to the large Envisat user community, demonstrating the operational efficiency reached by this ESA mission.

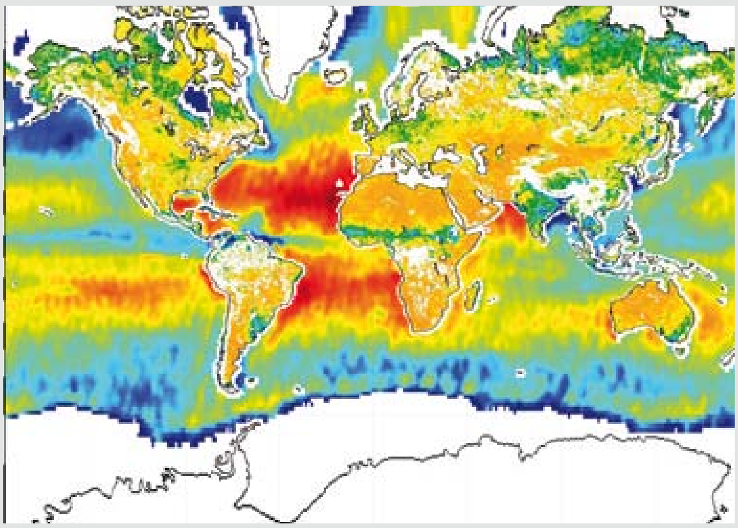
The orbital change had no substantial effect on the Envisat data quality, except for reduced SAR Interferometry (InSAR) capabilities. Envisat InSAR applications remain possible, but within a band centred around 38° latitude. The first SAR interferogramme with the new 30-day repeat orbit was generated over the San Francisco Bay, showing that the new orbit configuration still provides science opportunities for the InSAR community.

→ GOCE

GOCE data processing continues. The second generation of gravity-field models and derived parameters are under preparation, and preliminary versions have already demonstrated that GOCE is changing our understanding of the high-resolution gravity field. As a result, the application of such information is advancing rapidly. Recently, the first results in terms of ocean dynamic topography and ocean currents have shown that GOCE delivers a much sharper view of all the ocean's main current systems. Meanwhile, last summer, an anomaly in the main computer caused a temporary halt in the science data acquisition for about two months. The satellite has been fully operational with no further anomalies since September.

→ SMOS

SMOS celebrated its first 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 at large. The first global map of soil moisture and ocean salinity was released. The first SMOS Validation and Retrieval Team Workshop took place in November and provided an opportunity to present to the scientific community the status of the SMOS mission



The first global map of both soil moisture and ocean salinity delivered by SMOS (Cesbio, Ifremer, CATDS) and the calibration of level 1 products and collect feedback on the validation of the mission geophysical products over land and oceans. The radio-frequency interference situation in particular over Europe continues to improve.

→ ADM-AEOLUS

The preliminary Integrated System Test phase-1 of the Aeolus platform was completed with newly delivered software version and representative instrument electronics. This also closed most of the actions remaining from the platform qualification review. The equipment suppliers for the In-orbit Cleaning Subsystem (providing the required oxygen flow for 'cleaning' the high-intensity laser optics) have been selected and the subsystem CDR is being conducted. The corresponding leak tightness sealing of the laser transmitter is completed, as well as the design qualification of the sealed transmit and receive optics.

The implementation phase for changing the operational principle of the instrument from Burst Mode into Continuous Mode started after a CDR. The first laser transmitter FM is under integration and the related optical qualifications concerning laser-induced contamination and laser-induced damage are completed.

The contracts to upgrade the end-to-end simulator and ground payload data processing software to support continuous mode of the Aladin instrument are defined. In addition, there are two scientific impact studies to explore the potential of this new instrument operating principle.

→ SWARM

The thermal balance and vacuum test of the first satellite was completed in IABG. The second satellite should follow during early 2011. The first Electrical Field Instrument (EFI) and the Absolute Scalar Magnetometer were delivered in December. These two instruments will be integrated in the second satellite in 2011.

The Preliminary Mission Analysis Review for the launcher is under way in Moscow with Eurockot and Khrunichev. EFI validation studies with ground-based Incoherent Scattering Radars using Demeter data are providing interesting results for the in-orbit verification of Swarm, in particular for the plasma density measurement.

Activity for the 'Development of the Swarm Level-2 Algorithms and Associated Level-2 Processing Facility' was begun in October. This will generate models for the core lithospheric and magnetospheric fields, and for the mantle conductivity. In addition, potential precursor parameters for space weather studies will be generated.

The first satellite of the Swarm constellation completed its thermal balance and vacuum test at the IABG test facility, Ottobrunn, Germany (Astrium GmbH)

→ EARTHCARE

EarthCARE Phase-C/D preparation activities are under way in parallel with the closure of actions from System and Instrument PDRs. For the payload, the detailed ATLID bistatic analysis and design work is focusing on the laser head and new elements associated with the revised configuration of the lidar. The production of the Multispectral Imager EM is under way with SSTL. The Broadband Radiometer mechanism model testing is under way as planned and the life-test mechanism has been assembled together with its drive electronics.

