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# bulletin

→ space for europe



## European Space Agency

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

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

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

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

The ESA headquarters are in Paris.

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ESOC, Darmstadt, Germany.

ESRIN, Frascati, Italy.

ESAC, Madrid, Spain.

EAC, Cologne, Germany.

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Vice-Chairs:  
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Director General:  
Jean-Jacques Dordain



On cover:  
Swarm is ESA's first Earth observation constellation of satellites, launched on 22 November from Plesetsk Cosmodrome, Russia. The three Swarm satellites will help us to unravel one of the most mysterious aspects of our planet: its magnetic field (ESA/P. Carril)

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# → THE FIRST: SPACELAB AND ULF MERBOLD

A history of US/European cooperation in space

Carl Walker  
Communication Department, ESTEC, Noordwijk, the Netherlands





ESA's Spacelab-1 in orbit in the payload bay of Shuttle *Columbia* (NASA)

**Thirty years ago, in November 1983, the first European-built Spacelab was launched on board Space Shuttle *Columbia*. Also on board was ESA's first astronaut, marking ESA's entry into human spaceflight activities.**

On what was only the ninth Shuttle mission STS-9, Spacelab-1 was launched on 28 November 1983 at 11:00 local time from Kennedy Space Center, Florida. As well as the maiden flight of Spacelab, this was a landmark flight in other ways: one of the crew was German ESA astronaut Ulf Merbold, the first non-American astronaut to fly on the Space Shuttle.

The six-member crew was also the largest of any manned space mission at the time. They were: John W. Young, commander, a veteran Apollo astronaut with five previous flights; Brewster Shaw, pilot; Owen Garriott and Robert Parker, both mission specialists; and Byron Lichtenberg and Ulf Merbold. Lichtenberg was a researcher at the Massachusetts Institute of Technology. Working in two teams of three, this crew worked 12-hour shifts, allowing for 24-hour operations for the first time on a Shuttle flight.

After completing 166 orbits of the Earth, in just over 10 days, *Columbia* landed at Edwards Air Force Base in California on 8 December. During Spacelab-1, over 70 scientific experiments were conducted in a variety of fields including astronomy, solar physics, space plasma physics, Earth observation, material science, technology and life sciences.

Between 1983 and 1998, Spacelab modules flew on the Space Shuttle a total of 22 times, representing some 244 days in

orbit. Not only have Spacelab experiments made a major contribution to space science research, but also the knowledge and expertise gained by both ESA and NASA during the Spacelab missions has made a significant contribution to today's International Space Station programme.

### The beginning: 1969-73

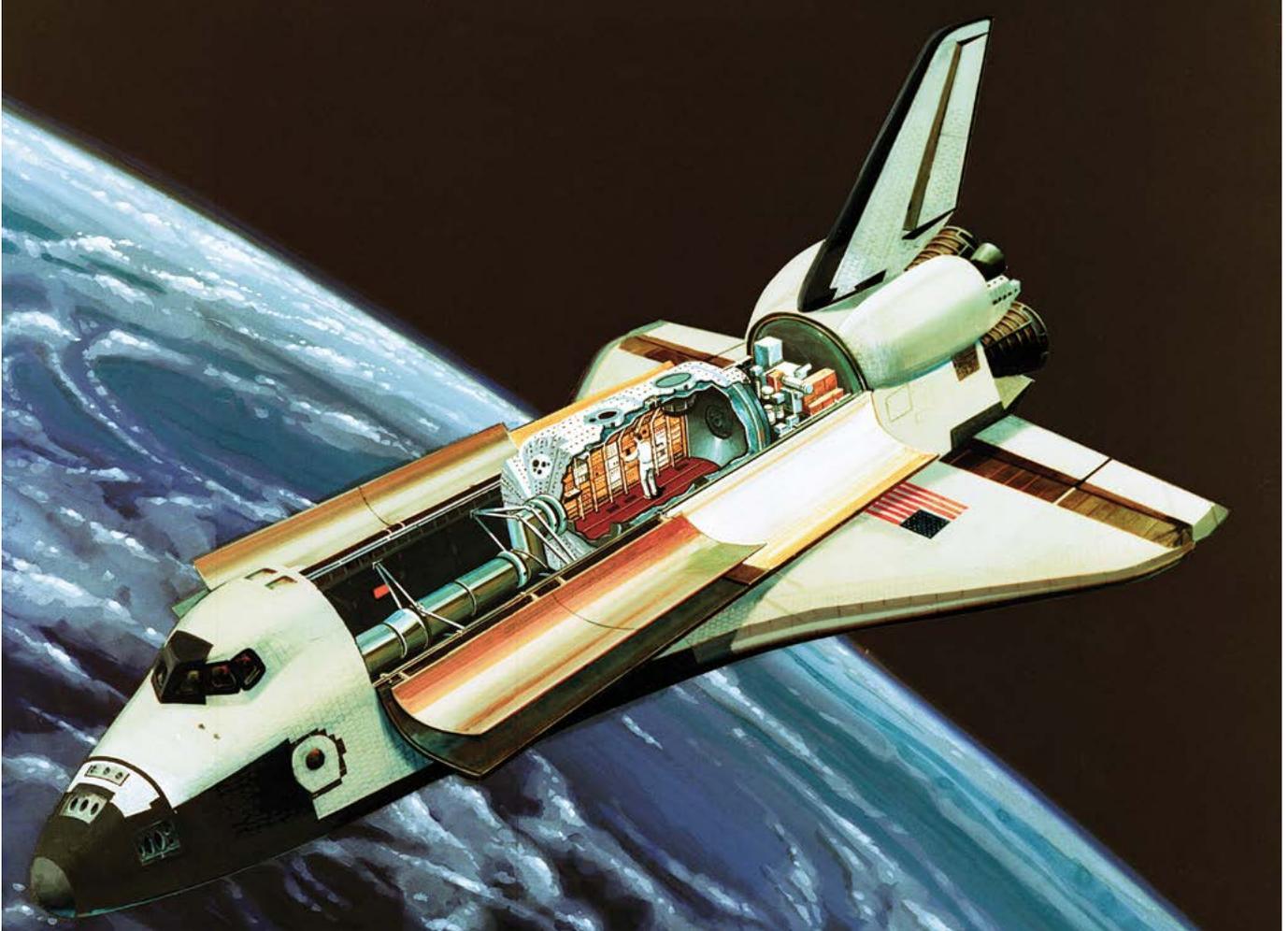
NASA had reached the Moon, with Apollo proving that the boldest goals could be achieved. However, to conduct post-Apollo programmes within reasonable budget limits, a new vehicle was needed to carry astronauts and cargo into space, without throwing away hundreds of million dollars per flight.

Europe, then represented by the European Launcher Development Organisation (ELDO) and European Space Research Organisation (ESRO), the precursors of today's ESA, was invited to take part in early studies in 1969. ELDO began developing a concept for a reusable 'space tug' to ferry cargo from low to geostationary orbits and beyond, but NASA eventually turned to US expendable 'kick stages' for this role.

By January 1972, the US President had approved NASA's next space programme, the pillar of which would be the first reusable launch system: the Space Transportation System (STS) – otherwise known as the 'Space Shuttle'. However, the Space Station was delayed for an undetermined period, and offers of collaboration with Europe were restricted as well, with the European space tug's future also uncertain. Still, ESRO continued to work on a 'sortie module' to be flown in the Shuttle's cargo bay, intended to help in performing space science, applications and technology activities.



The STS-9/Spacelab-1 crew: Owen Garriott, Byron Lichtenberg, Brewster Shaw, John Young, Ulf Merbold and Bob Parker (NASA)



↑ Concept for the Shuttle and the European 'sortie laboratory' (NASA)

Even though everyone agreed that this space laboratory could be built in Europe, this choice reflected some of the concerns of NASA in cooperation with other countries: the laboratory had to be self-funded, separable from the Shuttle, and even though it was an integral part of the post-Apollo programme, it should not require the transfer of highly advanced technical information.

But in Europe, the choice whether to accept the American invitation had a much wider significance. Spacelab, as it would be called in Europe from 1973, would begin a new approach to the utilisation of space, whose underlying principle was to support life in space for a long periods. ESRO's Director General, Alexander Hocker, said, "Spacelab was the indispensable element to transform the Shuttle into a first-generation Space Station."

Soon after the decision to focus on a sortie laboratory, a NASA technical team visited ESTEC in Noordwijk in June 1972 to share information acquired through previous NASA studies. This would help ESA to assess what financial and technical resources would be required for Europe to develop the laboratory. In the meantime, diplomatic contacts began to plan the cooperation.

In August 1972, a meeting between the European Space Conference Secretariat and NASA was held in Washington DC to discuss the content of agreements on the laboratory.

It was agreed that the laboratory was an essential part of the US Space Transportation System but NASA was adamant that its construction would not guarantee any preferential treatment in the use of the Shuttle; countries participating in the development of the laboratory would only have a priority right to use it but would be entitled to appoint crew members for its flights.

NASA would retain overall responsibility for the total programme and the last word in such vital areas as Shuttle/laboratory interfaces, quality control and safety. In particular, NASA wanted to be able to assess the efficiency of the management plan proposed by ESRO for the Spacelab and stressed the necessity for a 'unitary management agency' on the European side.

### Meanwhile, in Europe...

The approval of a cooperative Spacelab programme was the last stage of long and complex negotiations on European participation in the US post-Apollo programme. At the time though, Spacelab was only one of several major concerns of European Member States, these being the future organisational nature of Europe in space, in particular the impending liquidation of ELDO, as well as uncertainties about a new launcher capable of meeting all European needs in the field of application satellites.

The differences of French and UK positions over these points came up in a meeting of Ministers and representatives of participating states (November 1972) called to organise the December meeting of the European Space Conference. Faced with the reluctance of some countries to join the Europa III launcher programme of ELDO, France was prepared to carry out a programme meeting the same objective (LIIS, the future Ariane).

Not only that, but both France and the UK were not enthusiastic about joining the US in the post-Apollo programme. France noted that 'while the Spacelab would enable Europe to take an interest for the first time in the problems of manned flight, none of the economic needs of the next decade would be met by the development in Europe of a Sortie Laboratory, which can in no case be considered a substitute for a launchers programme'

The UK stated that, for the time being, the UK would not participate to the post-Apollo programme but thought it could change this position only if progress were made in the creation of a single European agency. Only Germany seemed to be ready to accept the US invitation. Despite this continuing divergence, some countries agreed, under certain conditions, to finance the next phase of studies for the laboratory.

The activities of ESRO and ELDO in the post-Apollo programme were reported at the European Space Conference of December 1972. After a series of 'harsh discussions' and 'horse-trading among European partners', agreement was reached in July 1973. There would be a single 'European Space Agency', which would have the task of integrating national and European space programmes in the future, there would be an Ariane launcher and the Spacelab programme was approved.

It was in this very difficult diplomatic setting that US/European negotiations on the Spacelab agreements



took place. The early months of 1973 were devoted to the drawing up of the final text of the US/European diplomatic instruments, with meetings, drafts, phone calls and memos going back and forth between the US and Europe. The signing of the Memorandum of Understanding between Europe and NASA for the implementation of Spacelab took place on 24 September 1973.

The first operational Shuttle flight was scheduled for late 1979, which meant that the Spacelab flight unit should be delivered to NASA at least one year before, to enable experiments to be installed in Spacelab and for Spacelab to be integrated with the Shuttle orbiter. Europe was heading towards human spaceflight.



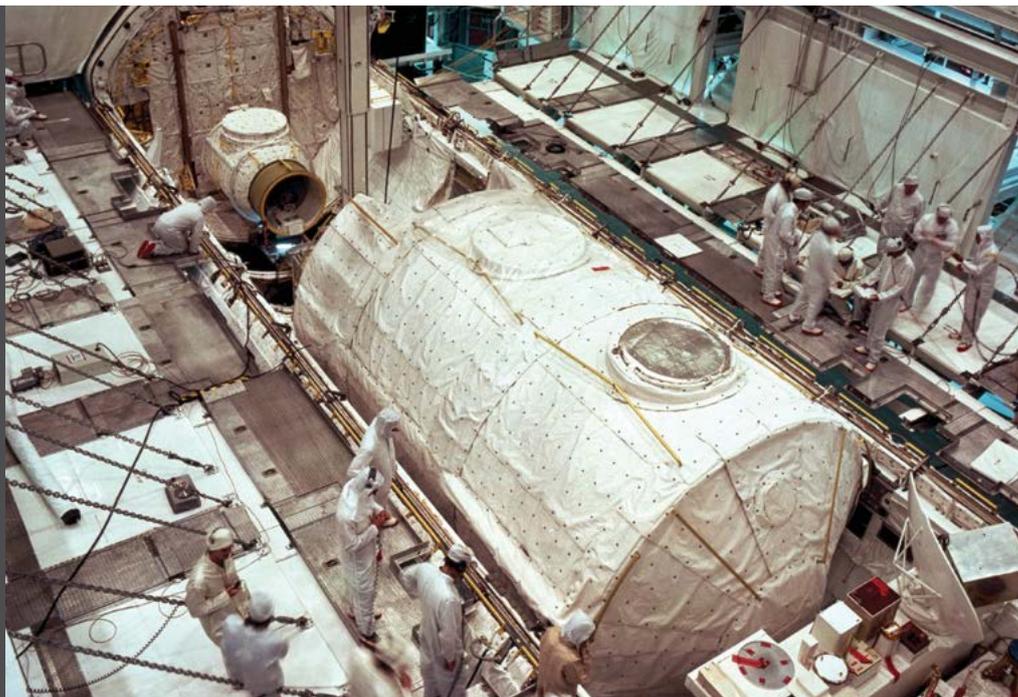
↑ The traditional crew walk-out to the astronaut van for the ride to the launch pad (NASA)



↑ 28 November 1983: "...Lift off of *Columbia* and first flight of the European Space Agency's Spacelab... the Shuttle has cleared the tower..." (NASA)



Views of Spacelab-1 integration with the Shuttle orbiter at Kennedy Space Center, 16 August 1983 (NASA)



## Building and flying Spacelab

The Memorandum of Understanding signed with NASA gave Europe the responsibility for funding, designing and building Spacelab. Europe agreed to deliver free of charge the Engineering Model and the first Flight Unit, plus ground support equipment, in return for a shared first mission.

Unlike Skylab, the first US space station, which had been built mostly from existing Apollo hardware, Spacelab was a new construction offering a much wider range of applications. In June 1974, ESA selected an industrial consortium led by VFW-Fokker/ERNO (later MBB/ERNO, now EADS Astrium) to develop the modular elements making up Spacelab: a

↓ Mission and Payload Specialists working inside Spacelab in orbit (NASA)



↑ John Young and Ulf Merbold during an off-duty meal break (NASA)



↑ STS-9/Spacelab-1 inflight portrait (NASA)



↑ ESA's first astronaut candidates selected in 1978

## → A new kind of right stuff

In 1974, Europe set about recruiting its first astronauts. When the first Shuttle flight was still set for 1979, Spacelab was slated to be the seventh mission. It was originally assumed that four Europeans would fly with three Americans on this mission.

NASA began looking for a new type of astronaut called 'payload specialists'. These would not be career astronauts, since they were being invited only to operate the experiments on Spacelab in the payload bay. They would have some generic astronaut training but mostly they would be familiarising themselves with the experiments to be flown on their mission.

In January 1977, NASA set the date for the first Spacelab mission as 15 July 1980, allowing ESA to initiate its first selection of astronauts on 28 March 1977. Each Member State went through its own selection procedure, working from common rules. For example, in France, 401 people applied and their numbers were reduced in stages to finally five (one of these being a certain Mr Jean-Jacques Dordain).

In summer 1977, NASA announced that two scientists would fly on the first Spacelab, which would last for one week, and one of these would be European. By mid 1978, Member States had proposed 53 candidates, out of which four were retained: Ulf Merbold of Germany, Wubbo Ockels from the Netherlands, Claude Nicollier of Switzerland and Franco Malerba of Italy.

Three candidates were chosen in May 1978 to go on for NASA training, and one of these would be selected to accompany the US payload specialist. Merbold was selected as Payload Specialist 1 along with US astronaut Byron Lichtenberg as Payload Specialist 2. Ockels and US astronaut Michael Lampton would be back-ups.

↓ NASA and ESA Mission and Payload Specialists with back-ups: Parker, Garriott, Merbold, Lampton, Ockels and Lichtenberg



pressurised laboratory or Pressure Module (PM), a gimbaled instrument pointing system and cargo bay pallets.

In the early 1980s, the Shuttle was planned to fly up to once a week and about a hundred Spacelab missions were anticipated through the 1990s. This number significantly decreased as the Shuttle began flying. Spacelab pallets were flown as early as the second Shuttle mission, STS-2, in November 1981, even before the first full Spacelab two years later.

Spacelab Flight Unit 1 (Spacelab-1) was formally accepted by NASA in February 1982. The maiden mission was designed to prove Spacelab's capabilities, requiring not only more experiment hardware than any previous ESA flight, but also more experimenters: 100 investigators across numerous disciplines. Half the payload was allocated to ESA's First Spacelab Payload (FSLP). This representative configuration was the PM plus one pallet with a total of 70 experiments.

Ulf Merbold's flight on STS-9 marked the beginning of an extensive ESA/NASA partnership that included dozens of

flights of ESA astronauts in the following years. With their NASA crewmates, nine Europeans have worked inside Spacelab while in space. Spacelab was even flown in 1995 on a milestone international mission: the first Shuttle docking with Russia's Mir space station. When Spacelab flights stopped in 1998, full Spacelab modules had flown 16 times and Spacelab pallet-only missions had flown six times.

Spacelab turned out to be one of the most important and most frequently flown Shuttle payload systems to date, most including a significant ESA science/payload contribution with some missions funded and operated by other countries, such as Germany and Japan.

### Spacelab's legacy: Columbus

As a key partner to NASA, ESA was invited in 1984 to participate in another major venture: the Freedom space station. ESA's contribution was the Columbus laboratory module, approved at ESA's Ministerial Council in The Hague in 1987. After completion of the design phase, the

↓ Descendant of Spacelab: ESA astronaut Hans Schlegel works outside the Columbus laboratory of the ISS (NASA/ESA)





development of Columbus was approved at the Ministerial Council in Toulouse in 1995.

Europe's Columbus laboratory was a natural evolution from Spacelab. The concept of standardised science racks that made a large contribution to Spacelab's success was adopted for all of the International Space Station's non-Russian laboratory modules: an International Standard Payload Rack design was defined for compatibility. Columbus, the US Destiny and Japan's Kibo laboratories, as well as the three nodes and the Quest airlock module, can accommodate up to 94 standard racks.

And just as Spacelab pallets were able to carry exposed science experiments inside the Shuttle's cargo bay, standardised pallets are today mounted outside Columbus and on other external

## → Memories of STS-9: Ulf Merbold

Born in 1941, Ulf Merbold's scientific career began at age 19 when he studied physics at the University of Stuttgart. He received his Doctorate in 1976. From 1967–1978, he worked in solid-state physics at the Max Planck Institute for Metals Research.

After Spacelab-1, he flew on the Space Shuttle STS-42/IML-1 mission in 1992. Immediately after this mission, he began preparing for the Russian Euromir '94 mission in October 1994. Euromir '94 was the first ESA mission to the Russian space station Mir, and it served primarily as the precursor to Columbus – preparing experimenters and the ground segment for the Columbus era. On this, his third spaceflight, he remained on the Mir space station for one month.

Merbold has logged 49 days in space over three missions. This is the most spaceflights for a German national, although this is not his only

historic distinction. As well as the first non-US astronaut to fly on the Shuttle, Merbold was also the first ESA astronaut to fly on a Russian mission.



← Ulf Merbold



At that time it was still not certain whether human spaceflight would be accepted as a permanent programme within ESA or whether it would be terminated after Spacelab-1. There were times when I did not feel secure but it was a great endeavour. It was fascinating to work with so many different scientists, to talk to and learn from so many people from different backgrounds. Wubbo Ockels and I put our noses into all of the various fields, vestibular research, plasma research, biology, physiology, etc.

Being the first non-Americans in the US space programme was really something special. When we started training for Spacelab-1 in Huntsville, Alabama, we received a warm welcome. After all, it was also for them the first flight where they had operational responsibility, what we now call payload operation, meaning the execution of the experiments. During our two years in training, people were really eager and happy to see us. They made sure everything was more than perfect.

But in Houston you could feel that not everyone was happy that Europe was involved. Some also resented the new concept of the payload specialist 'astronaut scientist', who was not under their control like the pilots. We were perceived to be intruders in an area that was reserved for 'real' astronauts. A couple of small things made us realise that Johnson Space Center management was suspicious. Now, of course, all this has changed. I think we broke the ice and all our colleagues who came after us had much easier lives.

When I heard that I would fly first, that was a situation of mixed feelings. Wubbo and I are close friends, we had been working together for two years in Huntsville, and at the end of the training in the Marshall Spaceflight

sites elsewhere on the Station to host long-duration payloads for astronomy, astrobiology and materials exposure, Earth observation, fundamental physics and other fields.

In the same way that Spacelab was operated by international teams of astronauts, so are today's European experiments and laboratories on the Station. They are kept running and performing science by the Station's permanent crew – which now includes European astronauts.

As well as Columbus, the legacy of Spacelab also lives on in the form of the Multi-Purpose Logistics Modules and other systems derived from it, including the Harmony and Tranquility nodes, and the Automated Transfer Vehicle and Cygnus spacecraft used to transfer payloads to the Station. ■

## Further reading

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Center we knew that only one of us could be the first. However, when the German government decided to fly the German D1 mission, they promised that the astronaut serving as back-up for Spacelab-1 would fly on D1, so in the end it was not that complicated because we both had the guarantee that we would fly.

In Huntsville, we had been working with the computer system that simulated the complete Spacelab-1 configuration, scientific experiments and potential problems. We had the same knowledge, and in the end the investigators working group had to take the decision between the two of us and their recommendation was in my favour. Of course I was happy, but I would have preferred to have the opportunity to share the experience with him.