In Japan, the mechanical test campaigns of both SMs and EMs were started at JAXA's Tsukuba facilities. Meanwhile, the equipment procurement process continues for the avionics and instruments, but at reduced pace for the elements potentially affected by the recent ATLID reconfiguration. The preliminary launcher accommodation study (Soyuz at CSG) has been started with Arianespace.

→ METEOSAT

Meteosat-8/MSG-1

The satellite and instruments are in good health. The last north/south stationkeeping manoeuvre was made at the end of October, after which the satellite inclination will drift at a rate of about one degree/year. Provided there are no serious failures, at least six additional years of mission are possible (from a design life of seven years). Nevertheless, preparations for reorbiting operations at the end of its life have started.

Meteosat-9/MSG-2

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

MSG-3
MSG-3 was removed from long-term storage just before Christmas 2010. Preparations for a launch in mid-2012 will start in January, driven by the availability of the test facility at Cannes for the optical vacuum test. This test will verify the performance of the imaging instrument after storage. The preliminary mission analysis with Arianespace has also started.

MSG-4
Acceptance testing of the new SEVIRI Drive Unit is on hold. A problem related to the movement accuracy is under investigation.

MTG
Final negotiations with the selected consortium were completed and Phase-B2 began in November. Thales Alenia Space (France) is the overall prime contractor and responsible for the MTG-I (imaging satellite) and Flexible Combined Imager. OHB System is as mission prime contractor for the MTG-S (sounding satellite) and will provide the MTG (common) platform. Kayser Threde is responsible for the Infrared Sounding Instrument. The full contract signature will take place in early 2011, following the formal inclusion of Astrium into the consortium, as system architect for MTG-S and responsible for several generic engineering packages for MTG-I.

Industrial activities are now running: consolidating the baseline design architecture and generating the associated requirements and support specifications at instrument, platform and subsystem level in preparation for the SRR in March; and preparing the schedule-critical and technically challenging Best Practice Procurements, such as the instrument detectors, scan mechanisms and cryogenic coolers.

→ METOP

MetOp-A
The satellite is in good health and completed its fourth year in orbit in October. All instruments are performing excellently, with a few exceptions: Eumetsat discontinued the LRPT Low Rate Picture transmission service in 2007 and AMSU-A1's channel 7 was declared as failed in 2009. The HRPT data transmission continues in restricted coverage area due to radiation potential issues. Recently Eumetsat decided to increase the HRPT coverage with an identified risk increase.

GOME-2 is operating well, although an investigation group has been set up to evaluate the in-orbit throughput degradation which could lead to some limitations in science data. MetOp-A deorbiting studies have started, planning for the first manoeuvres around the MetOp-C launch date.

MetOp-B
The Payload Module 1 (PLM-1) is back in storage, after completing its thermal vacuum test. Several instruments were already removed from PLM-1 to perform their last calibration campaign before launch. Two instruments (SEM/MHS) presented some out-of-specification results during the test and it was decided to swap with the MetOp-C units to reduce the risk on the launch of MetOp-B. Service Module 1 (SVM-1) completed all reference tests and is in 'soft' storage waiting for its thermal vacuum test in June. Meanwhile, the industrial team is focused on preparing MetOp-C as a back-up to MetOp-B.

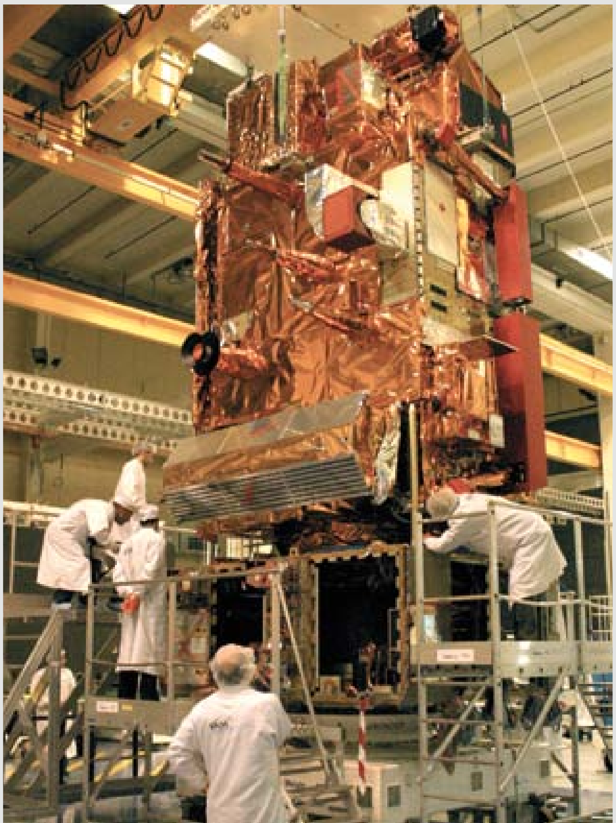
MetOp-B's launch period was established as 1 April to 30 June 2012, with the launch slot of one month to be confirmed in March 2011. The launch campaign is planned to start with transport to Baikonur in January 2012 for the launch on a Soyuz and Fregat-M upper stage.

MetOp-C
Functional tests of SVM-3 were completed ready for mating with PLM-3. PLM-3 was taken out of storage in April and passed the tests for coupling with SVM-3. PLM-3 arrived in Toulouse and was mated with SVM-3 on 17 November for the first time.

The satellite assembly, integration and tests activities (PLM-3, SVM-3 and solar array) are under way, in preparation for the vibration and acoustic tests starting in March at Intespace, Toulouse.

MetOp-C is planned for launch in October 2016, but needs to be ready by the middle of 2013 as a back-up for MetOp-B.

On 17 November 2010, MetOp-C's service module (from Astrium, Toulouse) and payload module (from Astrium, Friedrichshafen) were mated together for the first time



The contract for the MetOp-C launch in 2016, on a Soyuz and Fregat-M from French Guiana, was signed between Eumetsat and Arianespace in September.

→ SENTINEL-1

Sentinel-1 is in Phase-D (production of the flight units). All design reviews are completed and the delivery of the first flight units is taking place.

Platform development (Thales Alenia Space Italy) is progressing well. Test results for the various equipment EMs have been very positive. Tests of the integrated avionics subsystem and compatibility tests between the onboard computers are planned.

SAR instrument development is also progressing with the manufacturing of the flight units of the Waveguide Radiators (Astrium GmbH), Tile Control Units (RUAG, Sweden) and Tile Power Supplier Units (SELEX Galileo, Italy). The Sentinel-1A flight Deployment Mechanisms (SENER, Spain) have already been delivered to the SAR instrument, and the Electronic Front-End Module (Thales Alenia Space Italy) is in final EQM testing before beginning flight production. Test campaigns for the Antenna mini-Tile STM and Tile EQM are in place to verify the SAR antenna performance, and the thermo-mechanical design and life-test. The SAR Electronics (Astrium Ltd) breadboard test campaign was completed and the EM campaign is in progress.

The capability of integrating the Optical Communication Payload (OCP) has been proven after consolidating interfaces through the review of the OCP Interface Control Document (ICD) by ESA, DLR and TESAT, as OCP provider. The Sentinel-1A Launch Services contract was awarded to Arianespace for launch on a Soyuz from Kourou.

→ SENTINEL-2

The Multispectral Payload Instrument CDR was conducted in October, followed by the Satellite System CDR. The overall Satellite and Payload Instrument design has been judged through these two reviews as very mature, and the predicted mission performance established on the basis of EM results was promising. This overall status means FM equipment can be delivered in support of Satellite Protoflight Model integration and test. The most salient risk reported was the redesign of some multispectral optical filters to minimise stray light effects and improve their radiometric performance.

The first version of the onboard software was delivered to integrate EM equipment and initiate the satellite-level Assembly, Integration and Test using EMs and environment simulators. The Payload Instrument is undergoing EM integration and test, and FM equipment is being delivered, such as the payload instrument primary and secondary structure and the silicon carbide focal plane assemblies.

The Optical Communication Payload framework agreement was signed by ESA and DLR. At technical level, the OCP Interface CDR, complemented by the Satellite System CDR, identified some critical design and qualification activities that must be closely monitored to secure performance and delivery of the OCP FM for integration.

The first Sentinel-2 Mission Advisory Group meeting was held in November. Sentinel-2 Image Quality activities by CNES supporting Sentinel-2 are proceeding, including development of the Ground Prototype and Image Quality Processors to support the Sentinel-2 Payload Data Ground Segment (PDGS) Operational Processor and the preparation of in-orbit commissioning.

→ SENTINEL-3

Most of Sentinel-3's Phase-C/D equipment CDRs are complete. The first two instrument CDRs (SRAL and MWR Part1) were completed in the last months, as well as the Platform CDR. The OLCI Instrument CDR is ongoing, and the remaining CDRs (SLSTR Instrument, MWR Part-2 and satellite) start in 2011. The selected Sentinel-3 PDGS contractor has started their development activities, preparing for the PDGS PDR planned in 2011. The industrial consortium has been completed and all 122 subcontractors are in place.

At system level, coding of the flight software has started. In parallel, the ground processors simulators should be available around June for the optical simulators and around February for the topography simulators, compatible with the PDGS development planning. Preparations of calibration/validation activities and the commissioning plan have started.

Several STMs and EMs have been delivered for testing. So far, the onboard computer (SMU), GPS, coarse rate sensor and startracker EMs have been delivered to the prime contractor, allowing virtual EM testbed activities to start at satellite level, where all satellite avionics will be gradually integrated and validated with the flight software, before starting Assembly, Integration and Testing of the Proto Flight Model (PFM) satellite. Some PFM items have already been manufactured following equipment CDRs to protect the programme schedule.

→ SENTINEL-5 PRECURSOR

The two parallel Sentinel-5 Precursor System and Spacecraft Phase-A/B1 studies with Astrium Ltd and OHB initiated in 2010 are progressing. PDRs took place with both prime contractors last year. Satellite/system designs were compared against a red-lined System Requirements Document and updated TROPOMI Interface Requirements Document resulting from the Consolidation Review of TROPOMI in October. Prime contractor activities were subsequently streamlined for the remainder of Phase-A/B1.

For the ESA-procured TROPOMI payload elements, the UVN Detector Module was awarded to RUAG CH, the SWIR shortwave infrared spectrometer to SSTL UK and the Instrument Control Unit to RUAG Sweden.