After all these years I am still grateful to Wubbo that he, after a very short moment of frustration, accepted to be the back-up and to do his utmost to make Spacelab-1 a successful flight. The success of this mission was also a boost to continue with D1. After my flight, Wubbo and I went straight into training for the next mission, this time with reversed roles.

As a crew we had different roles. For some experiments, we were merely lab technicians we put materials sealed in cartridges into furnaces, heated and melted materials, pushed buttons and started computer programs. In other cases we were in scientific control of the experiments, and some of them were almost artistic, for example a silicon crystal experiment in a furnace called the Mirror Heating Facility. The investigator taught us to observe the liquid zone of the crystal rod, make an assessment of how long it would take until it would become unstable, what the material

should look like and what to expect to be able to judge the next step.

These experiments had many functional objectives and, after a lot of training, the experimenters gave us carte blanche. "You have control because you know as much as we do, use your sense," they said. Of course this kind of relationship has two sides: we were proud that they trusted us, but we also felt a huge responsibility.

How was life on board? It was marvellous. Spacelab was a very comfortable lab, and it is sad that NASA stopped with it after roughly 20 flights and switched to Spacehab. Spacelab worked perfectly, it was quiet, had a good life support system, super air quality, nice illumination and other fantastic features, for example the airlock through which we could transfer experiments into space and back into the lab.

There was also a high-quality optical window in the ceiling of the module, so you could turn the Shuttle so that the window faced Earth for an undisturbed view. A camera system took distortion-free pictures, and in the few free moments between experiments we had breathtaking views through the viewports.

Next to all the other impressions, the views are what make an astronaut's life an incredible experience. Earth is incredibly beautiful, and so are the stars in the black sky, the Sun in the black sky...

Do I think that the Spacelab programme was worthwhile for Europe? Absolutely no question: yes! Without it we would not be where we are. Being a valid partner in the International Space Station would be inconceivable if Europe had not qualified as a partner in the Spacelab programme. ”



Zarya and Unity in orbit in 1998 (NASA)

# → FIFTEEN YEARS IN ORBIT

## ISS anniversaries celebrated

Carl Walker

Communication Department, ESTEC, Noordwijk, the Netherlands

**The International Space Station (ISS) celebrated its 15th anniversary on 20 November, and another major space milestone on 2 November, as it clocked 13 years of continuous human presence in space.**

Today, the ISS is the largest cooperative project ever carried out in science, involving NASA, ESA, the Russian space agency Roscosmos, the Canadian Space Agency and the Japan Aerospace Exploration Agency.

The first launch of the ISS project took place on 20 November 1998, when a Russian Proton rocket lifted off

from the Baikonur space centre in Kazakhstan carrying the Zarya module, the Station's first component. However, the project has its roots when the agreement to construct the ISS was signed on 29 January 1998 by representatives from ESA, Canada, Japan, Russia and the United States.

On 4 December 1998, the Space Shuttle *Endeavour* delivered Unity, the second module, which docked with Zarya on 6 December. The Zvezda module was connected in July 2000, after being delivered by a Russian Proton rocket, enabling the ISS to be permanently habitable for the first time.

The ISS was manned by a resident crew for the first time on 2 November 2000, when the Expedition 1 crew arrived, consisting of US astronaut William Shepherd and two Russian cosmonauts Yuri Gidzenko and Sergei Krikalev. Since then, the Station has been continuously occupied for 13 years, currently the longest continuous human presence in space (in 2010, the Station surpassed the previous record of almost 10 years (3634 days) held by Mir).

The ISS continued to grow with the addition of the Italian-built Harmony Node-2 module in 2007, then ESA's Columbus and Japanese Kibo laboratories in 2008. Since Columbus was attached to the Station five years ago, a total of 110 ESA-led experiments involving some 500 scientists have been conducted, spanning fluid physics, material sciences, radiation physics, the Sun, the human body, biology and astrobiology.

The ISS is served by a variety of visiting spacecraft: Soyuz, Progress, the H-II Transfer Vehicle, Dragon, Cygnus and Europe's Automated Transfer Vehicles (ATV). To date, ESA has launched four ATVs to the ISS: *Jules Verne*, *Johannes Kepler*, *Edoardo Amaldi* and *Albert Einstein*.

To date, 211 people have visited and worked on the ISS over 352 spaceflights, including the six currently at the station (Expedition 38). These include European astronauts from Italy, France, Germany, Belgium, The Netherlands, Spain and Sweden.



**→ ISS TIMELINE: 15 YEARS IN THE MAKING**

- November – First ISS element launch (Zarya) on a Proton-K rocket
- November – Expedition 1, the first 'permanent' three-man crew established
- April – STS-100's Umberto Guidoni (IT) becomes first European astronaut to visit ISS
- October – Claudie Haigneré (FR) becomes first European woman to visit ISS
- October – Columbus Control Centre inauguration, Oberpfaffenhofen, Germany
- December – Node-1 (Unity) launched by STS-88

1998

2000

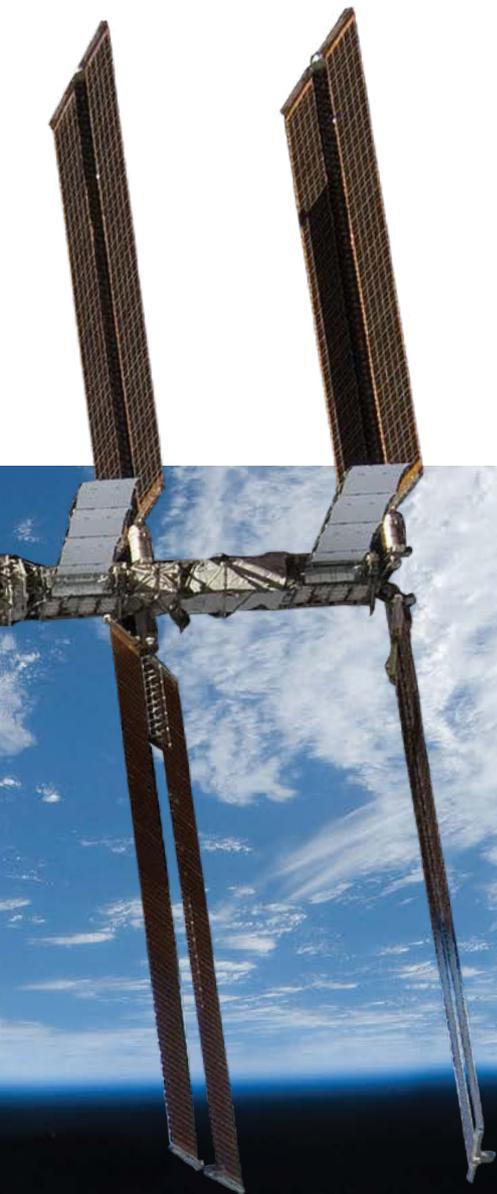
2001

2004

The ISS now provides a significantly expanded orbital research and technology development facility, and serves as an engineering test-bed for flight systems and operations to be used in future space exploration initiatives. These activities improve the quality of life on Earth by expanding the frontiers of human knowledge. ■



→ ↗  
 Inside Zarya, showing how much equipment has accumulated (top) with cosmonaut Vladimir Dezhurov, and (below) with ESA's Paolo Nespoli in 2007



- July – Thomas Reiter (DE) begins 150-day Astrolab mission, first European ISS long-duration flight
- February – Launch of Columbus and begin of the operational phase
- March – First ATV, *Jules Verne*, launched. Japanese laboratory module added.
- May – First permanent six-person crew and first time each ISS partner represented on ISS
- January – Cupola and Node-3 (Tranquility) installed
- March – ATV *Edoardo Amaldi* launched
- July – Last Shuttle flight, STS-135
- June – ATV *Albert Einstein* launched
- September – HTV-1, first Japanese cargo vehicle

2006

2008

2009

2010

2011

2013



The first ISS element Zarya in orbit



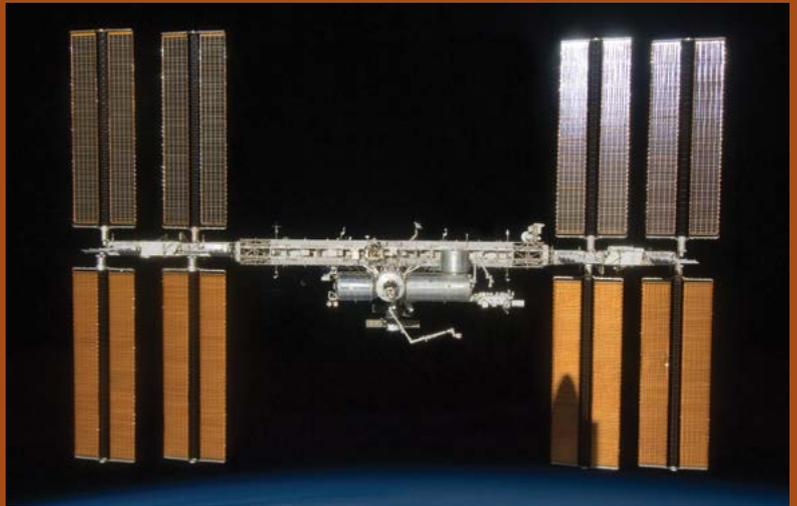
STS-88, the first Space Shuttle mission to the ISS, joining Russian Zarya and US Unity modules



Cables between Unity and Zarya connected by astronauts



First truss sections added in 2002, this image after the third segment added by STS-113



Addition of the P5 truss segment, STS-116 in 2006



View of ISS with ATV *Edoardo Amaldi* attached, from STS-134 after delivery of Alpha Magnetic Spectrometer



Last photo of ISS taken from a Shuttle: Multipurpose Logistics Module *Raffaello* left at Station by last Shuttle flight, STS-135, in 2011



Unity and Zarya seen in June 1999 from STS-96



Unity, Zarya and the Zvezda module in September 2000



First set of solar arrays connected by STS-97 in December 2000



Truss section complete and Japanese Kibo laboratory module added, as seen by STS-127 in 2009



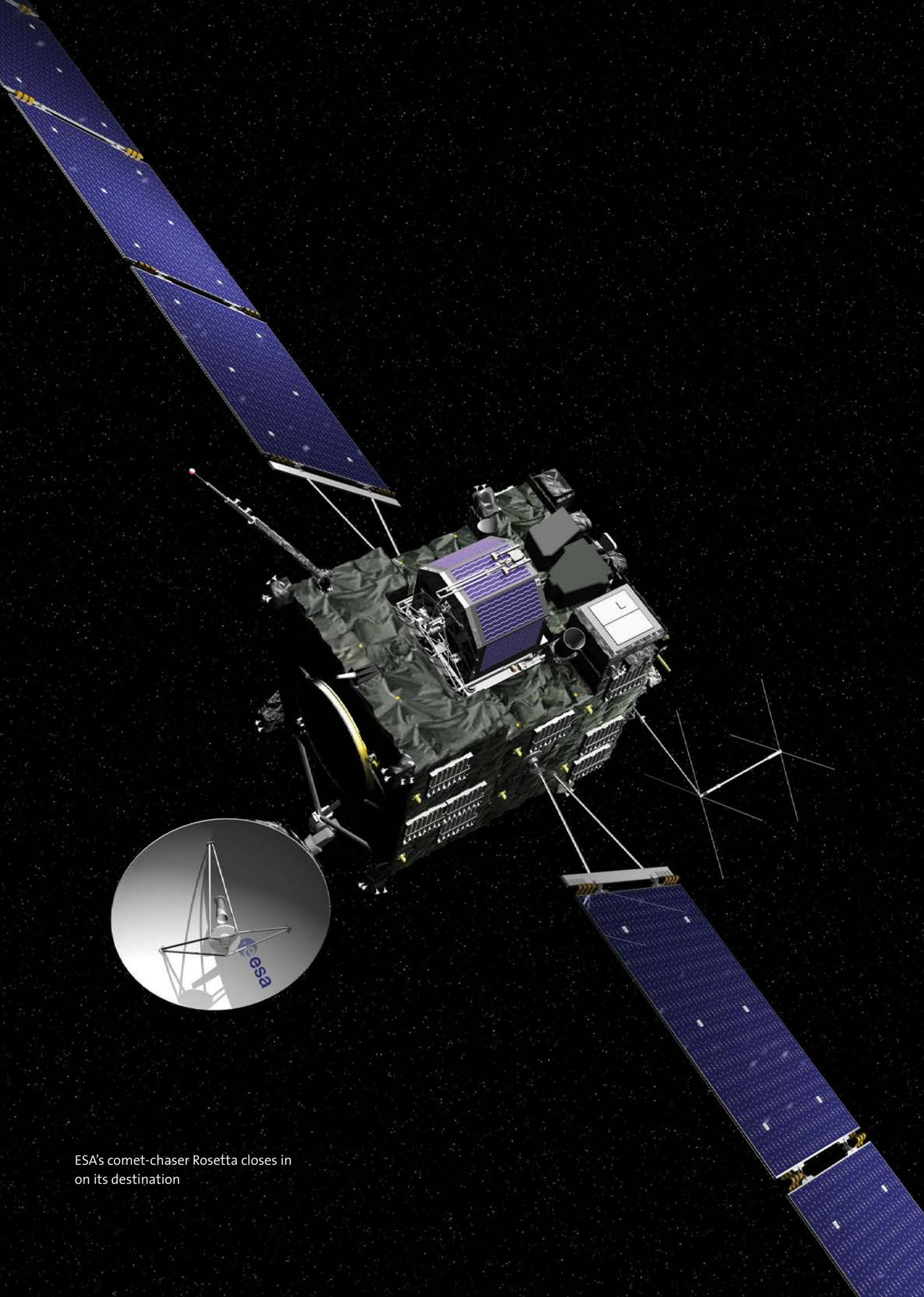
Almost complete, STS-132 installed the Russian Rassvet mini-lab module in 2010



↑ Expedition 1 crew, Yuri Gidzenko, Sergei Krikalev and Bill Shepherd, who stayed aboard the Station for 136 days, from November 2000 to March 2001.



↑ 2009: the first six-person crew, and first with all ISS partners represented: Russian cosmonauts Roman Romanenko, Gennady Padalka, ESA's Frank De Winne, Canadian astronaut Bob Thirsk, NASA's Mike Barratt and JAXA's Koichi Wakata



ESA's comet-chaser Rosetta closes in on its destination

## → WAKING ROSETTA

### On the eve of one of ESA's most ambitious missions

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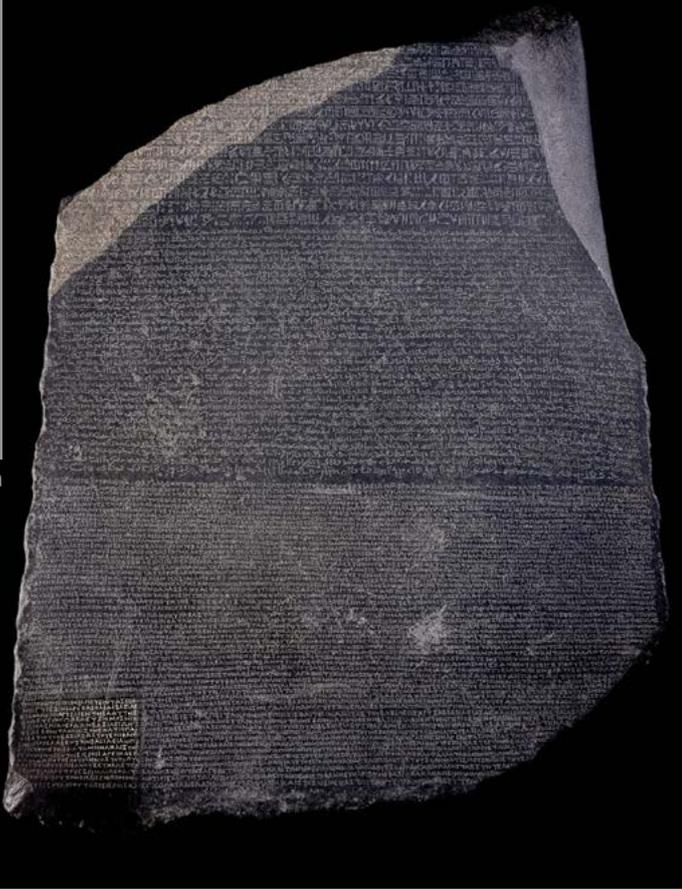
Communication Department, ESTEC, Noordwijk, the Netherlands

**ESA's comet-chasing spacecraft Rosetta is about to be roused from hibernation as it closes in on its destination after cruising in deep space for the last decade.**

Rosetta was launched on 2 March 2004, and through a complex series of flybys – three times past Earth and once past Mars – set course to its destination: Comet 67P/Churyumov–Gerasimenko. It also flew by and imaged two asteroids, Steins in September 2008 and Lutetia in July 2010.

In July 2011 Rosetta was put into deep-space hibernation for the coldest, most distant leg of the journey as it travelled some 800 million km from the Sun, close to the orbit of Jupiter. The spacecraft was oriented so that its solar wings faced the Sun to receive as much sunlight as possible, and it was placed into a slow spin to maintain stability.

Now, after ten years in space, as both the comet and the spacecraft are on the return journey back into the inner Solar System, the Rosetta team is preparing for the spacecraft to wake up. Rosetta's internal alarm clock is set for 10:00 GMT on 20 January 2014.



↑ The Rosetta Stone (British Museum)

## Why Rosetta?

ESA's mission of cometary exploration is named after the famous 'Rosetta Stone'. This slab of volcanic basalt – now in the British Museum in London – was the key to unravelling the civilisation of ancient Egypt. French soldiers discovered the unique stone in 1799, as they prepared to demolish a wall near the village of Rashid (Rosetta) in Egypt's Nile delta. The carved inscriptions on the stone included hieroglyphics – the written language of ancient Egypt – and Greek, which was readily understood.

By comparing the inscriptions on the stone, experts were able to begin deciphering the mysterious carved figures. Most of the pioneering work was carried out by the English scientist Thomas Young and the French scholar Jean François Champollion. As a result of this work, historians were at last able to piece together the story of a long-lost culture.

Just as the Rosetta Stone provided the key to an ancient civilisation, so ESA's Rosetta spacecraft will unlock the mysteries of the oldest building blocks of our Solar System. As the worthy successor of Champollion and Young, Rosetta will allow scientists to look back millions of years to an epoch when no planets existed and only a vast swarm of asteroids and comets surrounded the Sun.

## Comet hunting

Comets – from the Greek 'kometes' meaning 'long-haired' after a comet's classic tail – are considered the most primitive building blocks of our cosmic neighbourhood. Their ices and organic material have survived our Solar System's chaotic 4.6 billion year history and are the likely source of much of Earth's water, perhaps even delivering to Earth the ingredients that helped life evolve. By studying the nature of a comet close up with an orbiter and lander, Rosetta will show us more about the role of comets in the evolution of the Solar System.

Comets usually hail from either the Kuiper Belt, which extends from just beyond the orbit of Neptune for about 3 billion km, or the Oort cloud – a frigid repository of icy bodies a thousand times more distant. More recently, comet-like activity has also been observed in objects in the asteroid belt, between the orbits of Mars and Jupiter. These regions contain the remnants of the formation of the Solar System.

Occasionally, Kuiper Belt and Oort cloud objects become gravitationally dislodged, nudged onto an elongated orbit that sends them headlong into the inner Solar System, affording us a closer view of their primordial ingredients and therefore our distant past.

It is widely believed that water on Earth is not a remnant from the initial planet-building phase of the Solar System, but was delivered around 3.9 billion years ago during an intense bombardment of asteroids and comets – the Late Heavy Bombardment era – a side effect of gravitational interactions as the giant gas planets settled into their orbits. Comets may even have delivered organic material that helped to 'seed' Earth with life. As such, comets are considered the 'Rosetta Stones' of the Solar System.

Rosetta, with its Philae lander, will be the first spacecraft to spend a prolonged period of time scrutinising one of these primordial bodies. Previous missions to comets have only spent fleeting moments flying past their targets at high speed, for example, ESA's Giotto mission to Comet Halley set the stage in 1986, and later visited Comet Grigg-Skjellerup in 1992.

NASA's ICE mission, two Russian Vega spacecraft and two Japanese spacecraft were also part of the armada that visited Comet Halley. NASA's Deep Space 1 subsequently went to Comet Borely, and Deep Impact sent an impactor to the surface of Comet Tempel-1 so that material thrown up in collision could be analysed. Stardust returned dust particles from Comet Wild-2 to Earth for analysis. The Stardust spacecraft later revisited Tempel-1 and Deep Impact's extended mission took it past Comet Hartley-2.

But our view of comets remains incomplete, and these previous missions have shown there is great variety in their

physical structure, environment and orbital dynamics. Rosetta will provide us with a huge leap in our knowledge by rendezvousing with a comet within just a few tens of kilometres from its surface and then escorting it as it heads towards the inner Solar System and is gradually heated by the warmth of the Sun. It will also be the first spacecraft to orbit a comet's nucleus and the first to attempt a landing on its surface.

Rosetta's sights are set on the 4 km wide Comet 67P/Churyumov–Gerasimenko, which was discovered in 1969 and travels roughly between the orbits of Jupiter and Earth once every 6.6 years. Thanks to its regular trips into Earth's neighbourhood, preliminary observations of the comet have already been made from ground-based telescopes to study patterns in its activity. The Hubble Space Telescope has also been able to make preliminary estimates of the shape of the comet nucleus and its rotational period.

## A long road

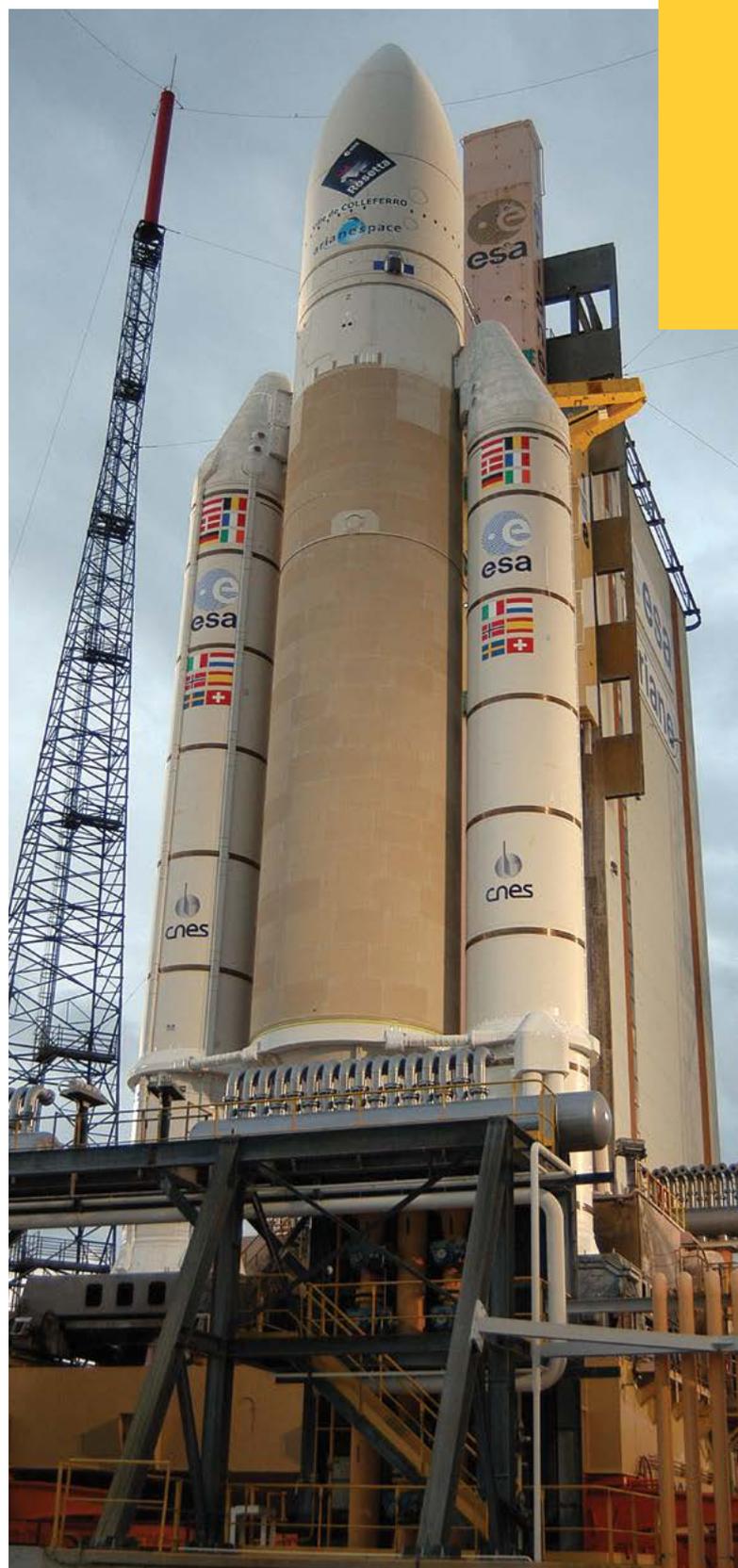
After a 14-month launch delay that led to the mission's destination being changed from Comet 46P/Wirtanen to 67P/Churyumov–Gerasimenko, Rosetta was finally launched in March 2004 on an Ariane 5 rocket from Europe's Spaceport in Kourou, French Guiana.

Rosetta exploited the gravity of Earth and Mars to set course with 67P/Churyumov–Gerasimenko. For the first half of its journey Rosetta played a game of cosmic pinball, first getting a boost from Earth's gravity in March 2005, then from Mars in February 2007, before bouncing back to Earth in November 2007 and again in November 2009.

Along the way, Rosetta has also visited two asteroids, taking extensive close-up images of 2867 Steins on 5 September 2008 and 21 Lutetia on 10 July 2010. The asteroid flybys not only provided new views of previously uncharted terrain, but also gave the mission science teams the opportunity to test out the performance of their instruments.

Rosetta is the first space mission to journey beyond the main asteroid belt while relying solely on solar cells for power generation, rather than the traditional radioisotope thermal generators. The spacecraft's two solar wings, each 14 m long, employ a new solar-cell technology to allow it to operate over 790 million km from the Sun, where sunlight levels are only 4% those at Earth.

Hundreds of thousands of specially developed, non-reflective, silicon cells generate up to 8700 watts in the inner Solar System and will provide around 400 watts for the deep-space comet encounter when it is still in the cold regions of the Solar System at around 675 million km from the Sun. Eventually moving to within 185 million km



Rosetta began its journey on this rocket, poised for flight on 2 March 2004, on Ariane 5 V158 (ESA/CNES/Arianespace/Photoservice Optique du CSG)



On 10 July 2010, Rosetta flew past asteroid (21) Lutetia, one of the largest objects orbiting within the main asteroid belt between Mars and Jupiter. Rosetta's encounter revealed an intriguing object that survived since the birth of the planets, some 4.5 billion years ago (ESA 2010 MPS for OSIRIS Team)

of the Sun – when the comet is between the orbits of Earth and Mars – Rosetta is equipped to handle a range of temperatures.

Near to the Sun, the problem of overheating is solved by using radiators to dissipate surplus heat into space. Conversely, in the outer Solar System, the hardware and scientific instruments are kept warm with heaters located at strategic points such as fuel tanks, pipework and thrusters. Wrapping the spacecraft in multi-layered insulation blankets also helps to cut down on heat losses.

When Rosetta entered hibernation in July 2011, all systems were switched off except for the thermal control and onboard computer, powered only by the solar panels. Just before everything was switched off, the spacecraft was oriented so that its solar wings faced the Sun, and placed in a slow spin – rotating once every 90 seconds – to maintain stability.

## Wake-up call

Rosetta will be woken up at 10:00 GMT on 20 January 2014, when it is around 9 million km from 67P/Churyumov–Gerasimenko and on the return leg of the journey back into the inner Solar System. Once awake, Rosetta will first warm up its navigation instruments and then it must stop spinning so that it can point its high-gain antenna at Earth, to let the ground team know it is still alive.

It is not known at exactly what time Rosetta will make first contact with Earth, but the first window of opportunity lies with NASA's Deep Space Network ground station at Goldstone, California, at around 17:45 GMT the same day. Ground stations at Canberra and New Norcia in Australia will pick up the baton from Goldstone to listen throughout the night, with ESA's Mission Operations Centre at ESOC, Germany, being the primary interface between spacecraft and ground station.

Once communications have been reestablished, the spacecraft will be given standard health checks, including an assessment of the power availability of the solar arrays, which will determine the precise schedule for subsequent activities. Also at the top of the list of health checks will be revisiting two problems that arose earlier in the mission: one associated with attitude control – two of Rosetta's four reaction wheels were showing signs of degradation – the other with the propulsion system whereby pressure in the propellant reservoir is below optimum.

## Catching up with the comet

Instrument commissioning will be carried out during March, and for many science teams this will be the time to calibrate instruments and make preliminary observations before getting closer to the comet, and before activity on 67P/Churyumov–Gerasimenko is expected to increase.

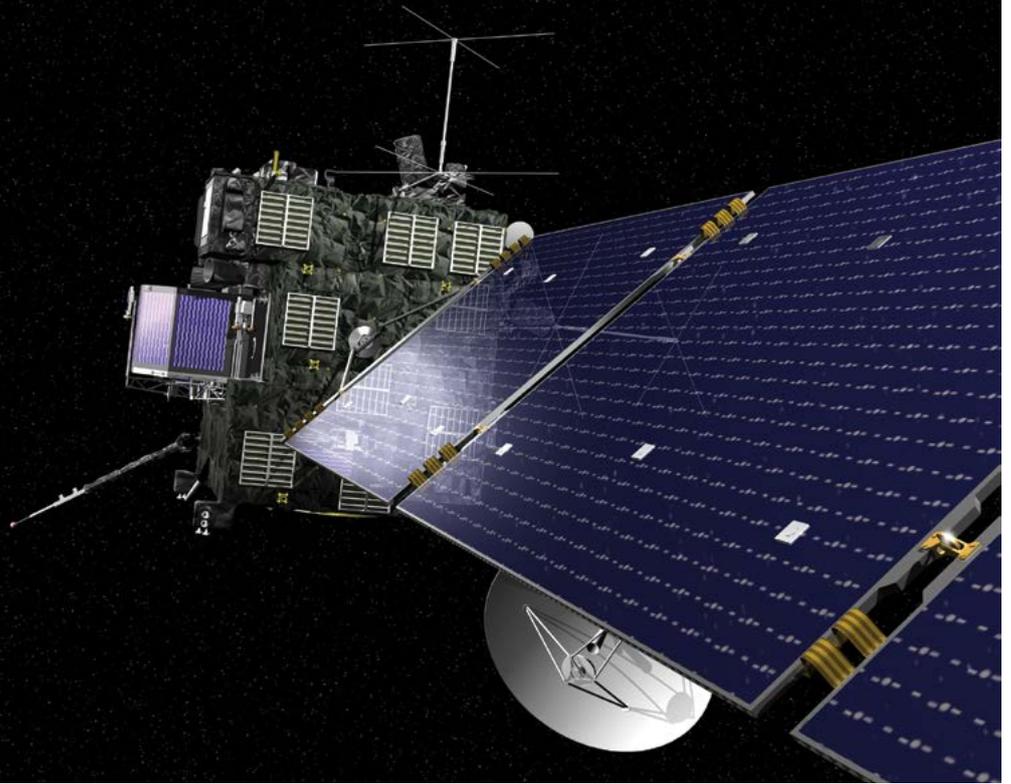
By early May, Rosetta will be 2 million km from 67P/Churyumov–Gerasimenko and on 21 May the spacecraft will execute its first major rendezvous manoeuvre to line it up for orbit insertion on 6 August. Nine separate manoeuvres will be carried out over the three months to gradually reduce the distance and speed relative to the comet to 100 km and 2 m/s, respectively.

During this period, the first images of 67P/Churyumov–Gerasimenko are expected, which will dramatically improve calculations of the comet's position and orbit, which currently is only known to within 10 000 km.

Closer in, the spacecraft will follow a two-step triangular path in front of the comet to get progressively closer to its target. The first orbit will be at a distance of 100 km from the comet, the second at 50 km. During these operations,



The spacecraft's two solar wings, each 14 m long, employ a new solar-cell technology to allow it to where sunlight levels are only 4% those at Earth. Hundreds of thousands of specially developed, non-reflective, silicon cells generate the power needed by the spacecraft operate over 790 million km from the Sun



the spacecraft will take thousands of images that will provide details of the comet's spin-axis orientation, its angular velocity, and major landmarks on its surface. With its suite of 11 instruments, the spacecraft will make important scientific measurements of the comet's gravity, mass, shape and the characteristics of the coma – the comet's gaseous, dust-laden atmosphere.

Science measurements during this phase will provide important information for the spacecraft operations, as well as laying a foundation and reference point for observations carried out during the 'escort' phase of the mission, as the comet makes its closest approach to the Sun and away into the outer Solar System again. For example, a complicating factor will be gas 'escaping' from the comet, which will have the effect of pushing Rosetta slightly out of its orbit, something that will have to be compensated for once it is better understood.

Throughout the mission, measurements of the comet's gas and dust production rates will be made, providing information on the size of the dust grains, their composition and velocity away from the comet nucleus. This will not only uncover clues as to the formation of comets, but will also reveal how their activity evolves and changes even on a daily basis. The spacecraft will also probe the plasma environment of the comet and how it interacts with outer atmosphere of the Sun, the solar wind,

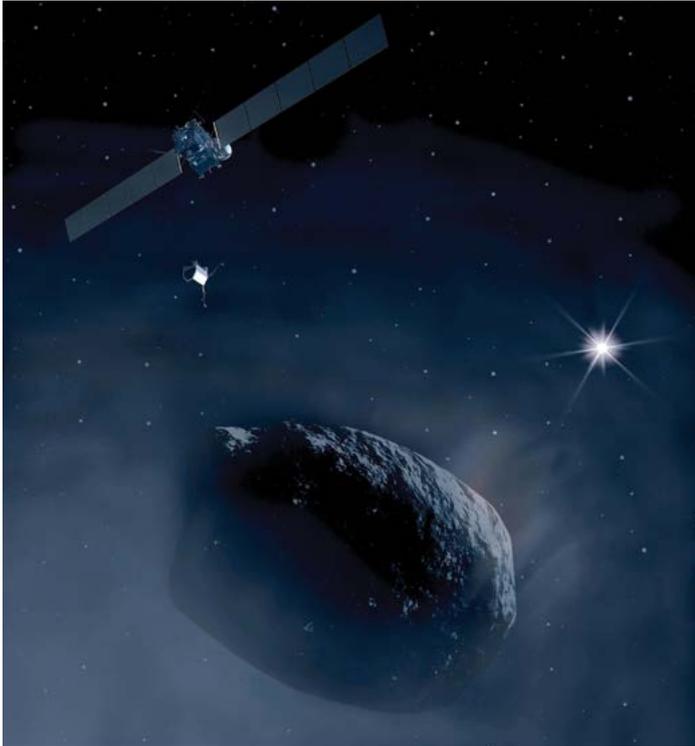
along its elliptical orbit through the Solar System. Extensive ground-based observations of the comet will also be made to complement those made in situ by Rosetta.

## Comet close-up

Eventually Rosetta will orbit at an altitude of about 25 km above the comet, allowing detailed mapping of its 4 km wide nucleus at a resolution on the order of centimetres. Five locations of particular interest will be identified as possible landing sites for the mission's 100 kg Philae probe. The locations will need to be interesting from a scientific point of view, but also be accessible from an operational perspective.

For example, landing at a latitude where there is a good balance between day and night will minimise thermal problems. It is also better to land on flatter terrain than be trapped in very rough terrain or a valley where there is a higher risk of tipping over, or where shadows may affect observations and communicating with the probe may be more difficult. The final decision on the landing site will be made in September, and then the operation schedule for landing will be designed accordingly.

Depending on the chosen landing site, the orbiter must release Philae at a certain time and on a specific trajectory to reach it; Philae does not have any propulsion to guide itself. Immediately prior to the deployment of Philae,



↑ Rosetta must release its Philae lander at a certain time and on a specific trajectory to reach the landing site on the comet; it does not have any propulsion to guide itself



↑ Philae moves closer to the surface – it does not so much land as ‘dock’ with the comet, to prevent it from rebounding back into space

Rosetta will come to within just 2.5 km of the comet’s nucleus. While Philae moves closer to the surface – at the equivalent speed to walking pace – the orbiter will move away and monitor the descent with radio tracking and imaging cameras.

Because the comet’s surface gravity is several tens of millionths of that at Earth, Philae does not so much land as ‘dock’ with the comet to prevent it from rebounding back into space. A landing gear will first absorb the small forces occurring during landing, while ice screws in the probe’s feet and a harpoon system will lock the probe to the surface. At the same time a thruster on top of the lander will push it down to counteract the impulse of the harpoon imparted in the opposite direction.

Once it is anchored to the nucleus, the lander will begin its primary science mission, based on its 64-hour initial battery lifetime. It will send back high-resolution pictures of the comet’s surface and will perform on-the-spot analysis of the composition of the comet’s ices and organic material. A drilling system will take samples from a depth of 20–30 cm and will feed these to the onboard laboratory for analysis.

The data are subsequently relayed to the orbiter, ready for transmission back to Earth at the next the period of

contact with a ground station. The data collected on the surface will complement the extensive measurements made by the orbiter, taking scientists closer to answering questions on how comets formed and how they evolve, and subsequently their role in the history of the Solar System.

### Roller-coaster ride

Once Philae’s battery power is exhausted, it will use solar cells to recharge and attempt to operate for several more weeks or months, depending on the activity of the comet and how quickly the solar cells become covered in dust. The focus of the mission then moves towards the ‘escort’ phase, whereby Rosetta will stay alongside the comet as it rushes towards the inner Solar System at speeds of over 100 000 km/h.

The orbiter will continue to collect dust and gas samples while monitoring the ever-changing conditions on the surface as the comet warms up and its ices begin to sublimate. This unique science period will reveal the dynamic evolution of a comet nucleus as never seen before. Its closest distance to the Sun of about 185 million km will come on 13 August 2015. Depending on the increase of activity of the comet, the orbit of Rosetta will be adjusted. The spacecraft will follow the comet throughout the remainder of 2015, as it heads away from the Sun again and activity begins to subside.

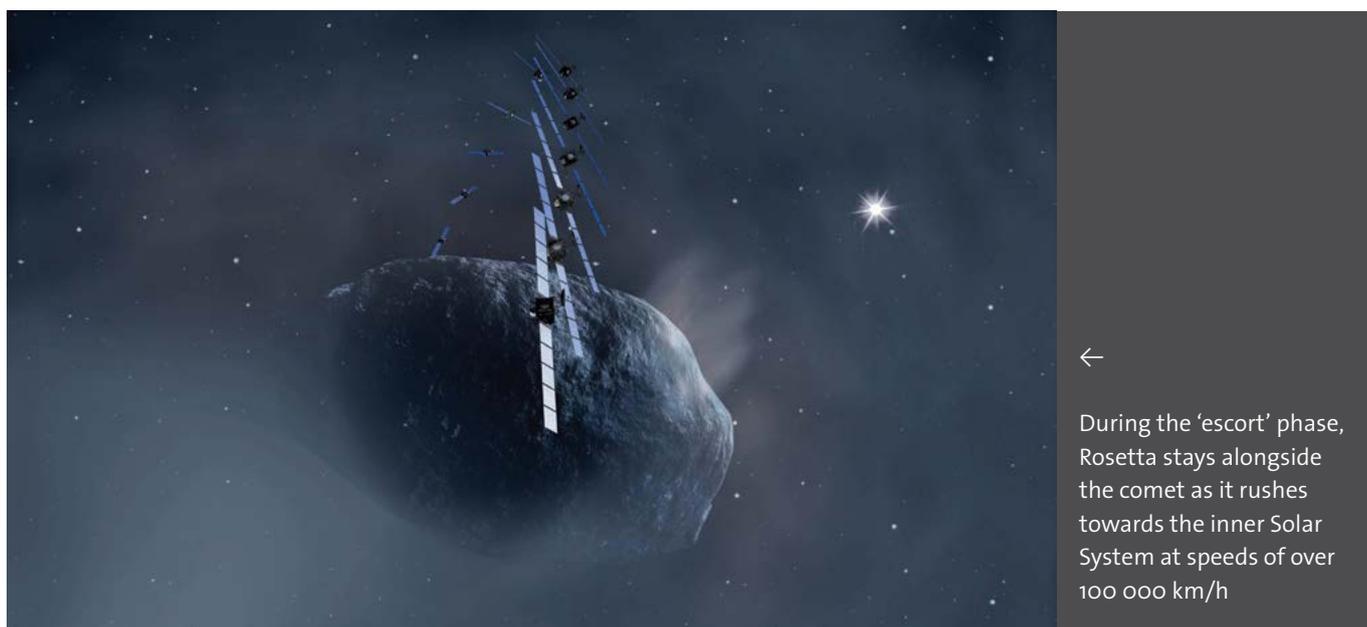


➤ Once anchored to the nucleus, the Philae lander commences its primary science mission, based on its 64-hour initial battery lifetime

Comets are unpredictable by nature and can outburst, fragment or even disintegrate completely, all without warning. Previous flyby missions to comets have given us a hint about what to expect, but each of those experiences revealed that every comet is different. Now, after a ten-year journey through space, and many more years since Rosetta was merely a sketch on the drawing board, ESA will

provide a daring ringside view of a comet's rollercoaster ride around the Sun. The aspect of 'not knowing quite what to expect' makes the mission all the more exciting. ■

Emily Baldwin is an EJR-Quartz writer for ESA



During the 'escort' phase, Rosetta stays alongside the comet as it rushes towards the inner Solar System at speeds of over 100 000 km/h

# → ROSETTA'S SCIENCE

The orbiter's scientific payload includes 11 experiments, in addition to the lander. Scientific consortia from institutes across Europe and the USA have provided these instruments. All of them are located on the side of the spacecraft that will permanently face the comet during the main scientific phase of the mission.