The newly appointed Minister of Economic Affairs of the Netherlands visited ESTEC in Noordwijk in December, where the rider to the contract for Sentinel-5 Precursor was signed by Volker Liebig, ESA's Director for Earth Observation Programmes, and Bart Reijnen, CEO of Dutch Space.

→ PROBA

Proba-1 is now in its tenth year in orbit as an Earth Observation third-party mission. It is operating normally, acquiring about 450 images per month, at five angles (–55, –36, 0, +36, +55 degrees) and up to 62 spectral channels (400–1050 nm). It covers several types of observations: land and vegetation, inland water, coastal areas, atmosphere and snow and ice. The spacecraft and instruments are healthy, allowing a continuation of the mission for a few more years, despite the degradation of the local time of the descending node.

→ HYLAS

The Hylas-1 test programme was completed in Bangalore, India, in August 2010. Consent to ship the spacecraft to Kourou was given at the Pre-Shipment Review in October, held with Avanti, ESA, the manufacturing team of Astrium and the Indian Space Research Organisation. The Launch Readiness Review took place on 24 November and the Ariane 5 launcher was rolled out to the pad with two satellites on board, Hylas-1 and its co-passenger, Intelsat 17.

The Hylas-1 launch campaign began on 12 October and progressed swiftly, thorugh health checks and propellant loading. Hylas-1 is seen mounted on the launcher at Europe's Spaceport in French Guiana

Hylas-1 launch, 26 November 2010

Ariane 5 V198 lifted off on 26 November within the first second of its launch window and reached geostationary transfer orbit 34 minutes later with a perfect injection. Both solar wings were deployed on Hylas-1 and the propulsion system was activated to maintain satellite attitude. In the early hours of 30 November, the satellite reached geostationary orbit and, by the following day, both antenna reflectors were deployed to their planned position. Since liftoff, Hylas-1 has remained in good health, with all systems operating within their anticipated current and temperature limits, including the Generic Flexible Payload.

→ SMALL GEO

The Small Platform Programme (Small GEO) is developing a European platform product line for the market of small geostationary telecommunication satellites, with payload mass of 300 kg, 3 kW power and lifetime of 15 years. A core team of industries was formed, under the leadership of OHB System, including Swedish Space Corporation, RUAG Space (CH, formerly Oerlikon Contraves Space) and LuxSpace (LU) to jointly define and develop a platform and to exploit commercially the resulting product.

Small GEO platform development

The Small GEO Platform Qualification Status Review (QSR) and PDR were held last year. Development at subsystem and unit level is progressing and will be valuable input for the review at system level. In parallel, development of critical technology, such as the High Efficiency Multiphase Thrusters (HEMPT) Electrical Propulsion System, is progressing. Thales Electronic Devices (DE) presented a new EM version with improved convergency of the beam plume, compatible with Small GEO needs.

Hispasat AG1 satellite development

This is a satellite that, in partnership with Hispasat (ES) will use the Small GEO platform developed by OHB and partners. Hispasat AG1 will be placed in a geostationary orbit, where it will supply Spain, Portugal, the Canary Islands and America with multimedia services. Hispasat will be integrating Hispasat AG1 in its existing fleet of geostationary communications satellites. This satellite will incorporate advanced payload technology such as a DVB S2 Processor and active radiating antenna.

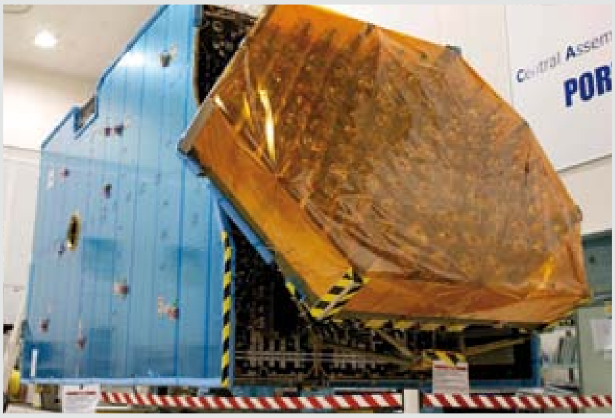
Hispasat is coordinating the activities of OHB, the prime contractor, focusing on the finalisation of the satellite sub-system design, payload accommodation and review of payload performance compliance with overall mission requirements and the overall satellite and system requirements. The mission and payload PDRs were completed in 2010.

Innovative Payload (REDSAT)

The System Onboard Processor (OBP) PDR was held in 2010. CDRs at unit level for the second element of the innovative payload, the Direct Radiating Array antenna, were completed in 2010 allowing industry to start the CDR at system level in January.

Transparent Payload

Manufacturing of most of the PFM/FM units started at the end of 2010. CDRs for the remaining units will be completed in early 2011.



The Alphasat Repeater Module with integrated antenna feed at Portsmouth, UK, ready for shipment to Toulouse, France (Astrium Ltd)

Small GEO platform extension

The industrial team submitted its proposal to cover the areas where additional investments are envisaged to enable full commercial exploitation of the Small GEO platform. The ESA Tender Evaluation Board reviewed the proposal and negotiation with industry will start in 2011.

→ ALPHABUS AND ALPHASAT

The Alphabus Qualification Review was conducted during in October and November with an ESA/CNES steering board on 22 December. This confirmed the qualification of the Service Module as a generic product line. Launch of Alphasat on Ariane 5 is scheduled for the second half of 2012.