MIDAS

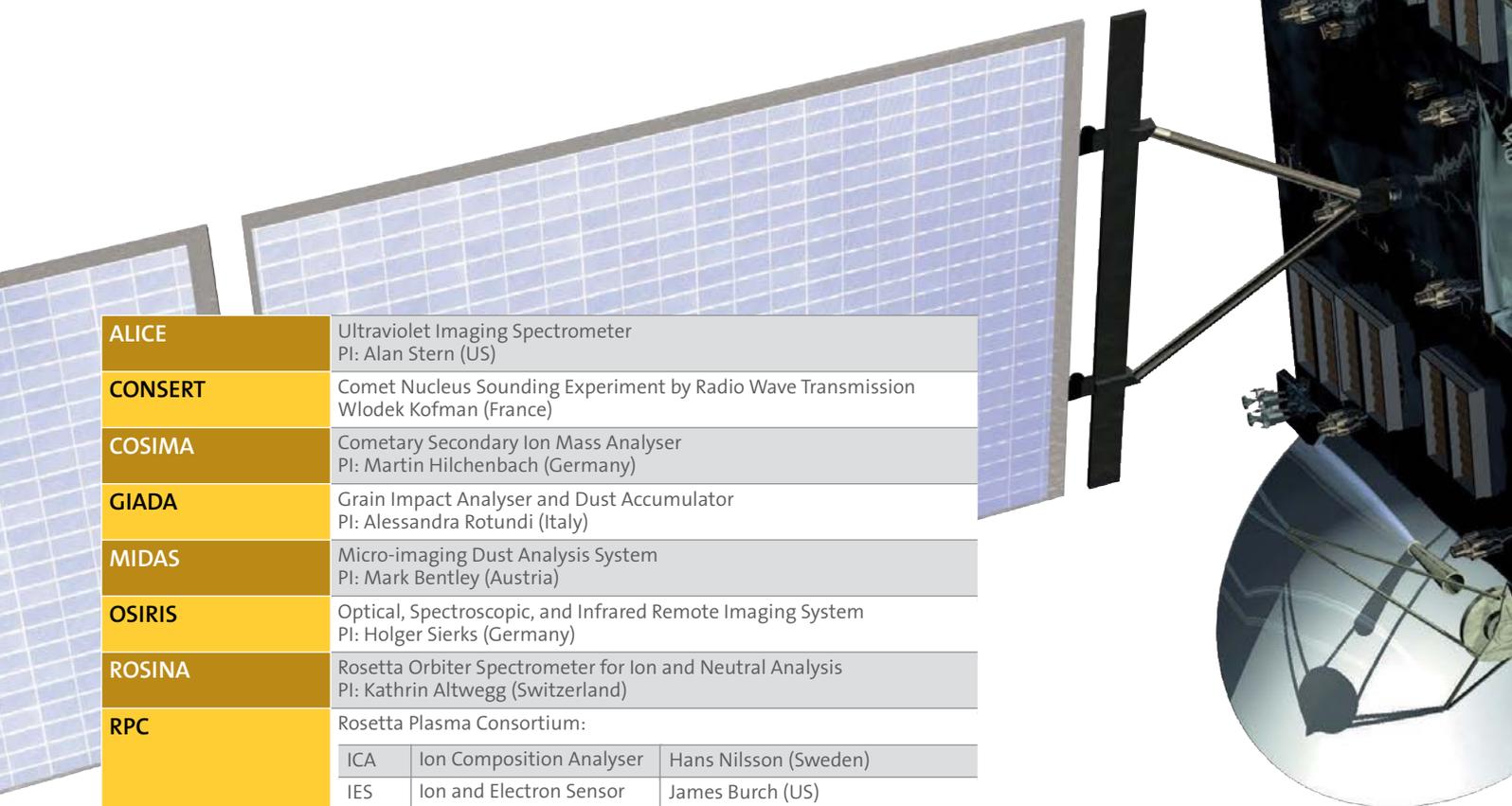
MIRO

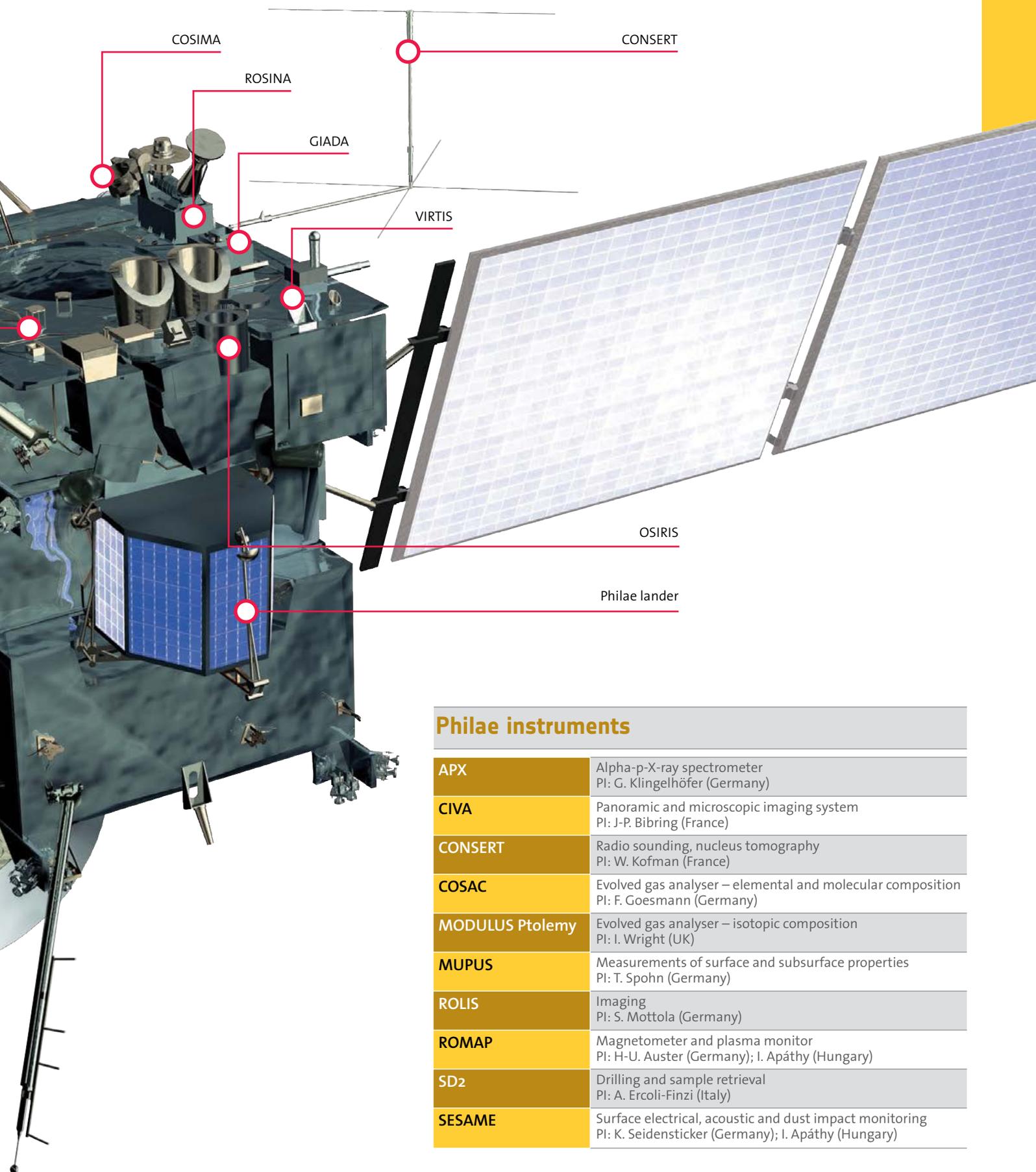
RPC

ROSINA

ALICE

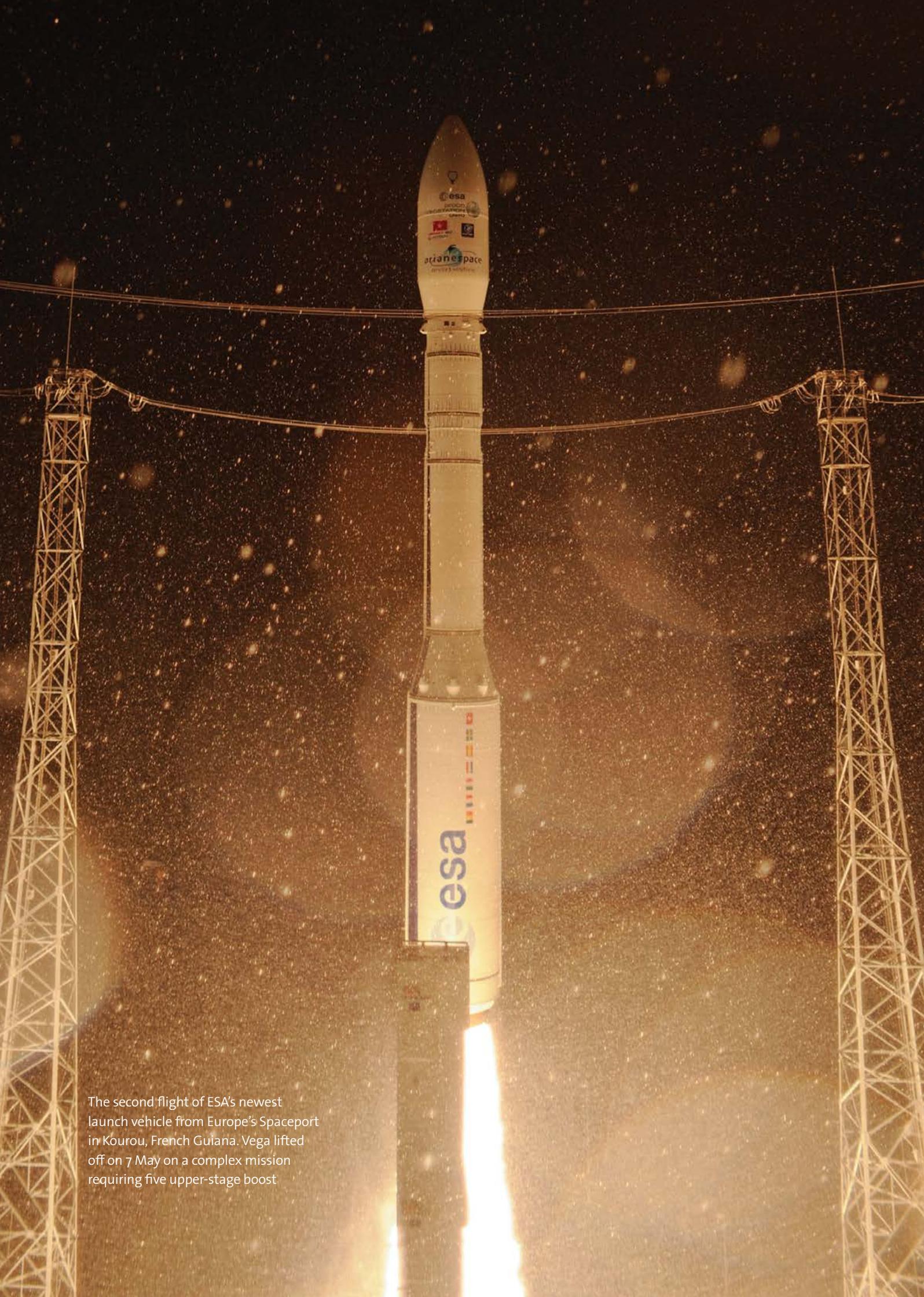
<b>ALICE</b>	Ultraviolet Imaging Spectrometer PI: Alan Stern (US)	
<b>CONCERT</b>	Comet Nucleus Sounding Experiment by Radio Wave Transmission Wlodek Kofman (France)	
<b>COSIMA</b>	Cometary Secondary Ion Mass Analyser PI: Martin Hilchenbach (Germany)	
<b>GIADA</b>	Grain Impact Analyser and Dust Accumulator PI: Alessandra Rotundi (Italy)	
<b>MIDAS</b>	Micro-imaging Dust Analysis System PI: Mark Bentley (Austria)	
<b>OSIRIS</b>	Optical, Spectroscopic, and Infrared Remote Imaging System PI: Holger Sierks (Germany)	
<b>ROSINA</b>	Rosetta Orbiter Spectrometer for Ion and Neutral Analysis PI: Kathrin Altwegg (Switzerland)	
<b>RPC</b>	Rosetta Plasma Consortium:	
	ICA	Ion Composition Analyser Hans Nilsson (Sweden)
	IES	Ion and Electron Sensor James Burch (US)
	LAP	Langmuir Probe Anders Eriksson (Sweden)
	MAG	Fluxgate Magnetometer Karl-Heinz Glassmeier (Germany)
	MIP	Mutual Impedance Probe Jean-Pierre Lebreton (France)
	PIU	Plasma Interface Unit Christopher Carr (UK)
<b>RSI</b>	Radio Science Investigation PI: Martin Pätzold (Germany)	
<b>VIRTIS</b>	Visible and Infrared Thermal Imaging Spectrometer PI: Fabrizio Capaccioni (Italy)	





## Philae instruments

<b>APX</b>	Alpha-p-X-ray spectrometer PI: G. Klingelhöfer (Germany)
<b>CIVA</b>	Panoramic and microscopic imaging system PI: J-P. Bibring (France)
<b>CONSERT</b>	Radio sounding, nucleus tomography PI: W. Kofman (France)
<b>COSAC</b>	Evolved gas analyser – elemental and molecular composition PI: F. Goesmann (Germany)
<b>MODULUS Ptolemy</b>	Evolved gas analyser – isotopic composition PI: I. Wright (UK)
<b>MUPUS</b>	Measurements of surface and subsurface properties PI: T. Spohn (Germany)
<b>ROLIS</b>	Imaging PI: S. Mottola (Germany)
<b>ROMAP</b>	Magnetometer and plasma monitor PI: H-U. Auster (Germany); I. Apáthy (Hungary)
<b>SD2</b>	Drilling and sample retrieval PI: A. Ercoli-Finzi (Italy)
<b>SESAME</b>	Surface electrical, acoustic and dust impact monitoring PI: K. Seidensticker (Germany); I. Apáthy (Hungary)



The second flight of ESA's newest launch vehicle from Europe's Spaceport in Kourou, French Guiana. Vega lifted off on 7 May on a complex mission requiring five upper-stage boost

# → ESA'S LATEST BRIGHT STAR

## Developments in the Vega launcher programme

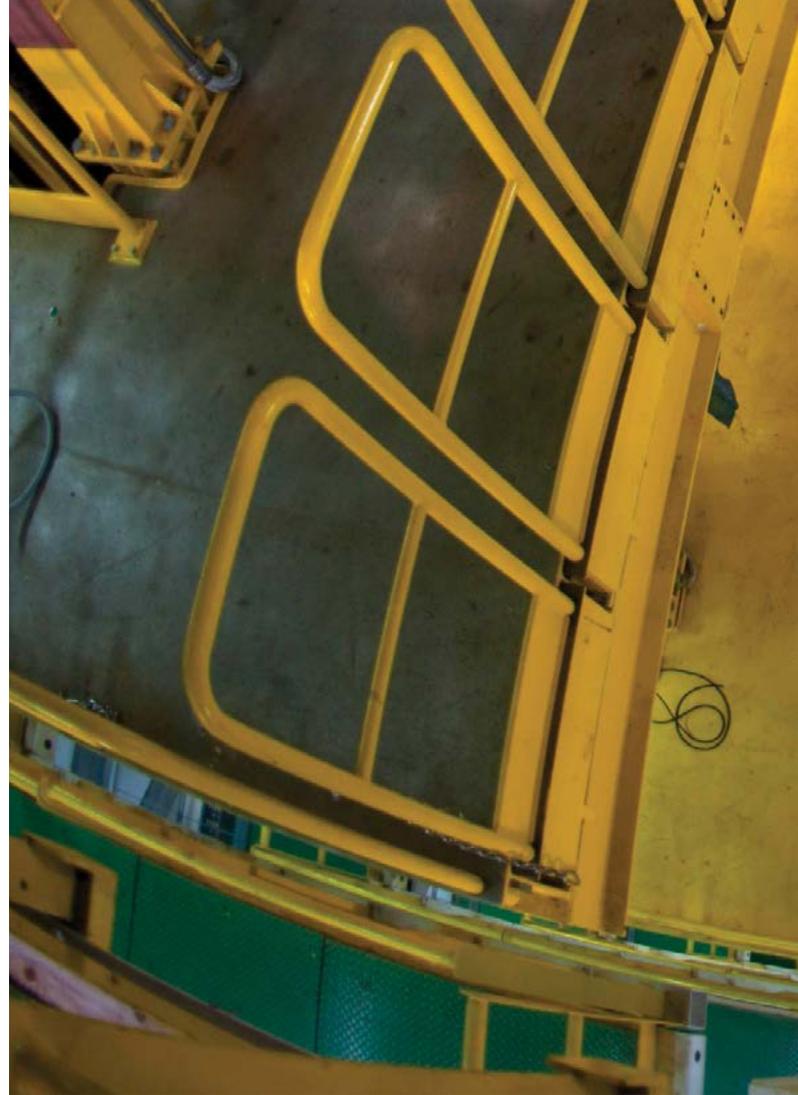
Renato Lafranconi and Miguel Lopez  
Directorate of Launchers, ESRIN, Frascati, Italy

**ESA's new Vega launcher made its qualification flight in 2012 and its first demonstration flight in May this year, validating most of the objectives set for its qualification and initial exploitation phases. So what's next?**

The Vega programme has its origins back in the 1990s, when studies in several European countries investigated the possibility of complementing the performance range offered by the Ariane family of launchers with a capability for smaller payloads.

Although there is a growing tendency for satellites to become larger, there is still a need for small launchers to place 300 kg to 2000 kg satellites, economically, into the polar and low-Earth orbits used for many scientific and Earth observation missions.

The Italian space agency ASI and Italian industry developed concepts and began pre-development work based on their established knowhow in solid propulsion. Vega officially became an ESA programme in June 1998, named after the second brightest star in the northern hemisphere.



The first Vega lifted off on 13 February 2012 on a flawless qualification flight (VV01) from Europe's Spaceport in French Guiana. The second Vega launch (VERTA1/VV02) took place on 7 May this year, marking the transition into commercial exploitation while still completing its qualification. This mission demonstrated the capability of the Vega launch system to provide a complete launch service for multiple payloads with the introduction of the VESPA multiple payload adapter and a New Flight Programme Software (FPS-A).

The mission confirmed one of the main targets of the Vega programme: the flexibility for achieving complex flight strategies with changes of orbits, multiple upper-stage engine reignitions (five in the case of VV02) and the upper-stage direct reentry in compliance with ESA's Space Debris Policy.

The three payload satellites (Proba-V, VNREDSat-1 and ESTCube-1) were injected into orbit with extremely high accuracy, to within less than 1 km with respect to the target. The launch system also demonstrated a very good availability,

← On 13 February 2012, the first Vega lifted off on its maiden flight from Europe's Spaceport in French Guiana



View Vega's P80 first stage installed in the mobile gantry for the maiden flight

especially considering that the VERTA1/VVo2 mission did not allow for a launch window. The VERTA1/VVo2 flight data was checked in June and confirmed the very good results.

## Exploitation programmes

Following the consecutive successes of the first two flights, the Vega programme is now aiming to industrialise the launcher production, maintain the qualified status and reduce the launch service costs. This will ensure a successful exploitation of the Vega launcher system, for a reliable and affordable service. The way to achieve these objectives will be through the VERTA and LEAP programmes.

### VERTA

The main objectives of the Vega Research, Technology and Accompaniment (VERTA) programme approved at the end of 2005 were to complete the initial exploitation phase, and to ensure that the Vega launch system is maintained in qualified status during its operational life.

The programme has three parts: the procurement of launch service activities for five flexibility demonstration flights (VERTA flights); the development of complementary services and hardware to improve the customer service based on Vega's specific markets; and a framework for component

testing to enable the qualification of new technologies, preventing obsolescences and, at the same time, contributing to the mitigation of risks in production.

In this role, VERTA was conceived as the equivalent of Ariane 5's ARTA-5 (Ariane Research, Technology and Accompaniment) programme. The new LEAP programme, approved at the end of 2012, ensures the continuation of the activities on the two last parts, while the VERTA programme focuses on the completion of VERTA flights and the initial exploitation phase.

Following the first VERTA launch with Proba-V, three more ESA users have launches planned with Vega, for the remaining VERTA flights. The next one is the Intermediate eXperimental Vehicle (IXV) planned for the second half of 2014. Launch preparation activities are in progress, in particular the Mission Analyses, which have entered their final phase. The remaining VERTA launches are then for ESA's LISA Pathfinder and ADM-Aeolus missions in 2015.

Commercial launches operated by Arianespace are also foreseen within the initial exploitation phase. This the case for next Vega flight planned for April 2014.

In the frame of the Customer Service Improvements, and in line with the Vega programme objectives, the final system



Vega's payload composite with fairing transferred to the launch pad

qualification process is running in order to generically qualify Vega to be compatible with a number of different of mission types. VVo1 and VVo2 qualified two specific configurations (single and multiple payload) and two mission types.

The generic qualification, planned for the beginning of 2014, will extend the qualification both for single and multiple payload missions, increasing the versatility of the launcher to respond to the forthcoming missions, in particular IXV, LISA Pathfinder, ADM-Aeolus and the Copernicus/GMES Sentinel-2 and -3 missions.

**LEAP**

The Launchers Exploitation Accompaniment Programme (LEAP), set up at the ESA Ministerial Council in 2012, aims to provide a stable and comprehensive accompaniment frame to the exploitation of the ESA-developed launchers (Ariane and Vega), with the main objectives of making sure that the launch systems are continuously in a qualified status during their exploitation phase, and that this phase is sustainable and economically balanced.

The typical activities under LEAP include the monitoring of the qualification status of the Vega launch system, enhancing our knowledge of launcher performance and reducing the system qualification reservations and limitations on use by analyzing ground operations and flight data. The risk of launch system incidents and malfunctions are minimised by constantly verifying and identifying critical issues through ground tests of the most sensitive elements of the launcher during operational phase.



↑ Artist views of Vega with 'Vega Evolution' launcher concepts from the new Vega Consolidation and Evolution Preparation programme

Activities related to maintaining ESA-owned facilities in Europe and French Guiana in operational condition are also covered by LEAP. These include engine-related test facilities, facilities required to manufacture, integrate and accept the launch vehicle components up to stage level and the Vega launch complex where integration and launch operations activities are performed.

A particular effort is being dedicated to ensure that the accompaniment activities funded by the participating Member States in 2013–14 quickly reach a balanced use of Vega after the initial exploitation phase. This means focusing on activities that will ensure the continuity of production (those relevant to hardware obsolescences and treatment of major anomalies) and on all cost-reduction measures to be applied to launcher production and to launch service activities in general.

## The future of Vega

In parallel with the ongoing initial exploitation, and following the decisions taken during the ESA Ministerial Council, activities dedicated to the evolution of Vega have been started in the Vega Consolidation and Evolution Preparation (VECEP) programme.

The main objectives of VECEP are the qualification of a consolidated version of Vega in the mid-term (2016–18). This would feature an increased performance without increase of cost, and the identification of a solid set of technical and programmatic elements to allow the development of a ‘Vega Evolution’ launcher, which would address a larger European institutional customer base in the long term.

Activities related to the consolidated Vega will increase the flexibility of the launch service for multiple payload missions and increase the performance, allowing a recovery of mission performance lost because of compliance with ESA’s Space Debris Policy and to capture an additional market segment.