Most flight hardware has been delivered and integrated in the PFM Service Module. The electrical integration in Toulouse has been completed and the full system functional test campaign has been performed. The Alphabus platform is ready for coupling with the payload. The formal Alphabus acceptance review with Inmarsat is planned for April.

The integration of the payload on the Repeater Module progressed well in Portsmouth, UK. More than 215 items of equipments have been mounted. The halves of the Repeater Module were coupled together in November, followed by the integration of the L-band feed in December. The payload Repeater Module will be shipped to Toulouse in February for integration with the platform.

Flight hardware for the Technology Demonstration Payloads (TDPs) is being manufactured and tested. Each TDP development offers unique challenges, but all are progressing towards inclusion on the satellite.

A new activity related to the ground segment of TDP5 has been started with Joanneum Research (AT) in coordination with ASI (IT), responsible for the TDP ground operations. This consists of definition, selection, installation and operation of a high-performance Q/V-band ground station with a tracking antenna at a fixed location in Graz.

The contract for the Alphabus Extension was awarded to industry in November, and several subcontractor activities were started in November and December. CNES has approved complementary funding to complete the Alphabus Extension scope, to be implemented through additional ESA and CNES national funding.

As part of the Alphasat Ground and User Segment programme, Inmarsat and ESA are initiating together the development of innovative value-added applications based on the Inmarsat Broadband Global Area Network and Global Handheld Service using the Alphasat and Inmarsat 4 satellites. ESA will launch an Open Call for Proposals in March to invite companies to apply for ESA funding to develop and trial applications addressing new and/or underserved markets.

→ ARIANE 5 POST-ECA

The Vinci M3 test-firing campaign continued at the DLR Lampoldshausen facilities. Test-firing 9 closed the year in a nozzle extension configuration and lasted 700 seconds. Two more M3 tests are planned to finish the campaign. The Vinci M4 campaign will start later in 2011. Test activities have also continued at engine and thrust-chamber level. The Vinci PDR review was completed in 2010.

Technology maturation activities on potential hybrid rocket engine applications for A5ME took place last year with the successful firing of 22 rocket engines. Long-duration test-firings are scheduled to take place in early 2011.

→ VEGA/P80

On 26 October, the Vega test campaign started at Europe's Spaceport in French Guiana with the transfer of the mock-up first stage from the Booster Integration Building (BIP) to the Vega Launch Zone. The first stage transfer from the BIP to the Mobile Gantry was successful, involving the mechanical validation of several elements of the launch vehicle and the ground segment.

For P80, the Final Key Point of Insulated Motor Case Shock Protection was performed and transfer to BIP was allowed. The P80 Loaded Motor Case First Article Configuration Review was also performed. In launcher system tests, the upgrade of the HWIL ('hardware in the loop') system test facility was completed. HWIL telemetry tests are also complete.

→ SOYUZ AT CSG

The industrial acceptance review of the Mobile Gantry structure was held in October. Mobile Gantry integration activities progressed, with the three-shift operation (implementing the 'Corps d'Etats Complémentaires' activities) switched to a two-shift basis (removal of night shift) in October, after the Low Current and Security (CFS) activities. A new modified hydraulic system for the Mobile Gantry motorisation was installed and tested at operational pressure in November. The first complete translation test of the Mobile Gantry to the Launch Zone was performed on 19 November, followed by a second test in December. The upper composite mock-up was hoisted to the 27-m platform and the launcher's ventilation systems were tested. The Mobile Gantry was transferred again to the Launch Zone on 18 December for a validation campaign of the upper composite ventilation system lasting until February.

Qualification of the Launcher System (CQ SL) was held in October in Samara. The Steering Committee will meet in February. The Critical Design Review for the Soyuz Launch System (SLS CDR) was held in November.

Mechanical, gas, hydrogen peroxide and kerosene test campaigns were completed in December. A post-test review of Technical Qualification (CRE QT) campaigns is planned for March. ELS installation property will then be transferred from CNES to ESA and from ESA to Arianespace on 1 April. The operational qualification campaign will start in early April. Launch is planned for Galileo IOV on 31 August.

→ FUTURE LAUNCHERS PREPARATORY PROGRAMME

All subsystem-level CDRs have been completed. Evaluation of the qualification status for the actual Intermediate eXperimental Vehicle (IXV) utilisation environment needed a detailed assessment of the qualification campaigns performed within past programmes for each of the approximately 40 components. Activities are heading toward the system-level CDR.

For the system, industrial activities implemented through the Astrium Frame Contract are progressing on the four launch vehicle concepts under investigation, preparing a project Key Point planned for mid-2011. For the High Thrust Engine, after the Architecture Key Point of the Stage Combustion Rocket Engine Demonstrator (SCORE-D), the system technical specification and the subsystems functional specifications are being prepared for the SRR in early 2011. The industrial proposal targeting activities up to PDR was received in December and is being evaluated. In solid propulsion, the PDR for the Pressure Oscillation Demonstrator started in December. Activities have started in the domain of hybrid propulsion.