The new configuration is based on an enhanced first-stage Solid Propulsion Rocket Motor and on an increased AVUM propellant capability. A major driver in these activities is the investigation into possible synergies with the Ariane 6 programme, which could range from the Filament Wound Solid Rocket Motor Case technologies and materials, to common components (for example, ignite or Thrust Vector Control) or major parts (Inert Motor Case), up to the use of the same Solid Rocket Motor.

To maintain competitiveness of the Vega launch service, with respect to present and future competitors (such as Angara, Soyuz 2-1v, Athena and Epsilon), without support to the exploitation, VECEP activities will also be driven by cost-reduction considerations. ■



↑ Vega’s mobile launch gantry at Kourou, French Guiana, with a fully assembled rocket for flight VVo2



TT&C antenna at the Galileo Sensor and Uplink Station, Nouméa, New Caledonia

## → GALILEO'S EARTH

### The Galileo ground segment

Sean Blair

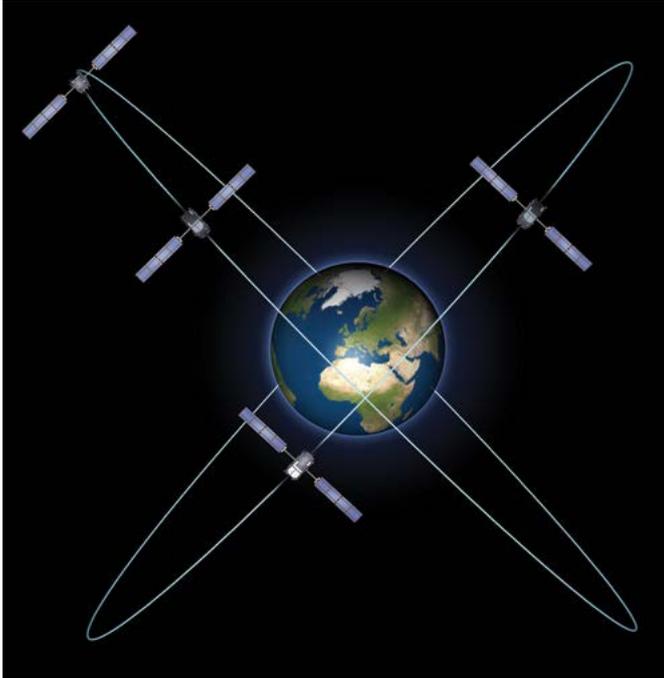
Communication Department, ESTEC, Noordwijk, the Netherlands

**The satellites in space are only the tip of the Galileo iceberg – a far-flung ground segment, unique in its complexity and scope, has taken shape all over the planet.**

For the equivalent cost of expanding the European motorway network by less than 600 km, Galileo is Europe's independent satellite navigation system, a wise and essential investment. And it will do more than just keep our continent's traffic from snarling up during the century to come: Galileo is set to enable a host of future location-based

businesses and services while supporting and expanding the estimated 6–7% of Europe's economy – around €800 billion in value – already reliant on satellite navigation.

ESA and the European Commission are partners on the Galileo programme. The definition, development and In-Orbit Validation (IOV) phases of Galileo have been undertaken by ESA, co-funded by ESA and the EC. The follow-on Full Operational Capability (FOC) phase is being managed and fully funded by the European Commission, with ESA acting as design and procurement agent on behalf of the Commission.



↑ The first four Galileo IOV satellites served to validate the overall design of the Galileo system and represent the nucleus of the full 30-satellite Galileo constellation to follow

The first four Galileo IOV satellites – launched in 2011 and 2012 respectively – are already working in orbit, broadcasting navigation signals. Having served to validate the overall design of the Galileo system, they represent the operational nucleus of the full 30-satellite Galileo constellation to follow. Those follow-on FOC satellites are taking shape through a Europe-wide production and testing line that ends in Kourou, French Guiana, with the next tranche of launches.

But the satellites in space are only one element of the overall satellite navigation system – the tip of the Galileo iceberg. ESA has also been busy putting a global ground segment in place, extending to some of the world's loneliest places. This work has been among the most complex developments ever undertaken by ESA, having to fulfil strict levels of performance, security and safety.

Galileo engineers were also working to a strict time schedule: the initial IOV ground segment infrastructure needed to be fully in place and online – linked by satellite to Galileo's two control centres – before Galileo's first position fix could be carried out, eventually carried out in March this year. A fast-track programme of station openings was implemented to make the deadline.

Like any standard ground station, each Galileo station has to be built on an area of flat ground – no easy task in some

locations – away from inhabited areas or other potential sources of radio interference, with a steady power supply plus back-up generator and fuel supply as well as on-site spare parts.

Day to day, the stations operate autonomously, with technicians needed only for maintenance and anomaly investigation. The degree of attention likely to be required depends on the station type – on one hand, a Galileo Sensor Station is simply an automated 50 cm omnidirectional antenna while Uplink Stations incorporate steerable 3 m antennas and, at the top of the scale, Telemetry & Tracking Stations employ steerable 13 m diameter antennas. Each station is overseen by a local 'hosting entity', and is connected to the secure Galileo Data Dissemination Network via satellite link.

Because Galileo is an independent European programme, all the elements in its ground segment – while covering the world – have to be sited on European territory. This requirement saw ESA engineers despatched to some of the remotest European dependencies and colonies on the planet, a process that is continuing today. Just as the Galileo constellation is advancing from the IOV phase to the FOC phase, so the Galileo ground segment goes on growing to accommodate the many new satellites to come, and consolidate this truly global satnav system.

## Why does 'satnav' need a ground segment?

Satellite navigation: wherever you go, there it is. As long as there's a sufficiently open patch of sky above your head, from just about anywhere on Earth you can switch on your receiver to find out exactly where you are and in which direction you are heading.

The ubiquity of satnav is a major factor in why it has so swiftly transformed the way we live and work. Added to that is its apparent simplicity – from the user's point of view, all that are needed are the navigation signals from the satellites in space and suitable equipment to receive them, whether handheld or embedded into a car or smartphone. At least that's what most people think, but this misses a large part of the true picture.

If the orbiting satellites were left to operate alone – in the aftermath of a global catastrophe, for example – then the surviving population who consult their satnav receivers would find the accuracy begin to decline. Within a matter of days, their satnav systems might be unable to pinpoint which town they are in and, in a matter of weeks, which country.

The reason for this is that a world-spanning ground segment is needed to maintain contact with all satellites in the satnav constellation and to keep their performance from straying off track. Recall that satnav is ultimately

based on the highly precise measurement of time: the signal from each satellite contains a time code from its onboard atomic clock, so the length of time it has taken from the signal to reach the receiver can be deduced.

Multiply that value by the constant speed of light to derive your distance from the satellite – you now know you are somewhere within a fixed sphere around the satellite (to sharpen accuracy further, your receiver contains details of all the satellites' orbits – their 'ephemerides'). Do the same with other satellite signals simultaneously – from a minimum of four satellites, in practical terms – and your receiver calculates a set of overlapping spheres, with you placed within their point of shared overlap. This method is called 'trilateration', the three-dimensional equivalent of triangulation.

However, individual atomic clocks might be prone to drift – and an error of just a billionth of a second corresponds to a 30 cm increase in ranging error. A clock error of an entire second would put users 300 000 km off target, or most of the way to the Moon. So a network of ground stations continuously checks each satellite's clock against the system time generated by a much more accurate collection of ground-based atomic clocks (the Galileo System Time, in the case of Galileo).

Satellite orbits can drift too, nudged by the gravitational tug from Earth's equatorial bulge, and by the Moon and Sun. Even the slight but continuous pressure of sunlight itself can influence satellites over time. So for satnav to work well, their present positions in three-dimensional space need to be certain to sub-metre accuracy. Three or more adjacent

ground stations viewing the same satellite at once perform trilateration up to space, to quantify any drift (laser-ranging can also be employed for even better accuracy).

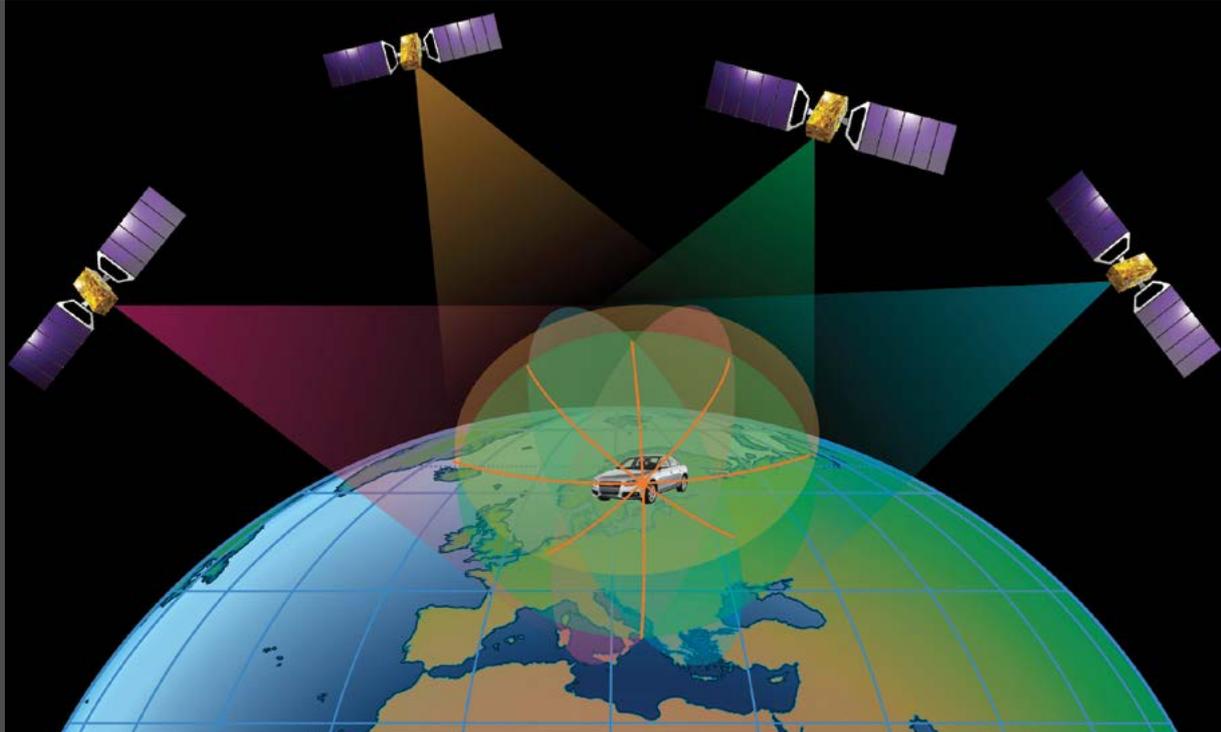
Ground stations around the globe also need to identify any signal delay or disturbance because of perturbations in the ionosphere – the electrically active outer layer of the atmosphere, which can be influenced by solar activity. Ionospheric delay can be largely subtracted by employing dual-frequency satnav receivers, but to date the majority of receivers remain single frequency, so these effects need to be accounted for.

Finally, all these data gathered at widely dispersed ground stations need to be collected together at the control centre of the ground segment so that a list of corrections can be made then uplinked to the satellites for rebroadcast within the navigation signal for user receivers to take account of when determining position. This correction process takes place as often as needed, typically on a daily basis. In essence, the satellite constellation with its ground segment forms an enormous self-correcting closed-loop system.

In addition, Galileo's ground segment is even more complex than the other global navigation satellite systems that have come before, because it is designed not only to deliver worldwide positioning services, but also their associated integrity information – with an estimate on the current trustworthiness of the signals plus prompt error messages in the event of failure. This is essential for the 'Safety of Life' applications, such as managing air traffic, highways, railway networks and shipping.



The three-dimensional equivalent of triangulation, 'trilateration', the method used to calculate our positions when using satnav



# Outposts on the edge

## → FROZEN FRINGE OF EUROPE



Location: Kiruna, northern Sweden  
Host: Swedish Space Corporation



One of two telemetry, tracking and command (TT&C) stations for Galileo's IOV phase – the other is based at Kourou, French Guiana. Kiruna's extreme northerly attitude, 200 km north of the Arctic Circle in the forests of Swedish Lapland, gives it good visibility for Galileo satellites at the top of their three orbital planes, while its remote location avoids any signal interference from built-up areas. The station is hosted at the Esrange Space Center of the Swedish Space Corporation, one of the oldest space sites in Europe, first established by ESA's predecessor ESRO in the mid-1960s as a rocket range as well as satellite ground station.



## → BOTTOM OF THE WORLD



Location: Troll research base, Antarctica  
Host: Kongsberg Satellite Services

The most southerly Galileo site to date is Troll base in Antarctica. Hosting a combination of Galileo Sensor Station and Uplink Station, this Norwegian facility is located some 235 km inland in the thin air 1270 km above sea level. The stations are sited on the solid foundation of a mountain peak rising through surrounding glaciers. This is also home to the TrollSat satellite ground station, staffed year round, with supplies coming in via an adjacent glacier-based airfield and supplemented by overland convoys during the round-the-clock sunlight of the brief Antarctic summer.



## → POLAR OPPOSITE



Location: Spitsbergen Island, Svalbard archipelago, Arctic Ocean  
Host: Kongsberg Satellite Services

The site of an Uplink Station and Sensor Station, Svalbard is the most northerly node in the Galileo ground segment, positioned at more than 78°N, less than 1000 km from the North Pole. The Svalbard Satellite Station, SvalSat for short, also serves as a ground station to numerous polar-orbiting Earth observation missions. But it remains one of the remotest Galileo sites. The road to Spitsbergen's main settlement of Longyearbyen is regularly blocked by severe weather – a helicopter pad provides back-up access for the 23-strong engineering team operating SvalSat around the clock. There are more polar bears on the island than people.



## → BLACK BEACH



Location: Jan Mayen Island, Arctic Ocean  
Host: Kongsberg Satellite Services

Famed for having some of the worst weather in the world, this remote volcanic island is linked to the outside world by Norwegian military flights to an unpaved airfield, operating only a few times per year, with access strictly controlled to protect its pristine Arctic environment. Jan Mayen hosts a Galileo Sensor Station set up on a beach of volcanic black sand, littered with bleached timber washed up from the distant Russian mainland – the only flat plain available on the island.





## → 'HMS ASCENSION'



Location: Ascension Island, South Atlantic Ocean  
Host: C&W



This isolated tip of an underwater volcano enjoys a mild tropical climate, although much of its land is made up of lava flows and cinder cones. The greenest place on the island is actually its rain-prone highlands, planted with trees and plants introduced by amateur gardeners during the last two centuries. Britain's Royal Navy officially assigned Ascension Island as a vessel or 'stone frigate' – HMS *Ascension* – after taking possession of it in 1815. It was thereafter used as military base, cable station and, latterly, satellite ground station. A Galileo Sensor Station came online this year. Uniquely, Ascension Island also hosts a GPS ground antenna and monitor station, located at a US Air Force base on the island.



## → MELANESIAN OUTPOST



Location: Nouméa, New Caledonia, Pacific Ocean  
Host: TDF

Already home to a Galileo Sensor Station and Uplink Station with a TT&C station due to come online soon, this French-administered group of tropical islands is far from a hardship posting. But at the start of July, the engineers manning the site found themselves marooned by a flash flood. Nouméa is built on a flat plain surrounded by bowl-like hills that normally help to screen out unwanted radio signals, but in this case funnelled water down to the site in the heaviest rains on New Caledonia since 1951. As a nearby stream burst its banks, the waters washed away the access road to the site. The engineers sat tight for 40 hours, the time it took for rescuers to repair the road. The station remained operational throughout, helped by high foundations and an onsite generator.





## → DESOLATION ISLE



Location: Grande Terre, Kerguelen Islands, Indian Ocean  
Host: Terres australes et antarctiques françaises (TAAF)

There is no airport on this sub-Antarctic French territory – also known as the Desolation Islands – and a boat calls only four times a year. The main island of Grande Terre, much of it covered by glaciers, is home to seabirds, feral cats and about 100 polar scientists. This is the site of a Galileo Sensor Station that had to be constructed during a hectic stay by Galileo engineers at the end of 2011, who saved time in this case by reusing a surplus protective facility to host the station rather than starting with an empty field.



## → STATIONS FOR SEARCH AND RESCUE



Locations: Maspalomas, Canary Islands /  
Spitsbergen, Svalbard



Not all Galileo ground stations are devoted to navigation. ESA has prepared a trio of sites for satellite search and rescue, part of the international Cospas–Sarsat programme. Founded by Canada, France, Russia and the US, Cospas–Sarsat has assisted in the rescue of tens of thousands of people in its three decades of service. Distress signals from across the globe are detected by participating satellites, then swiftly relayed to the nearest search and rescue (SAR) authorities.

Now the programme is introducing a new Medium-Earth Orbit Search and Rescue (MEOSAR) system to provide enhanced coverage and response times. Just a trio of MEO Local User Terminals (MEOLUTs) are required to cover all of European territory: ESA has already completed the sites at Maspalomas in the Canary Islands and Spitsbergen in Svalbard, with Larnaca in Cyprus currently approaching completion. These three sites are monitored and controlled from the SAR Ground Segment Data Service Provider site, based at Toulouse in France.

Each MEOLUT is equipped with four antennas to track four satellites. The stations are networked to share raw data from participating satellites (Glonass as well as Galileo, with GPS Block III satellites also participating later in this decade), effectively acting as a single huge 12-antenna MEOLUT, delivering unprecedented detection time and localisation accuracy.



↑ Maspalomas

↓ Spitsbergen





↑ Fucino is the site of one of the largest satellite communication stations in the world and the home of the home of the Galileo Mission Segment (Telespazio)

## Galileo's double heart

At the centre of Galileo's worldwide ground segment is not a single control centre but two. This built-in redundancy provides reliability and robustness to the overall Galileo system. During the IOV phase, each centre runs a different half of the ground segment, but in future the two centres will host equivalent facilities, working together as 'hot' back-ups with real-time data synchronisation. In the event of loss of one centre, the other will be able to pick up operations seamlessly.

The Fucino control centre in central Italy is the home of the Galileo Mission Segment (GMS), which oversees the running of all navigation services provided by Galileo. It ensures highly accurate mission performance on an ongoing basis by processing data from the worldwide network of ground stations, then embeds any necessary corrections into the navigation message being uplinked to the satellites. The GMS includes two million lines of

software code, 500 internal functions, 400 messages and 600 signals circulating through 14 different elements.

Fucino is the site of one of the largest satellite communication stations in the world. The location is ideal because it has plenty of broad flat ground, screened from terrestrial electromagnetic signals by surrounding hills. This distinctive geography is the result of one of the ancient world's greatest feats of engineering: the Romans dug a tunnel to drain much of the lake that originally covered the Fucino basin. This pioneering work of Emperor Claudius was finally completed in 1875, when the rest of the lake was drained using the very same tunnel. The rich soil left behind is today used for farming.

The Oberfaffenhofen control centre near Munich in southern Germany is the home of the Ground Control Segment, which monitors and controls the Galileo satellite platforms across the whole of their 12-year operating lives. Each satellite sends at least 20 000 signals about its

status to Earth – data being continuously analysed in the control centre. Satellite performance has to be checked daily, to ensure that important parameters remain within defined ranges, including power availability and attitude control. Each satellite's orbit is being monitored down to an accuracy of less than 50 cm. Of course, managing this task will grow progressively more challenging as the Galileo constellation grows.

Oberpfaffenhofen is one of the largest sites of the German Aerospace Center, DLR, home to the German Space Operations Center, which has been overseeing Germany's space missions since the 1970s. Oberpfaffenhofen, like Fucino, hosts a Galileo Precise Timing Facility, an ensemble of atomic clocks on site to generate Galileo System Time (GST) on an averaged basis, employed to synchronise all system clocks and signals in the Galileo system. The difference between GST and GPS time – known as the 'offset' – is then broadcast in the Galileo navigation message, helping to enable ongoing interoperability of Galileo and GPS.

Operational management of the two control centres is undertaken by Spaceopal, a joint venture between the Fucino owner and operator Telespazio with DLR GfR, a company set up by the German Aerospace Center. ■

Sean Blair is an EJR-Quartz writer for ESA



↑ Galileo's spirit lives on at Fucino, Italy, where a sculpture of the astronomer appears to be studying the skies (Telespazio)



↑ Oberpfaffenhofen is one of the largest sites of the German Aerospace Center, DLR, and home of the Galileo Ground Control Segment

# → GALILEO GROUND SEGMENT OVERVIEW



## KEY

- GCC: Ground Control Centre
- GSS: Ground Sensor Station
- ULS: Uplink Station
- TTCF: Telemetry, tracking and Command
- SAR MEOLUT: Search and Rescue Medium Earth Orbit Local User Terminal
- GSMC: Galileo Security Monitoring Centre
- TGVF: Timing and Geodetic Validation Facility
- IOT: In Orbit Test Centre
- LEOPCC: Launch & Early Operations Phase Control Centre

Status: March 2013

## → Definitions

**Telemetry, Tracking and Command (TT&C) Stations** – the space/ground interface for telemetry acquisition and telecommand uplink to the satellite platforms, as well as two-way ranging

**Uplink Stations** – a network of stations to uplink the corrections and integrity data to the satellites for rebroadcast to users as part of the navigation message

**Galileo Sensor Stations** – spaced across the globe to receive navigation signals from the constellation for rebroadcast to the control centres, enabling continuous clock synchronisation, signal quality and satellite ranging measurements

**MEOLUTs** – Medium-Earth Orbit Local User Terminals, not part of Galileo's navigation infrastructure but instead used to relay search and rescue messages to local authorities as part of the international Cospas-Sarsat programme





Bedrest volunteer wearing a mask to measure oxygen intake and carbon dioxide exhaled (CNES/E. Grimault)

# → THE MAKING OF A PILLOWNAUT

## European bedrest studies

Julien Harrod

Communication Department, ESTEC, Noordwijk, the Netherlands

**Who would volunteer to spend months doing nothing in bed, and why? The answer is a special kind of person, who wants to help improve our life on Earth and enable humankind's long-term presence in space.**

All animals live with the constant pull of Earth's gravity. Our bodies have evolved over millions of years to cope with this, for example, the system in our inner ears that controls our balance relies on liquids reacting to gravitational forces. The system that stops blood rushing to our heads usually only needs to kick in if we do a handstand or we are lying down.

Our body makes sure that blood in our feet is pumped back to the lungs, even though this requires more energy than returning blood from our fingertips.

Take the pull of gravity away and all these systems have to work in completely different conditions. Astronauts have proven that our bodies cope very well in microgravity as they float gracefully through the modules of the International Space Station. Their adaptation to weightlessness is remarkable and forms a field of research that is revealing the inner workings of our bodies.



↑ Expedition 37, October 2013: An ISS Expedition consists of six astronauts, except during crew change-overs when one Soyuz crew of three returns and there is a short gap between the next crew arrival (NASA)

However, this adaptation is not without side-effects. Astronauts in space often suffer from weakened immune systems, muscle atrophy, bone loss and headaches as blood rushes to their heads. After a long spaceflight, they return to Earth in a weakened state and often require medical support before being able to walk on their own. The longer the spaceflight, the longer the period of recuperation. With a one-year mission on the International Space Station planned for 2015, understanding the human body's reaction to spaceflight, and finding ways to help it adapt to life in space and back on Earth, is of increasing importance to researchers and space agencies.

Presently, three-person crews are exchanged every six months and typically six astronauts are in space at any one time. This limits potential research subjects for study and also limits the amount of testing that can be done with new approaches to help the human body live in this new environment. In addition, astronauts have a heavy workload of science and maintenance, making them far from ideal guinea pigs for studies that involve strict diets and exercise regimes. Human spaceflight researchers need a more accessible way to study

the human body and test measures to counteract unwanted changes. This is where bedrest studies come in.

### Restless nights

Early Soviet cosmonauts reported that they had trouble sleeping in normal beds when they returned to Earth. Lying horizontally in bed did not feel right; they felt they were slipping down towards their feet. Even though this was not the case, the motion detection systems in their inner ears had adapted to spaceflight and were reporting conflicting signals to the brain. In desperation, enterprising cosmonauts took to raising the legs of their beds at their feet to counteract the falling sensation and enjoy a good night's sleep.

The practice took off, so much so that many astronauts start to sleep with their bed propped up before a mission starts in the hope that they will get used to sleeping in microgravity and get a headstart in adaptation.

Astute crew medical officers noticed the early cosmonauts' practice and wondered if lying down with your feet up



↑ Preparing a bedrest meal for a controlled diet (CNES/E. Grimault)



↑ Performing physiological testing as part of the 'baseline data collection' period diet (CNES/E. Grimault)

physically changes the body in ways similar to spending a long time in space. The idea is not as strange as it might sound. The main effects of living without gravity are a shift of bodily fluids towards the head, muscles are used less and the bones receive less stress. Spend a month in bed with your head down and these three effects are recreated.

From the 1960s, US and Russian space agencies started conducting bedrest studies, keeping volunteers in bed for up to a whole year. After some experimentation, the ideal angle for the beds was found to be with the head end 6° below horizontal. This angle offered a good compromise between comfort, practicality and physical response in the volunteers' bodies.

However, each study had its own goals and constraints, with little coordination between them. Studies lasted from days to months with varying degrees of freedom allowed to the participants. Some studies allowed the participants to get up to go to the toilet, for example, whereas others asked them to lie down at all times, making it impossible to compare data scientifically.

## Setting the standard

When ESA started its first bedrest studies in the early 1990s, the lack of standardisation was limiting scientific results on a global scale. "In 2005 we restructured the programme and started to standardise our bedrest studies," says Oliver Angerer, ESA's human exploration science coordinator. "A 6° incline was set and stricter constraints given to the participants, such as their hips and one shoulder must always be in contact with the bed."

ESA now organises bedrest studies as part of ELIPS, the European Programme for Life and Physical Sciences. Studies are divided by length from short-term studies of five days to long-term studies lasting up to 60 days. Each type can test a technique to counteract specific effects of spaceflight while recording useful data for other studies.

Short bedrest studies are used to screen and test for the effectiveness of countermeasures and are suitable for recording changes in the cardiovascular system. Medium-duration studies confirm and refine selected countermeasures

↓ Setting the angle of a bed with the head end at 6° below horizontal offers a good compromise between comfort, practicality and physical response in the volunteers' bodies



↑ Boredom is real problem, but participants use the time on their hands for self-improvement programmes, and a large collection of films and music comes in handy (CNES/E. Grimault)



↑ A bedrest eyetest. Other typical invasive tests endured include regular blood-taking and muscle biopsies (CNES/E. Grimault)

and offer researchers data on more long-term effects, such as muscle loss. A long bedrest is used for a final validation of countermeasures to be used during spaceflight.

Each study requires a pre-rest period for the participants, called the 'baseline data collection period'. Data are collected about the subjects as a benchmark of normal values, and then they are introduced to their new standardised and controlled environment and the diets they will follow for the duration of the study. A rehabilitation period after the study is also necessary, to help participants regain their feet and sense of balance, up to two weeks for long studies.

Shorter studies with around 12 subjects are often divided into groups with one or more groups testing countermeasures and a control group that goes through the study without testing new equipment or protocols. The same participants return after the study and a period of normal life to undergo the same bedrest period but in a different group. In this way, participants act as their own control. This is called a 'crossover study' design.

Data collection is very similar to that in an astronaut mission. Depending on the study, data can be collected on physical values such as red blood cell count, measurable values such as muscle strength but also psychological aspects such as state of mind. During the bedrest period, participants' health is regularly monitored, tested and analysed.



↑ Lack of privacy, strict diet and no luxuries: a bedrest study is anything but restful (CNES/E. Grimault)

## Not a restful job

Despite its calm-sounding name, a bedrest study is not an easy activity and cannot be taken lightly. Participants, often called 'pillownauts', are under constant scrutiny and there is very little privacy with the rooms being shared with other participants. In most studies, visits from friends and family are not allowed. Typical invasive tests endured by participants in the name of science include regular blood-taking and muscle biopsies. Then there are the inevitable backaches and, of course, boredom.

Organising a crossover bedrest study is not unlike organising a mission to space – but the emphasis is on the organisation and human elements rather than engineering and technology. Preparing test equipment, making sure it is available during the study and fitting all research experiments together can be a headache for the organisers. Some experiments require a subject to have an empty stomach, whereas others might require the opposite. Blood is a sought-after commodity.

"If all the researchers from the eight experiments in this year's bedrest had their way, the tests would require one litre of blood from each person," explains Marie-Pierre Bareille from the French Institute for Space Medicine and Physiology (MEDES), in Toulouse, France (the average human body has around five litres of blood). MEDES is handling ESA's current bedrest study, run with the French space agency CNES. "Obviously we try to share and reuse data between experiments, it is like a puzzle to fit everyone's needs," said Marie-Pierre.

Finding participants who are willing to sacrifice months of their normal life, endure the discomfort and fit the psychological profile is the hardest part. An ideal pillownaut would resemble an astronaut – being healthy, willing to take orders, easygoing and not impulsive. Participants are paid for their time, but Oliver Angerer says, "If money is the only driving factor for participation, we would not consider them a good test subject. Drop-outs do happen, which is especially damaging in a crossover study, so we conduct lengthy psychological screening to avoid this as much as possible."

The pillownaut selection process also resembles the astronaut selection process by weeding out applicants with unwanted characteristics. Of the hundreds of applicants, only a handful is invited to take medical tests. Psychological screening further cuts down the number of potential pillownauts, leaving those with the 'right stuff'. A number of backup pillownauts are kept on hand in case of last-minute drop-outs.

So what motivates a pillownaut to withdraw from society and spend boring and painful weeks in bed? Certainly the experience offers an opportunity for introspection, but there

is the knowledge that you are helping humankind's scientific endeavour. Many pillownauts mention that they feel they are doing their part for human exploration of the Solar System. Money is a factor, of course, because the participants need to take time out from their normal jobs and daily lives for several weeks. Many pillownauts are unemployed when they start the study. Participants use the time on their hands for self-improvement programmes, or for projects such as writing a book or preparing a start-up company. Naturally, a large collection of films and TV series on DVDs is brought as personal luggage.

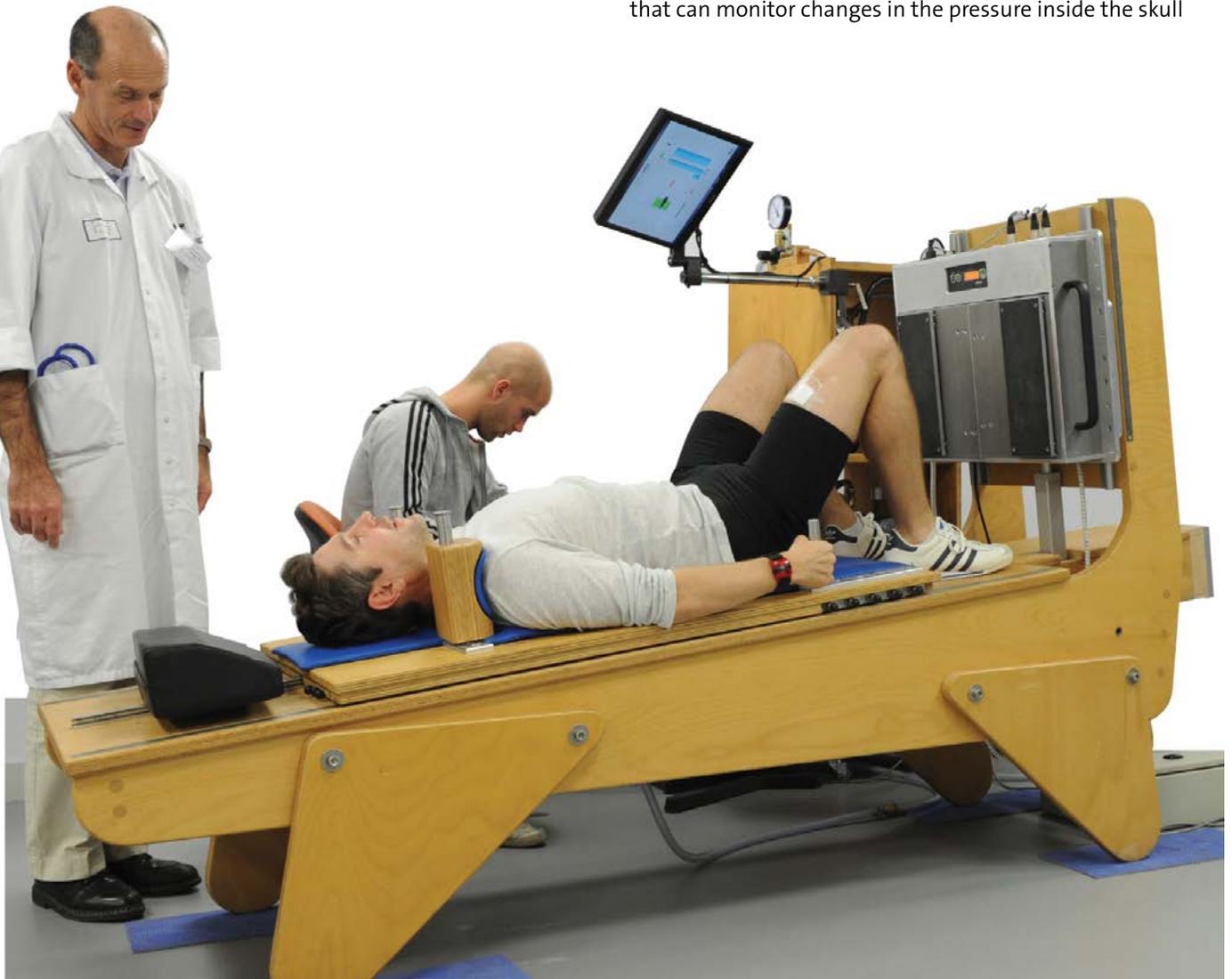
Marc, a subject from this year's French study, explains, "It is an extraordinary adventure, like crossing an ocean, and the results will be used for everyday life and that makes me proud." His pillownaut colleague Nicolas adds, "Become a volunteer: it's an unforgettable experience and you get to participate in humankind's space adventure."

## Couch potatoes and skull pressure

Results from bedrest studies not only help astronauts, but also people on Earth. One of the most visible spin-offs from bedrest studies are the vibrating exercise machines used in gyms and used by millions of people around the world. 'Couch potatoes' and astronauts have something in common: they both want to do a full body workout in as little time as possible. The vibrating exercise machine not only gives a good workout, but also appears to counteract bone loss in space.

The workout was conceived and tested on bedrest patients before becoming common in gymnasiums. ESA recently tested a variation of the workout in Toulouse, whereby participants are pushed onto the vibrating plate – the equivalent of doing bench squats wearing a 75 kg backpack, upside down.

The studies offer a greatly controlled environment to test new equipment against known values. A new device that can monitor changes in the pressure inside the skull



↑ A variation of the vibrating exercise workout under test in Toulouse (CNES/E. Grimault)



↑ DLR's EnviHab facility centrifuge (DLR)

(intracranial pressure) was tested during a bedrest study held in Germany last year. The main way to measure a patient's intracranial pressure is to do an invasive and painful procedure drilling directly into the skull. A new technique uses sound waves bounced off the inner ear to measure changes in pressure and can offer early warning signals in the health of people recovering from brain surgery or a head injury. The bedrest study allowed its inventor to improve the system and make it more portable, reducing it to the size of a typical external hard disk. The system is easy to use for people with little or no training and is undergoing more testing in ESA's research programme at Concordia base in Antarctica.

## → Get involved

ESA recently issued an announcement of opportunity for researchers to propose new experiments for upcoming bedrest studies and regularly issues more. If you think you have what it takes to be a pillownaut and can be missing from your daily life for a few weeks, you could sign up at the next pillownaut selection and take part in the human endeavour of the exploration of space.

Opportunities to become a pillownaut are published regularly by ESA's partner institutes: MEDES ([www.medes.fr](http://www.medes.fr)) and the DLR Institute for Aerospace Medicine ([www.dlr.de/me/](http://www.dlr.de/me/)). The next study will be held at DLR and recruitment will start around the middle of 2014.

An ESA-led bedrest in 2000 conducted an experiment in collaboration with Japanese space agency JAXA that tested the effectiveness of an anti-osteoporosis drug to prevent bone loss caused by lack of activity. Pillownauts were injected with a bisphosphonate solution before their bedrest and they showed less bone loss than the untreated controls. Based on these positive results, trials are now being conducted on the International Space Station.

ESA works with CNES and the German Aerospace Center (DLR), alternately, organising bedrest studies. This year, DLR opened a new dedicated centre for human studies called 'EnviHab'. In addition to state-of-the-art monitoring equipment such as MRI scanners, the building offers scientists complete control of the pillownaut's environment.

At the flick of a switch, scientists can change the type of lighting, the air pressure and even the amount of oxygen the participants breath during their stay. The building has a centrifuge that can put volunteers under hypergravity, producing up to 12 times the normal force of gravity. Exercise bicycles and other machines can be installed in the centrifuge to test techniques for keeping fit in space.

Future pillownauts will not have it easy, but the exploration of our Solar System owes a lot to these brave and dedicated 'layabouts'.

Julien Harrod is an EJR-Quartz writer for ESA



→ NEWS IN BRIEF

The three satellites that make up ESA's Swarm magnetic field mission seen in 2012 at IABG, in Ottobrunn, Germany



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ASTRIUM

## 2016 Mars lander named

The entry, descent and landing demonstrator module that will fly on the 2016 ExoMars mission has been named 'Schiaparelli' after the Italian astronomer Giovanni Schiaparelli, who famously mapped the Red Planet's surface features in the 19th century.

ExoMars is a joint mission with Russia's Roscosmos space agency, and comprises two missions that will be launched to Mars in 2016 and 2018. The Trace Gas Orbiter and Schiaparelli make up the 2016 mission, while the ExoMars rover, with its carrier and surface platform, will be launched in 2018. Working together, the orbiter and rover will search the planet for signs of life, past and present.

Schiaparelli will prove key technologies for Europe with a controlled landing on Mars. It will enter the atmosphere at 21 000 km/h and use parachutes and



The ExoMars Entry, Descent and Landing Demonstrator Module, 'Schiaparelli', undergoing entry load tests at Thales Alenia Space, Turin, Italy (ESA/B. Bethge)



thrusters to brake to less than 15 km/h before landing a few minutes later. The module will collect data on the atmosphere during the entry and

descent, and its instruments will perform local environment measurements at the landing site, which is in a region of plains known as Meridiani Planum.

## Einstein's mission complete



ATV *Albert Einstein* shortly after undocking from the International Space Station on 28 October (NASA/ESA)

ESA's fourth Automated Transfer Vehicle cargo ferry, *Albert Einstein*, ended its five-month mission to the International Space Station by reentering the atmosphere on 2 November.

ATV *Albert Einstein* burned up safely over an uninhabited area of the southern Pacific Ocean. At 20 tonnes, it set the record for the heaviest Ariane 5 launch when its mission started from Europe's

Spaceport in French Guiana on 5 June, docking with the Station 10 days later. The record ATV cargo of 2480 kg included more than 1400 individual items.

# Farewell to Planck

ESA's Planck space telescope was turned off on 23 October, after over four years soaking up the relic radiation from the Big Bang and studying the evolution of stars and galaxies throughout the Universe's history.

Project scientist Jan Tauber sent the final command to the Planck satellite from ESA's European Space Operations Centre, marking the end of operations for ESA's 'time machine'. Launched in 2009, Planck was designed to tease out the faintest relic radiation from the Big Bang – the Cosmic Microwave Background (CMB). The CMB preserves a picture of the Universe as it was about 380 000 years after the Big Bang, and provides details of the initial conditions that led to the Universe we live in today.



↑ Project scientist Jan Tauber sends the final command to Planck from ESA's European Space Operations Centre

The mission began drawing to a close in August, when the satellite was nudged away from its operational orbit around the Sun–Earth 'L2' point, towards a more

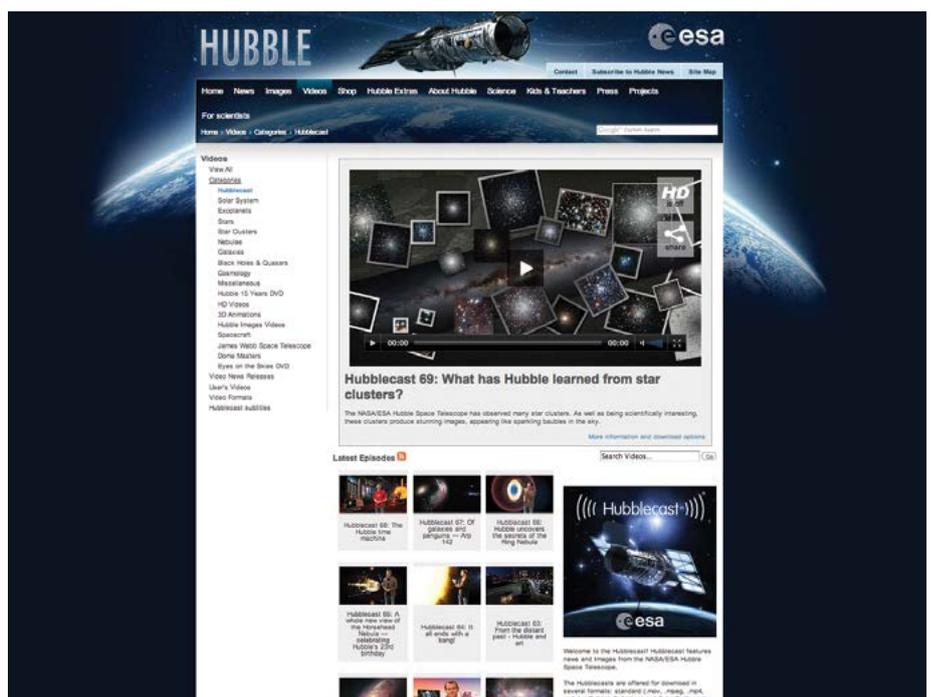
distant long-term stable parking orbit around the Sun. In its last weeks, the spacecraft was prepared for permanent

hibernation, with the closing activities using up all of the remaining fuel and finally switching off the transmitter.

# Award for Hubblecast

The Hubblecast, ESA/Hubble's video podcast series, won a Parsec Award for best 'Fact Behind the Fiction' podcast series this year. The Parsec Awards are a set of annual awards created to recognise excellence in science fiction podcasts and podcast novels.

An international panel of judges considered the Hubblecast to best portray the facts — including the science, history, culture, and mythology — that influence and inspire speculative fiction podcasting. Exploring Hubble's discoveries, stunning images, complex topics within astronomy, the future of the space telescope and more, the Hubblecast releases ten episodes annually.



# Gerst's Blue Dot

ESA astronaut Alexander Gerst is set for a six-month stay on the International Space Station in 2014 as part of Expedition 40/41. His flight came one step closer when his mission patch and name were announced in September.

Alex will be launched from Baikonur cosmodrome in Kazakhstan in May 2014. He will fly on a Soyuz spacecraft to the International Space Station with Russian cosmonaut Maxim Surayev and NASA astronaut Reid Wiseman.

The mission name and logo are inspired by an image of Earth taken by NASA's *Voyager* spacecraft as it travelled six billion kilometres from our planet. US astronomer Carl Sagan

described our faintly visible planet on the photograph as 'a pale blue dot'.

During his 166-day mission, Alex has an extensive scientific programme with around 40 experiments, all designed to improve life on Earth and prepare future exploration projects. His mission also has the theme 'shaping the future' and will include educational activities to inspire the next generation of engineers and scientists.



➤ Logo for the ESA Blue Dot mission



## HEOS-1 anniversary



Launched 45 years ago, on 5 December 1968, the Highly Eccentric Orbit Satellite HEOS-1 was a mission through the boundaries of Earth's protective magnetic 'bubble' (the magnetosphere) into interplanetary space.