Industrial activities are progressing with the PDR for the Cryogenic Upper Stage Technologies (CUST). The CDR is in progress for the in-flight experiment of the Propellant Management Device (PMD) to be flown on a Texus sounding rocket. In Materials and Structures, advanced technologies are progressing towards sample tests and preparation of sub-scale demonstrators.

→ HUMAN SPACEFLIGHT

ESA participated in the 50th anniversary meeting of the International Academy of Astronautics (IAA) Heads of Space Agencies Summit in Washington DC in November. Heads of agencies welcomed the Summit Declaration and highlighted the need to foster closer international cooperation across four topic areas, including human spaceflight, to strengthen

MagISStra, ESA's third long-duration mission on the ISS, began on 15 December, when the Soyuz TMA-20 spacecraft carrying ESA astronaut Paolo Nespoli (right) and his crewmates Dmitri Kondratyev and Catherine Coleman was launched from Baikonur Cosmodrome in Kazakhstan

the effectiveness and support of global space activities. The Declaration highlighted that human missions to the surface of Mars are the long-term goal of the space exploration in view of the scientific interest and strategic prospects for humankind.

The latest International Space Exploration Coordination Group (ISECG) meeting was also held on occasion of the IAA Summit. Senior management representatives from ASI, CNES, DLR, ESA, KARI, JAXA, NASA and the UK Space Agency discussed the content and development plan for the first version of the Global Exploration Roadmap, to be finalised by mid-2011. The ISECG plans to organise, in partnership with IAC, AIAA and possibly COSPAR, a Global Space Exploration Conference in 2011.

The 'Call for Ideas: ISS for Exploration', published in October received considerable interest. More than 180 proposals from 19 countries were received. The call is intended to support the preparation of a Programme Proposal to be submitted to the ESA Member States at the next ESA Ministerial Council in 2012.

ESA received 34 Letters of Intent following the Announcement of Opportunity (AO-10-IBER) to study the effects of radiation exposure with a ground-based accelerator facility. A workshop with around 50 participants was held at the facility, the Gesellschaft für Schwerionenforschung (GSI) in Darmstadt, Germany, on 24 November.

Paolo Nespoli shields his eyes from the Sun in the Cupola module on the ISS

Soyuz TMA-20 seen approaching the ISS on 17 December, with a hand-written sign 'ISS Exp 26 Here we come' held in the window by Paolo Nespoli, reminiscent of the sign held up by Gemini 6 astronaut Wally Schirra over 45 years ago during the rendezvous with Gemini 7 (inset)

→ SPACE INFRASTRUCTURE DEVELOPMENT/ISS EXPLOITATION

The launch date of ATV *Johannes Kepler* remains set at 15 February with a docking planned on 23 February and undocking on 4 June. The independent ATV-2 Flight Acceptance Review Boards were held in November and December.

By January, ATV *Johannes Kepler* was fully loaded with propellant (7.4 tonnes) and oxygen, and the loading of 'late access' cargo completed the ATV-2 cargo manifest. On 11 January, the independent Operations Readiness Review board signed the Certificate of Flight Readiness and declared that the Control Centre and operational products will be ready in time for launch. On 20 January, ATV *Johannes Kepler* was transferred to the launcher assembly building to be mounted on the Ariane 5. This was followed by 20 days of combined launcher/spacecraft operations. The Launch Readiness Review takes place on 10 February.

Astrium announced the 'ready for launch' date for ATV *Edoardo Amaldi* as end of February 2012. The Pre-shipment Review for Kourou is planned for August. The ATV-4 system integration is on schedule.

→ UTILISATION

Implementation of Increment 25/26 started and will run until March, and will cover the largest part of the science programme planned for Paolo Nespoli's MagISStra mission starting on Increment 26.

External Payloads

The SOLAR platform has been acquiring data at various intervals during Sun visibility windows. A new Sun visibility window opened again on 24 December. Following the conclusion of the detailed technical feasibility study for on-orbit lifetime extension, the science team will be able to continue gathering science data in a period of increasing but still fluctuating solar activity up to 2013 and possibly beyond.

The Expose-R facility with nine exobiology experiments continues to function well and acquire scientific data. A tentative return of the sample trays was foreseen for November 2010 which allowed for a scientifically beneficial extension of the open space exposure period to more than 1.5 years. A request from Roscosmos led to a mission extension until Spring 2011, when the sample trays will be retrieved on an EVA and returned to Earth either by Shuttle

ATV *Johannes Kepler* Integrated Cargo Carrier is ready for mating with the spacecraft's Propulsion Module or the next Soyuz in March. A new experiment complement for the tentative future Expose-R2 mission has been identified, and is being implemented in collaboration with the Russian partners.

The Vessel Identification System (also known as the Automatic Identification System, AIS) data acquisition is ongoing and telemetry is still being received by the Norwegian User Support and Operation Centre (N-USOC) in Trondheim via ESA's Columbus Control Centre in Germany. The AIS has acquired an extensive amount of data since its installation in Columbus, and NATO is also interested in using the data.


Paolo Nespoli in his first session of the NeuroSpat experiment

Life Sciences

The culture chambers for the Genara-A experiment (which took place in the European Modular Cultivation System) are currently in a General Laboratory Active Cryogenic ISS Experiment Refrigerator (GLACIER) until their return on Shuttle mission ULF-5. Genara-A is studying plant (Arabidopsis) growth at molecular level in weightlessness.