←

HEOS-1 launch (NASA)

NASA launched the satellite on a Thor-Delta rocket from Cape Canaveral's Launch Complex 17B for the European Space Research Organisation, a predecessor of ESA. HEOS-1 was the first European space satellite to make a highly eccentric orbit around Earth, in order to monitor the effects of energetic solar events on Earth's

# Luca's return

ESA astronaut Luca Parmitano, Russian commander Fyodor Yurchikhin and NASA astronaut Karen Nyberg returned to Earth in their Soyuz TMA-09M spacecraft on 11 November.

Luca and Karen then travelled to Houston, Texas, where they underwent medical checks before meeting media on 13 November. Luca and his colleagues spent five months on the International Space Station. His Volare mission was under a bilateral agreement with the Italian space agency and NASA. Luca conducted more than 30 scientific experiments, performed two spacewalks and operational tasks as well as helping to maintain the orbital outpost.

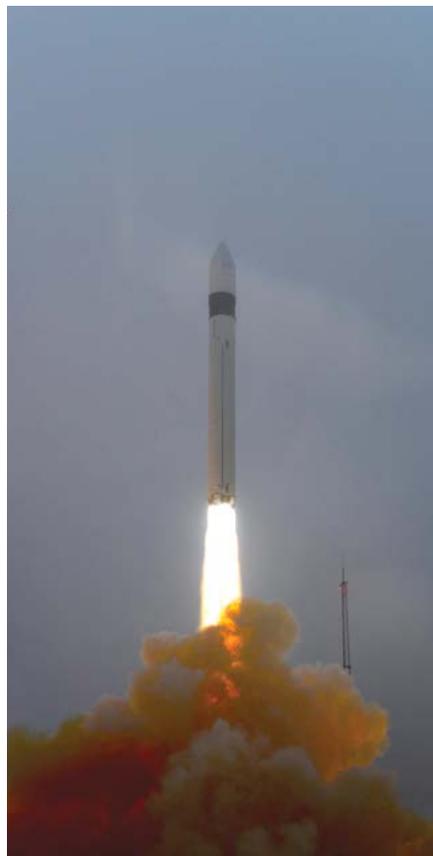


↑ ESA's Luca 'Skywalker' Parmitano feels the force, of gravity that is, on his return to Earth on 11 November

# Swarm launched

ESA's three-satellite Swarm constellation was launched into a near-polar orbit by a Russian Rockot vehicle from the Plesetsk Cosmodrome on 22 November.

For four years, it will monitor Earth's magnetic field, from the depth of our planet's core to the heights of its upper atmosphere. The Swarm satellites will give us unprecedented insights into the complex workings of the magnetic shield that protects our biosphere from charged particles and cosmic radiation. They will perform precise measurements to evaluate its current weakening and understand how it contributes to global change.



Swarm liftoff



The ESRO HEOS-1 team in 1968. A reunion gathering was held at ESTEC in Noordwijk this November for original team members



magnetic environment, the solar wind and cosmic rays.

Pioneering missions such as HEOS-1 (1968–75) and its successor HEOS-2 (1972–74) paved the way for the next generations of ESA missions dedicated to the dynamics of Earth's space environment.

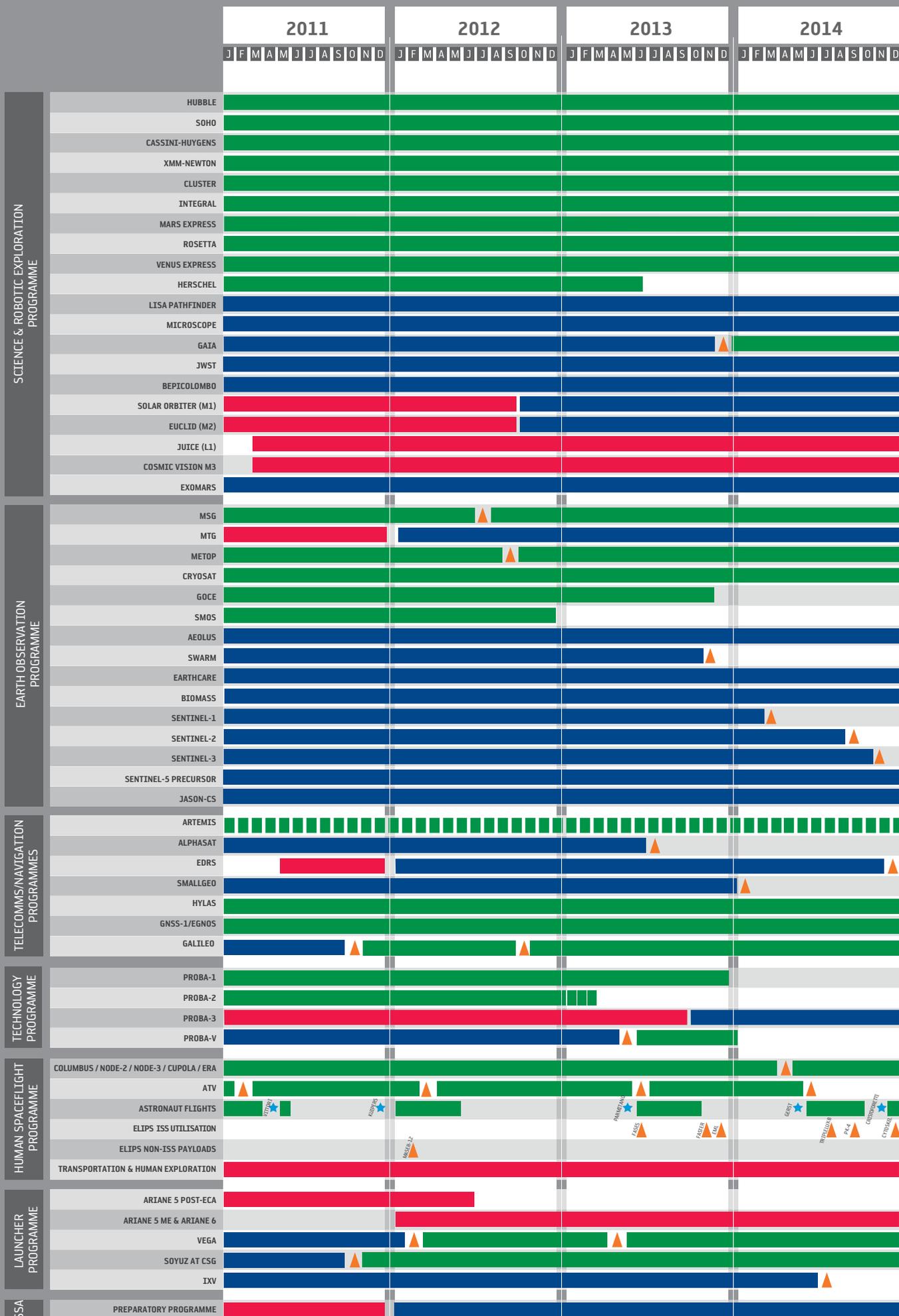
# → PROGRAMMES IN PROGRESS

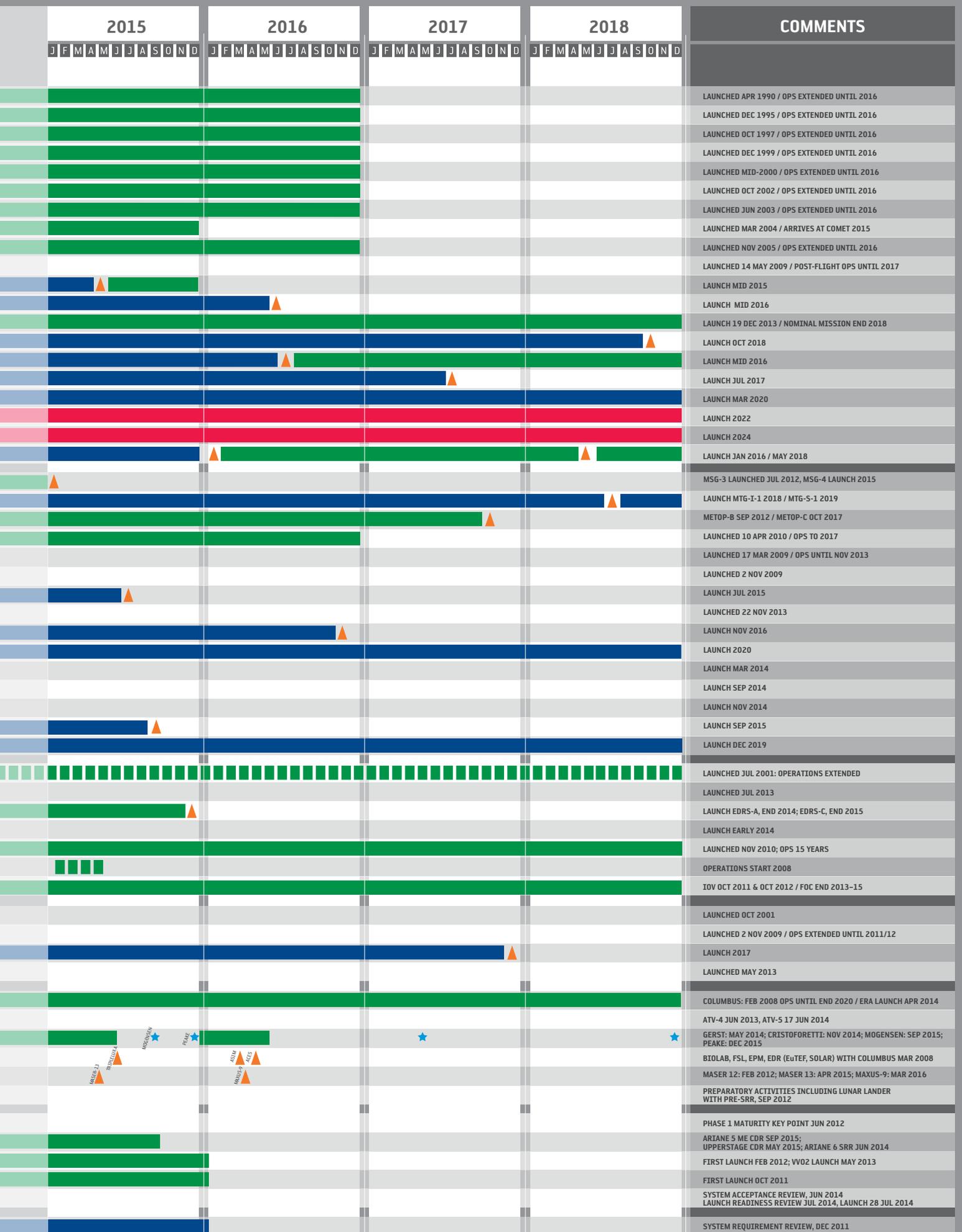
Status at end of October 2013



Gaia's Deployable sunshield Assembly being deployed during testing at Europe's Spaceport in Kourou, French Guiana, on 10 October







## KEY TO ACRONYMS

AM - Avionics Model	ITT - Invitation to Tender
AO - Announcement of Opportunity	LEOP- Launch and Early Orbit Phase
AIT - Assembly, integration and test	MoU- Memorandum of Understanding
AU - Astronomical Unit	PDR - Preliminary Design Review
CDR - Critical Design Review	PFM- Proto-flight Model
CSG - Centre Spatial Guyanais	PLM- Payload Module
EFM - Engineering Functional Model	PRR - Preliminary Requirement Review
ELM - Electrical Model	QM - Qualification Model
EM - Engineering Model	SM - Structural Model
EMC - Electromagnetic compatibility	SRR - System Requirement Review
EQM- Electrical Qualification Model	STM- Structural/Thermal Model
FAR - Flight Acceptance Review	SVM- Service Module
FM - Flight Model	TM - Thermal Model

### → XMM-NEWTON

A report about Integral, XMM-Newton and radio observations of IGR J18245-2452 by A. Papitto *et al* was published in *Nature*. Neutron stars in low-mass binary systems can accrete matter and angular momentum from the companion star and are spun-up to millisecond rotational periods. During the accretion stage bright X-ray emission is observed. When the rate of mass transfer decreases, these binaries host instead a radio millisecond pulsar, whose emission is powered by the neutron star's rotating magnetic field. It has been proposed that a rotation-powered pulsar may temporarily switch on during periods of low mass inflow in some such systems. However, only indirect evidence for this transition had been observed. Papitto reports the detection of accretion-powered, millisecond X-ray pulsations from a neutron star previously seen as a rotation-powered radio pulsar. Within a few days following a month-long X-ray outburst, radio pulses were again detected. This demonstrates the evolutionary link between accretion and rotation-powered millisecond pulsars and that some systems can swing between the two states on very short timescales.

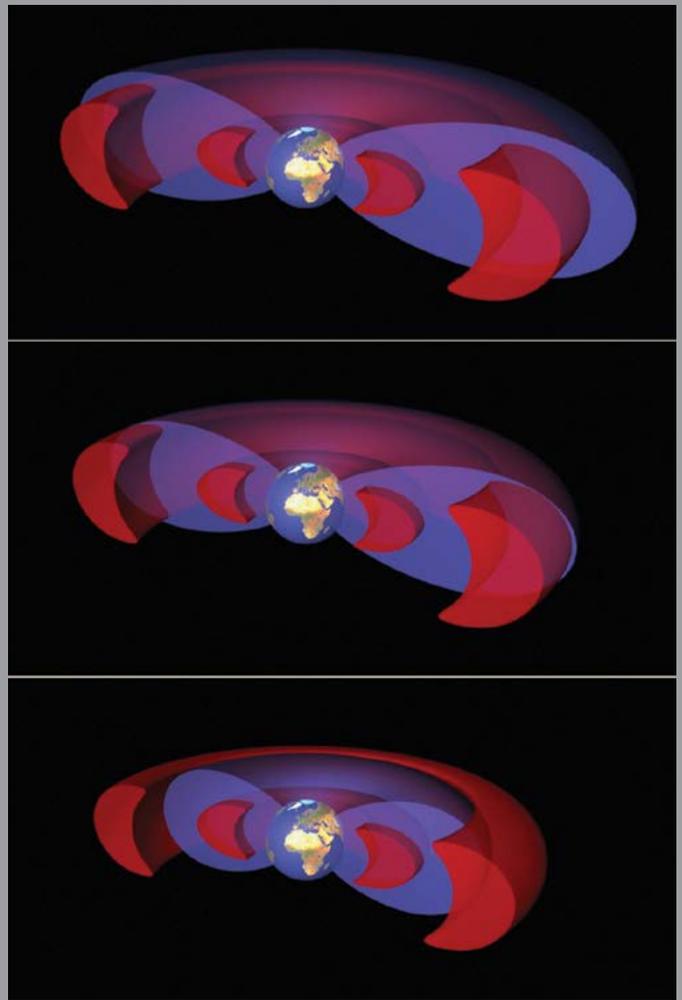
### → CASSINI

A study based on the Cassini Langmuir probe data reports that the electron density in the ionosphere of Titan is consistent with the predictions of the so-called 'Chapman ionisation model', widely used to derive the amount of ionisation by solar irradiation in planetary atmospheres. An interesting aspect at Titan, which could only be measured recently thanks to the long duration of the Cassini mission, is the amount of ionisation resulting from an increased activity of the Sun, reaching a maximum of its 11-year cycles in 2013. Measurements obtained during different Cassini flybys, years apart, allow us to compare the response of Titan's ionosphere when the Sun was at a minimum level of

activity at the beginning of the mission with the conditions imposed by the recent high solar activity. The analysis takes into account the biases introduced by the different flyby geometry and conclude that the amount of ionisation in the ionosphere of Titan is linked to the solar activity level as theoretically predicted.

### → CLUSTER

Near-Earth space is populated by charged particles (electrons and ions) which occupy regions known as the plasmasphere and the Van Allen radiation belts. One of the first scientific breakthroughs made by a spacecraft was the discovery of Earth's radiation belts in 1958. Two concentric, tyre-shaped belts of highly energetic (0.1–10 MeV) electrons and protons, which are trapped by the magnetic field and



The relative locations of the outer boundary of Earth's plasmasphere, the plasmopause (blue) and the van Allen belts (red) changing according to geomagnetic conditions. Top, low geomagnetic activity conditions; middle, medium geomagnetic activity; and bottom, high geomagnetic activity (ESA/C. Carreau)

travel around Earth, were revealed by an experiment on the Explorer 1 satellite. They were named after the instrument's lead scientist, James Van Allen. Over the past decade, the four identical spacecraft of ESA's Cluster mission have made numerous studies of the plasmasphere and the Van Allen radiation belts, and a recent paper has revealed intriguing links between electron populations in these interacting regions. The radiation belts partly overlap with the plasmasphere, a doughnut-shaped region of low-energy charged particles (known as plasma) that co-rotate with Earth. Very Low Frequency radio waves are commonly observed in the plasmasphere, and it is generally accepted that these waves remove energetic electrons, creating a low-density 'slot' region between the two main Van Allen belts.

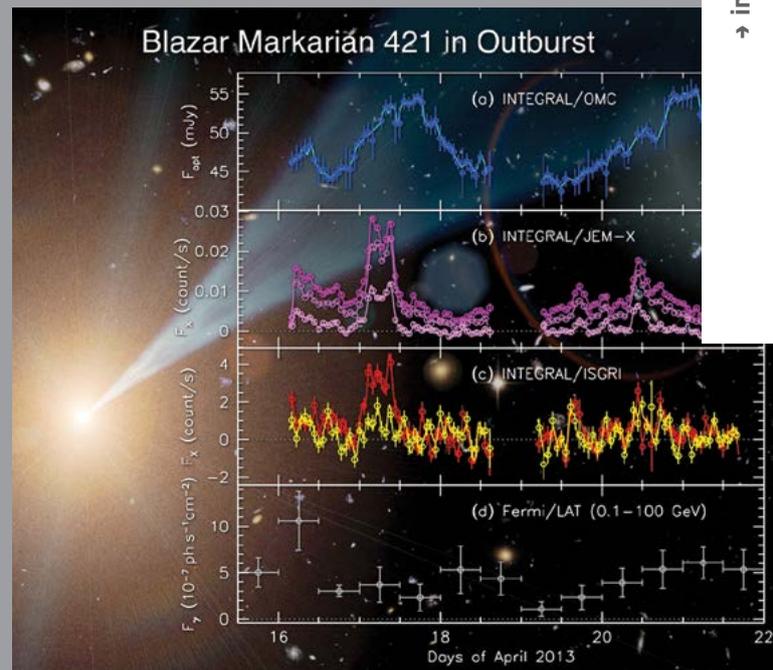
An important new contribution to the story has been made by an international team of physicists, led by Fabien Darrouzet, a researcher at the Belgian Institute for Space Aeronomy in Brussels. Their paper, published in the *Journal of Geophysical Research*, is based on data sent back by one of the quartet of Cluster spacecraft, which has been flying in formation around the Earth since 2000. For long periods, when geomagnetic activity was low, the plasmopause (outer boundary of the plasmasphere) was located toward the more distant part of the outer belt – typically around  $6 R_E$  (Earth radii), but sometimes expanding outward to  $8 R_E$  or beyond. This result was unexpected, since previous studies based on other spacecraft observations indicated a correlation between the position of the inner edge of the outer belt and the position of the plasmopause.

Cluster spacecraft reached their closest separation since launch at 4 km on 19 September. Instruments were put into special modes to study electromagnetic waves in the radiation belts in collaboration with the NASA Van Allen probes. Science and operations planning continues in anticipation for the November launch of ESA's Swarm mission.

## → INTEGRAL

Blazars are the most luminous and variable active galaxies, with spectra extending from the radio wavelengths to the X- and gamma-ray energies. In 2013, Markarian 421, the prototype of this class, underwent a phase of high activity, which culminated in April with the detection of a huge outburst at TeV energies observed by ground-based Cherenkov telescopes. The source was also exceptionally bright at hard X-rays, when a Target of Opportunity observation was done by Integral in April.

Remarkably, the flare maxima at MeV-to-GeV energies are not simultaneous with those occurring at X-rays and in the optical. This fact underlines the complexity of high-energy variability in blazars. The analysis of the correlation of the



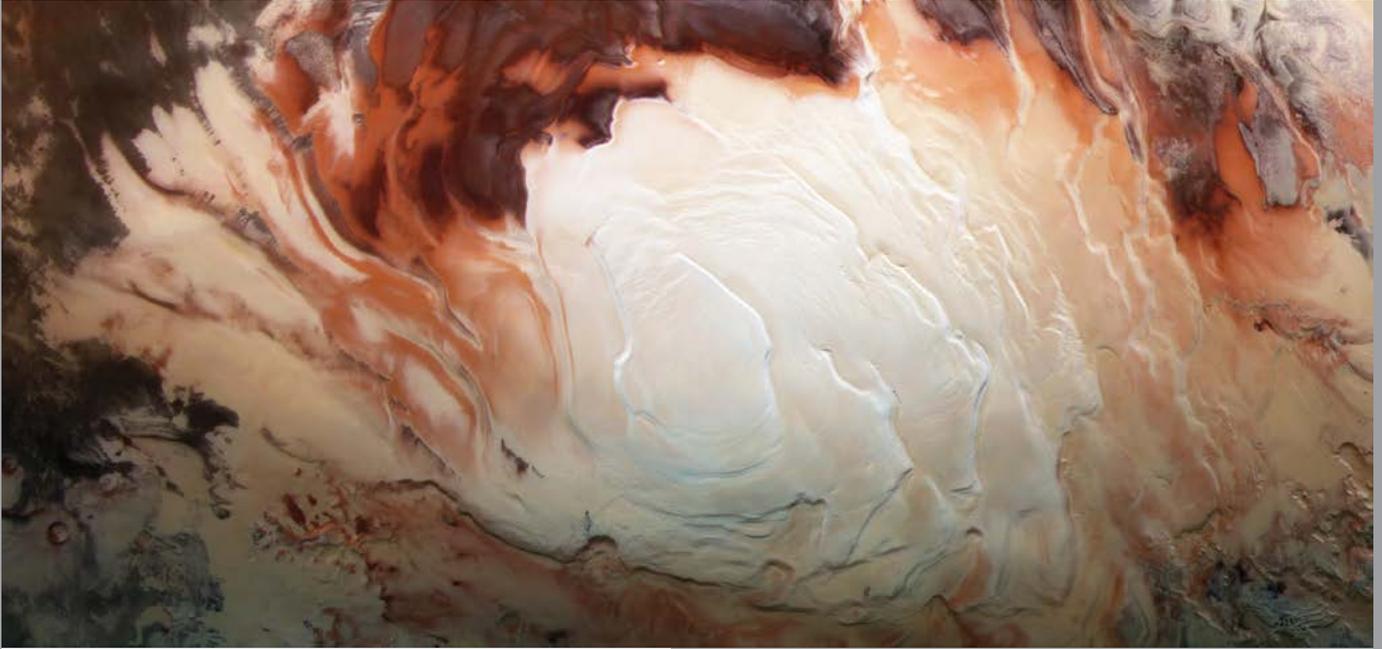
A multi-wavelength outburst of the blazar Markarian 421. Two fully resolved flares were seen with the Integral instruments OMC (a), JEM-X (b) and IBIS/ISGRI (c). The source was observed also with NASA's Fermi satellite (d)

IBIS/ISGRI and JEM-X light curves during the rising part of the first flare indicates that the emission at higher frequencies precedes that at lower frequencies by tens of minutes. The correlation is chromatic, i.e., the lower the radiation frequency the larger its delay with respect to the higher frequencies. This finding puts constraints on the emission model for the multi-wavelength spectrum, which is essentially of non-thermal nature, with the synchrotron mechanism dominating at optical to X-ray energies, and self-Compton scattering being responsible for the MeV-to-TeV gamma-rays.