Functional recovery activities for the Biolab facility are still ongoing. The feasibility of a full repair in orbit has been demonstrated by industry. Biolab utilisation will be resumed in 2012 with the TripleLux experiments when the microscope unit has been repaired on the ground. The objective of TripleLux is to understand the cellular mechanisms underlying the aggravation of radiation responses, and the impairment of the immune function under space conditions.

The samples from the short-duration biology experiments PADIAC and SPHINX were returned with Soyuz TMA-19 (23S) on 26 November. The experiment samples are undergoing analysis at the respective research team laboratories. The objective of SPHINX is to determine how Human Umbilical Vein Endothelial Cells modify their behaviour when exposed to real weightlessness. This could provide better knowledge of endothelial function, which could be useful for clinical application. The scientific objective of PADIAC is to determine the different pathways used for activation of T cells, which play an important role in the human immune system.

On 20 December, Paolo Nespoli set up the hardware for the NeuroSpat experiment. The following day, he was assisted by NASA astronaut Catherine Coleman in donning and setting up the Electroencephalograph (EEG) cap and carrying out his first session of the experiment. On 22 December, Nespoli transferred data to the hard disk of the Multi-Electrode EEG Measurement Module (one of the European Physiology Modules subracks). These data will be downlinked to ground following a subsequent session of NeuroSpat.

NeuroSpat, which was the first experiment to make full use the European Physiology Modules facility when performed by ESA astronaut Frank De Winne in June 2009, is investigating the ways in which crew members' three-dimensional perception is affected by long-duration stays in weightlessness. NeuroSpat also incorporates an experiment (Prespat) from the European Commission within the SURE project.

Portable Clinical Blood Analyser cartridges for ESA's Sodium Loading in Microgravity (SOLO) experiment were transferred from the Soyuz TMA-20 spacecraft to the MELFI 1 freezer in the Japanese laboratory on 18 December. SOLO is carrying out research into salt retention in space and related physiological effects, important for long-duration spaceflights.

A new session of ESA's Vessel Imaging experiment was carried out in conjunction with NASA's Integrated Cardiovascular Experiment on 15 November. This session of both joint experiments was carried out by NASA astronaut Shannon Walker (assisted by Doug Wheelock). A further session was carried out on 30 December by Catherine Coleman (assisted by Nespoli). Both sessions consisted of an echography scan with ECG and heart rate measurements also being taken. On the ESA side, support came from DAMEC and CADMOS, two of the User Support and Operations Centres for ESA, via the Columbus Control Centre in Germany. The Vessel Imaging experiment evaluates the changes in central and peripheral blood vessel wall properties and cross-sectional areas of long-duration ISS crewmembers during and after long-term exposure to weightlessness.

The Portable Pulmonary Function System (PPFS) continues to support ESA's ThermoLab experiment in conjunction with NASA's Maximum Volume Oxygen (VO2 Max) experiment. ThermoLab uses the ESA-developed PPFS (combined with exercise) to investigate thermoregulatory and cardiovascular adaptations during rest and exercise in the course of long-term exposure to weightlessness. On 18/19 October, experiment sessions were carried out by Expedition 25 Commander Doug Wheelock and Shannon Walker respectively. On 29 December, Catherine Coleman completed her first session.

ESA's Matroshka radiation phantom, in Japan's Kibo laboratory since May, is continuously acquiring data about the radiation environment inside the ISS. Following agreements with JAXA and Roscosmos, the joint long-duration experiment run was performed until HTV-2 arrived on 27 January.

The Dose Distribution inside the ISS (DOSIS) experiment is progressing well, with the instrument still acquiring data using one of the active DOSTEL detectors (DOSTEL-2) in the European Physiology Modules. The passive detectors for DOSIS, which were removed and returned to Earth on STS-132, are being analysed.

Materials and Fluids Research
Twelve of the CETSOL/MICAST experiment samples have been processed to date with the processed samples being analysed by the relevant science teams. CETSOL and MICAST are omplementary material science projects, researching the formation of microstructures during the solidification of metallic alloys. US scientists have joined the European science teams and are performing joint experiments.

The next SODI experiments are 'Diffusion and Soret Coefficient measurements for improvement of crude oil recovery' (DSC) and Crystallisation of Advanced Photonic Devices (Colloid). The Colloid experiment cell assembly was uploaded to the ISS on Progress 39P on 10 September together with the refurbished SODI control unit. The experiment was set up in the Microgravity Science Glovebox (MSG) with Near Field Scattering diagnostics to record the fluctuation speckle field of small aggregates doing the typical 'random walk' of Brownian motion.

After the SODI-Colloid experiment, the MSG rack was moved from Columbus back to the US laboratory on 21 October. The subsequent DSC experiment will be the third and final SODI experiment processed in MSG, now tentatively planned later in 2011 after a redefinition of the liquid mixtures.

The GeoFlow-2 experiment has been stowed in the Integrated Cargo Carrier of ATV Johannes Kepler for launch in February and subsequent processing of an exhaustive scientific programme for a couple of months in the Fluid Science Laboratory. Final science and experiment operations preparation activities are taking place at the USOCs.

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

Educational activities
An illumination test was performed by Paolo Nespoli in connection with the 'Greenhouse in Space' education project on 26 December. In this project the concept of fresh food production in space will be related to the biology and science curriculums of 12–14 year olds through film and ISS live-link activities. A website for the educational 'Greenhouse in Space' experiment is online, inviting up to 1000 schools in Member States to participate in the experiment.

The Greenhouse in Space project payload (Orbital Technologies Corp.)

Non-ISS Missions
Two bedrest studies are under way at DLR (nutrition focus) and MEDES (with centrifuge and artificial gravity).

→ ASTRONAUTS

Crew training for ISS Expeditions 28 to 31 are on schedule. Roberto Vittori is in training for his planned mission in April 2011, and André Kuipers continues his mission training for the Expeditions 30/31 starting at the end of 2011. Basic Training for the six astronaut candidates has been completed. ESA has three new flight opportunities to the ISS before 2015, so half of the new astronauts will have an opportunity to fly in space very soon. The first will head into orbit in 2013.

ESA's astronaut candidates were named officially as 'astronauts' in a ceremony held at the European Astronaut Centre (EAC) in Cologne, Germany, in November. From left: Director General Jean-Jacques Dordain, Thomas Pesquet, Luca Parmitano, Alexander Gerst, Samantha Cristoforetti, Director of Human Spaceflight Simonetta Di Pippo, Andreas Mogensen, Timothy Peake and Head of EAC Michel Tognini

→ CREW TRANSPORTATION AND HUMAN EXPLORATION

Advanced Reentry Vehicle (ARV)
Phase-A industrial activities are progressing on an agreed three-module configuration providing added flexibility and operational capability. An assessment is being carried out by ESA and the prime contractor of the information received from NASA at the last Technical Interchange Meeting on the ARV/ISS Interface aspects. In October, JAXA discussed possible synergies and opportunities for cooperation for the ARV and the HTV reentry derivatives. This is being pursued to identify key interests and technical options.

International Berthing Docking Mechanism (IBDM)
The industrial proposal for the IBDM development for the ISS – Advanced Tasks, funded via the Transportation Early Activities, has been received and negotiated. The related activities start in January.

The ISS Multilateral Coordination Board released an International Docking System Standard (IDSS), which contains the information necessary to describe the physical features and design loads of a standard docking interface. The IDSS is an outstanding example of international collaboration and will help to make joint spacecraft docking operations more routine and eliminate critical obstacles to joint space exploration undertakings.

→ EXPERT

Vehicle integration at Thales Alenia Space Italy is progressing, with the main structure delivered to Turin by SONACA. All experiment FMs have been delivered by the responsible research institutes, and integration of the payload and avionics has started.

The metallic hot structure has been delivered to Turin after the final test at Dutch Space. Agreements to finance the European industrial subcontractors have been confirmed by Belgium, Austria, Switzerland and the Netherlands. The permission for launch is expected from Russian authorities in time for the Spring launch.

Lunar Lander Activities
On the Lunar Lander Phase-B1, the preparation of the ITT for the lidar breadboard activities with the Canadian companies will be issued in January. Work with Arianespace for the Soyuz launcher performance analysis has been initiated. The fourth and last ITT for the payload accommodation studies, financed under the General Studies Programme, was issued in November. A meeting with DLR took place on 3 November to coordinate the technology activities and to review the status of the documentation/interface definition of the Mobile Payload Experiment in preparation for the ITT issued by DLR in mid November.

Roberto Vittori in the cockpit of a NASA T-38 jet during training for his mission on STS-134

Human Exploration Technology
The industrial proposal for the Advanced Closed Loop Systems (ACLS) Phase-C2 leading to a System PDR was received in November and is under evaluation. An industrial proposal was received for the MELiSSA Food Characterisation Phase-2 activity. The Tender Evaluation Board procedure was finalised and possible options to proceed are being evaluated.

International Architecture Development and Scenario Studies
EADS Astrium (DE) presented their international industrial team and their work on the analysis of future human exploration mission scenarios on 12 October, and a first progress meeting was held on 13 October with Alenia, and with Astrium on 22 November. An ESA internal 'critical design facility' study was completed to prepare for the ESA internal mid-term scenario review on 13 January (development of ESA benchmark scenarios and methodology for a comparative scenario assessment).

Terms of Reference of the Scenario Review Committee, composed of representatives from states funding

Mission X logo and website screen saver

the Scenario Study Element of the Human Transportation and Exploration Preparatory Programme, were developed. The Committee will be responsible for the implementation of Public Scenario Review planned for March.

→ OUTREACH AND PROMOTIONAL ACTIVITIES

A website for 'Mission X: Train Like an Astronaut', an educational project by ESA and its international partners, went live at the start of October, with exercises, activities and information aimed to help children to 'climb aboard'. Some 4000 pupils around the world have embarked on a unique mission to train like an astronaut and boost their fitness. Teacher training days have provided support in participating countries.

Paolo Nespoli, known to his Twitter followers as @astro_paolo, tweeted a good luck message from the ISS to all participants on the launch of Mission X

Swedish astronaut Christer Fuglesang and Dutch Olympic swimming champion Pieter van den Hoogenband officially launched Mission X in the Netherlands on 14 January at Space Expo, Noordwijk

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