## → MARS EXPRESS

Spacecraft and payload overall health remains excellent. Discussions have started within the project to review and evaluate the risks associated with the very close flyby of Comet Siding-Spring on 19 October 2014. The comet is expected to pass at a distance of about 130 000 km, a third of the distance between Earth and the Moon. In the meantime, and to get prepared for such event, Mars Express is observing comet ISON around its closest approach to Mars in early October.

A recent study (Withers and Pratt, *Icarus*, 2013) using Mars Express radio-science data has shown that the dust storms not only substantially affect the properties of the lower atmosphere of Mars, but also its upper atmosphere, at



A recent image taken by the High-Resolution Stereo Camera on Mars Express of the south pole of Mars in infrared, green, and blue light (ESA/DLR/FU Berlin/G. Neukum/F. Jansen)

heights above 80 km. In particular, the upper atmospheric regions affected by even a small dust event can include nearly all latitudes. Also, atmospheric temperatures can be affected by dust storms at altitudes as high as 160 km, which is very far from the storms on the surface. Finally, the atmospheric densities can vary by a factor of 10 during a storm. These events are a very peculiar characteristic of the Red Planet, and represent a serious concern for Mars surface missions, especially during the atmospheric entry and descent.

## → HERSCHEL

Herschel has moved into the 'post-operations phase'. In the last months, a new version of the Herschel Science Archive (HSA) became operational, and its entire contents have been reprocessed. The new version of HSA enables data products (such as images and spectra) provided by Herschel users to be ingested and provided to the entire astronomical community, enhancing the value of Herschel and its data.

The Orion A molecular cloud as seen by Herschel this year. The Orion Nebula is located within the central bright region of this scene, where massive star formation is most intense. Cooler gas and dust is seen in red and yellow, with point-like sources the seeds of new stars (ESA/Herschel/Ph. André, D. Polychroni, A. Roy, V. Könyves, N. Schneider for the Gould Belt survey)



A new version of the data processing software (HIPE) was released. Data processing workshops have been held on both sides of the Atlantic, with increasing numbers of ‘attendees’ participating at a distance via the internet.

Since the ‘last telecommand’ event on 17 June, when Herschel was turned off, ESA is no longer in a position to track the spacecraft, but interestingly it has continued to be tracked optically. What may become the last observation of Herschel for many years took place on 24 October. These observations of Herschel’s apparent location in the sky help to refine our knowledge of the orbit of Herschel around the Sun.

## → PLANCK

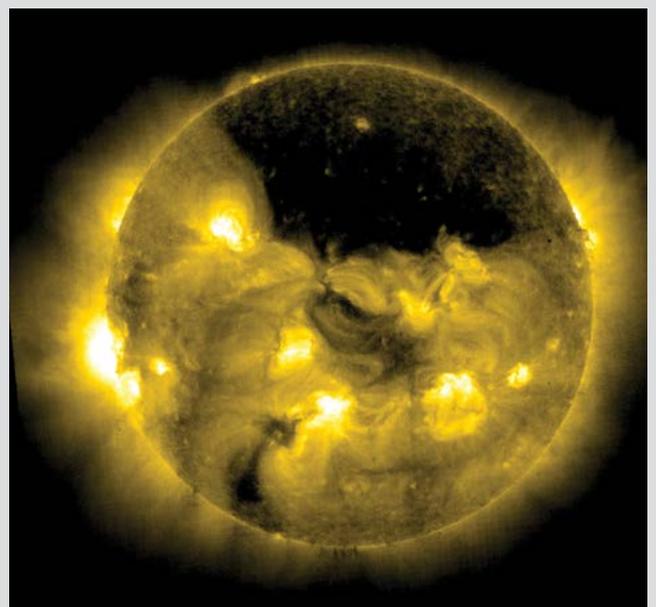
Planck is approaching the end of its life. Having gathered five full sky surveys with its full complement of observations, and an additional three surveys with the Low Frequency Instrument, the Planck satellite will be switched off on 23 October. Planck was originally designed to carry out two full-sky surveys, but the excellent performance of its payload allowed it to continue observing the sky much longer. The mission was extended three times. The long life of Planck, enabled by the impressive in-flight performance of its payload, has significantly increased its scientific return.

## → SOHO

In mid-July an extensive coronal hole hovered over the Sun’s north pole. Coronal holes are dark, low-density regions of the Sun’s outermost atmosphere, the corona. They contain little solar material, have lower temperatures, and therefore appear much darker than their surroundings. Coronal holes are important to our understanding of space weather, because they are the source of high-speed wind streams. They are a typical feature of the Sun, though they appear at different places and with varying frequency at different times of the Sun’s activity cycle. The activity cycle is still ramping up toward what is known as ‘solar maximum’, currently predicted for late 2013. This particular coronal hole reminds us of the large, polar coronal holes often seen during solar minimum conditions.

## → GAIA

All activities on the spacecraft have been completed in Europe. The Flight Acceptance Review took place on 22 July, authorising the shipment of Gaia to the launch centre in French Guiana. The launch campaign started on 22 August with the arrival of the spacecraft; the major highlight was the last deployment of the sunshield before launch.



SOHO/EIT image of the Sun’s corona in extreme ultraviolet light showing plasma at about 2000 000 °C

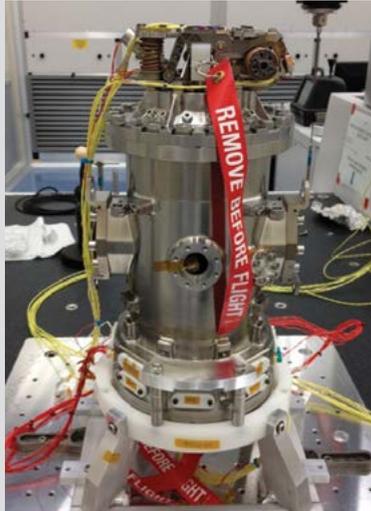
A serious anomaly on a component, discovered on another mission, was considered as a potential risk to Gaia. It was decided to retrofit the two affected transponders as a mitigation action. Activities on the spacecraft were suspended and will be resumed in November with the integration of the two retrofitted units on the SVM. After that, fuelling of the spacecraft and combined operations with the launcher will start.

Operations and Science Ground Segments activity is now focused on the simulations of the LEOP and commissioning. Activities with Arianespace progressed, with three-stage Soyuz launcher in the integration hall. First and second stages are already mated, the Fregat upper stage is ready and fuelled. The payload adaptor and the fairing are also ready.



The Gaia spacecraft after last deployment test of the sunshield

LISA Pathfinder Inertial Sensor Head Qualification Model on its integration jig during qualification tests at CGS (IT). On the top and bottom (not visible) sit the single-shot launch-lock mechanisms in safe and unarmed condition



## → LISA PATHFINDER

The Science Module had earlier been taken out of storage in order to fit panels kitted with the various components of the cold-gas micro-propulsion system. An integrated system test on the Science Module, the Propulsion Module and the solar array showed the good health of the system. Astrium (UK) has initiated the Science Module retrofit to accommodate the cold-gas micro-propulsion equipment.

The gold-coated flight units of the new-design Electrode Housing have been delivered. These are the last flight items needed to start the integration on the two Inertial Sensor Head (ISH) flight units. Concurrently, the ISH Engineering & Qualification Model was environmentally qualified and functionally tested. Among other functional tests, the

launch-lock mechanism was operated about 60 times. This qualification is a significant milestone closing the issue of holding the delicate, 2 kg Au-Pt test masses safe during ground operations and launch, while allowing their in-orbit release into drag-free flight conditions.

Imperial College London (UK) delivered the Ultra-violet Lamp Unit (ULU) flight model. The ULU emits ultraviolet light into the ISH via vacuum-tight fibre injectors with the purpose of transferring electrical charges – without physical contact – from the free-floating test mass to and from the surrounding electrodes. Launch will be on a Vega as one of the VERTA flights.

## → BEPICOLOMBO

The mechanical/electrical integration of the first platform and payload units took place for the Mercury Planetary Orbiter (MPO) PFM spacecraft, followed by the individual functional tests. The Mercury Transfer Module (MTM) PFM module was delivered to Thales Alenia Space Italy, Turin, in September and prepared for spacecraft harness integration. Following a confidence test, the solar cell FMs have been ordered. Difficulties continue on the manufacturing of the MTM solar array structure that are currently being sorted out by a dedicated test programme.

The material problems on the MPO Solar Array drive mechanisms, solar electrical propulsion thrusters and printed circuit board technology on power units, were resolved and mitigation measures were implemented.

To keep the MPO thermal test on schedule, some scientific payload as well as a limited number of spacecraft items will



BepiColombo Mercury Transfer Module during system integration and test (Thales Alenia Space Italy)

be substituted by qualification models because of the late availability of FM equipment. These units will be exchanged for FMs prior to the mechanical test campaign.

The mechanical test campaign for the Mercury Magnetospheric Orbiter is planned for November, followed by a move of the spacecraft to the vibration facility at JAXA premises. The HSS3+, the new low-shock fairing separation system of the Ariane 5, was demonstrated on the ATV *Albert Einstein* launch, and is now the baseline. This removes some remaining concerns on the shock environment for some payload units. The schedule remains under pressure due to critical equipment deliveries; mitigation actions have been implemented to achieve the July 2016 launch readiness date with margin in the AIT schedule.

## → MICROSCOPE

The manufacturing of the ESA-provided cold-gas micro-propulsion system is progressing. The delivery of the electronic controller EQM together with two micro-thruster QMs is planned for early 2014.

## → EXOMARS

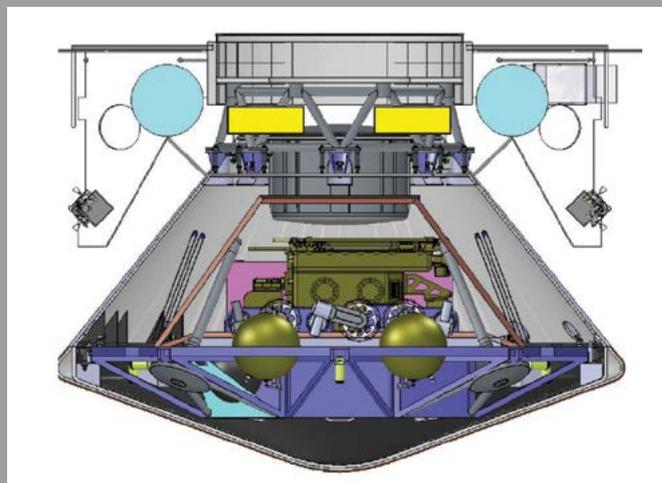
The ESA/Roscosmos cooperation is fully endorsed with signed documents to direct the management of the programme. Progress on hardware for the 2016 Trace Gas Orbiter (TGO) and Entry, Descent and Landing Demonstrator Module (EDM) is good and nearing completion at OHB. The Mechanical, Thermal and Propulsion Module will soon be delivered to Thales Alenia Space France. EDM SM tests are complete and the SM is being prepared for use in testing planetary protection procedures at Thales. For both modules, the avionics test benches are proceeding with software testing in a progressive versioning approach. TGO instrument development is proceeding.

The SRR for the 2018 mission was completed with a combined ESA/Roscosmos team reviewing the contractors from Europe (Thales Alenia Space Italy, ASU, OHB and other sub-contractors) and from Russia (Lavochkin, Tsenki, Khrunichev and other organisations).

The PDR for the Rover Analytical Design Laboratory (ALD) and the Rover vehicle continued. The ALD PDR included principal investigators and lead funding agencies to ensure a common understanding and a common goal for achieving the review objectives. In light of financial restrictions affecting some of instrument contributors, an analysis of the completeness of the qualification of the ALD with the instruments will be necessary. Once this is completed, a Rover Instrument Steering Committee

meeting will discuss in November any concomitant effects on the objectives of the science.

The 2016 mission Ground Segment Design Review began and the development phase of the Rover Operations Control Centre for the 2018 mission was restarted.



Cutaway schematic of the ExoMars 2018 mission spacecraft

## → SOLAR ORBITER

The build-up of industrial consortia is near completion and only a few procurement activities are still ongoing. Design reviews were held for a number of units. The Engineering Test Bench (i.e. spacecraft EM) campaign has started. Manufacturing for several units has started, including the Onboard Computer FM and the Instrument Boom EQM. Some changes of the software in the Solid State Mass Memory unit (both to correct identified deficiencies and to improve data return) are being coordinated with BepiColombo (very similar unit). The schedule of the solar generator continues to be worrisome. Solar Orbiter depends on BepiColombo technology developments for the solar generator that are not yet completed.

Further investigations and tests of several high-temperature surface-treated materials under simultaneous high temperature and high solar flux continue. The facility commissioned to use one of these technologies has successfully produced blackened titanium sheets, which are being integrated in the front layer of the Heat Shield STM. In addition, more encouraging results were received from an 8000-hour ultraviolet test of a white coating for possible applications elsewhere on the spacecraft.

Instrument CDRs are well under way. The SoloHI CDR, led by NASA with ESA participation, has been completed. The SPICE, PHI and MAG CDRs are ongoing. The METIS coronagraph



Solar Orbiter  
Remote  
Interface Unit  
Engineering  
and  
Qualification  
Model

PDR will be rerun, following the restart of the development. Development of both Science and Operational Ground Segments is on schedule. The US launch vehicle interface technical definition with NASA is progressing.

The difficulties of the schedule of the solar array development and the late start of the METIS instrument development and its corresponding late delivery have made the launch date of January 2017 not achievable anymore. A new date of July 2017 has been selected as the next opportunity.

## → JAMES WEBB SPACE TELESCOPE

All four flight instruments have been delivered, including NIRSpec from ESA. The first Integrated Science Instrument Module (ISIM) cryogenic vacuum test, including the Mid-Infrared Instrument (MIRI) and the Fine Guidance Sensor, is ongoing. The NIRSpec FM acceptance test campaign was completed with the last cryo test after the vibration and acoustic tests. The NIRSpec Acceptance/Pre-Shipment Review concluded on 19 September. NIRSpec was shipped to NASA's Goddard Space Flight Center.

Incoming inspection of the NIRSpec flight instrument at Goddard Space Flight Center (NASA)



NASA completed the manufacturing of the first new spare micro-shutter array. Testing of the new NIRSpec detector arrays started and two flight candidates have already been identified. The overall NIRSpec recovery plan anticipates the exchange of the micro-shutter assembly by the end of 2014, at the same time as the detector is being exchanged. This will take place before the ISIM vibration test and final cryo performance test.

The MIRI STM was upgraded to a Thermal Optical Model and shipped to JPL. Here it will be used for the upcoming end-to-end verification of the MIRI cooler system.

## → EUCLID

The PLM Phase-B2 activities began in December 2012 under direct ESA contract with Astrium SAS. In July, the prime contract began with Thales Alenia Space Italy. The PLM SRR is taking place. In parallel, early procurement of long-lead items, such as telescope silicon carbide structures, the dichroic plate element, the mirrors and the secondary mirror mechanism, the mirror polishing and others has started. On the SVM, the prime contractor is preparing the System Requirements Documents data package and here too the procurement of long-lead items has started: in particular the Reaction Wheels characterisation and the novel Fine Guidance Sensor.

Procurement of the Near Infrared Spectro-Photometer (NISP) detectors is proceeding. Teledyne Imaging Sensors (TIS) of Camarillo (US) has produced all the necessary detectors for the Evaluation and Qualification phase and the relevant tests are ongoing in TIS, NASA and the Euclid Consortium facilities. Procurement of the CCD detectors for the Visible Imager (VIS) is also proceeding with e2v (UK). Many STM devices have been delivered and the QM/FM production of the various parts is proceeding according to schedule.

Phase-B2 for VIS, NISP and the Science Ground Segment developed by the Euclid Consortium is also proceeding. The VIS and NISP SRR were held. The Science Ground Segment also passed a Preliminary Requirements Review. A contract with Arianespace to support the launcher (Soyuz at CSG) interface activities until system CDR is currently running.

## → ADM-AEOLUS

The first laser transmitter FM passed the operational qualification in vacuum. Satellite tests carried out in July and August demonstrated very low micro-vibration disturbances in the laser transmitter with the newly installed reaction wheel dampers. The VESTA test validated the compatibility of satellite equipment with Vega launcher shock environment.

The value of this mission to weather forecasts as well as climate research has been corroborated by the second independent scientific Impact Study, conducted by a consortium led by KNMI. After a period of hibernation, the development of payload data ground segment has been resumed.

## → SWARM

The satellites were transported to the launch site at Plesetsk, Russia. This milestone paves the way of the launch campaign that will last nearly two months. An improvement was made on the three Langmuir Probes. The surface coating of the probe sensors was reworked with gold instead of the classical coating of titanium nitride. The launch date of Swarm was 14 November (subsequently updated to 22 November).

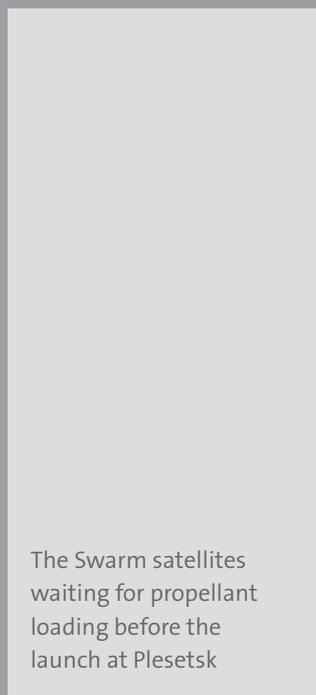
## → EARTH CARE

Following propellant tank integration in the PFM, Base-Platform activities are proceeding at Astrium Ltd with the assembly of the spacecraft Reaction Control Subsystem. At Astrium GmbH, the spacecraft ELM progressed with the exercising of the second integration version of the central software.

Development of the challenging payload is proceeding. Initial performance tests performed on the ATLID transmitter amplifier qualification unit produced by Quantel had satisfactory results. In parallel, the Master Oscillator assembly was nearing completion at Selex-ES. Overall, the detailed design phase of the major ATLID subsystems progressed towards their respective CDRs.



ADM-Aeolus at Intespace after the release of the fairing of Vega



The Swarm satellites waiting for propellant loading before the launch at Plesetsk

Assembly of the Broadband Radiometer PFM telescopes began at RAL with particular focus on alignment. The Multi-Spectral Instrument ECM test campaign was temporarily delayed because of an issue affecting its dichroic and filter assembly. In Japan, Cloud Profiling Radar activities are proceeding.

## → METEOSAT

### Meteosat-8/MSG-1

Meteosat-8 is located at 3.9°E longitude and operating normally.

### Meteosat-9/MSG-2

The satellite is in good health and performance is excellent.

### Meteosat-10/MSG-3

Meteosat-10 is now Eumetsat's operational satellite located at 0° longitude, performing the full-disc mission (one image every 15 minutes in 12 spectral channels), as well as the data collection, data distribution and search and rescue missions.

## → MSG-4

Visual inspection of SEVIRI before reintegration of the Scan Assembly unit revealed a delamination of the nickel coating of the Neodyme magnets from the Calibration Unit (CALU) motor. Further investigation established that the three available spare motors were also affected by the same issue. Procurement of new improved magnets is under way. As a result, the delivery of the repaired SEVIRI instrument to Thales Alenia Space Cannes, originally planned for September, is now postponed until January 2014. Recovery actions are being studied to keep MSG-4 launch at the beginning of 2015.

## → MTG

After closure of the MTG-I PDR in May, the FCI and IRS instrument PDRs were closed in July and September respectively. The subsystem and equipment development PDR is now well under way. In Best Practice Procurement activities, 95% (by value) of the subcontractors have been selected. The predicted Flight Acceptance Reviews for MTG-I and MTG-S protoflight satellites are now July 2018 and 2020 respectively.

## → METOP

### MetOp-A

The satellite continues to perform very well. MetOp-A will be operated in a dual operations scenario with MetOp-B initially until 2018 or the completion of MetOp-C calibration and validation.

### MetOp-B

MetOp-B is the operational satellite as of 24 April.

### MetOp-C

The satellite is stored in three separated modules (platform, payload, solar array). Some equipment and instruments have been dismantled for repair or calibration. Annual reactivation and tests were performed. An aging review took place and all actions were agreed with industry. The launch is planned with a Soyuz-Fregat from French Guiana; the launch slot starts in October 2017. If needed, the satellite can be readied in a short time, between 14 and 18 months after request.

## → SENTINEL-1

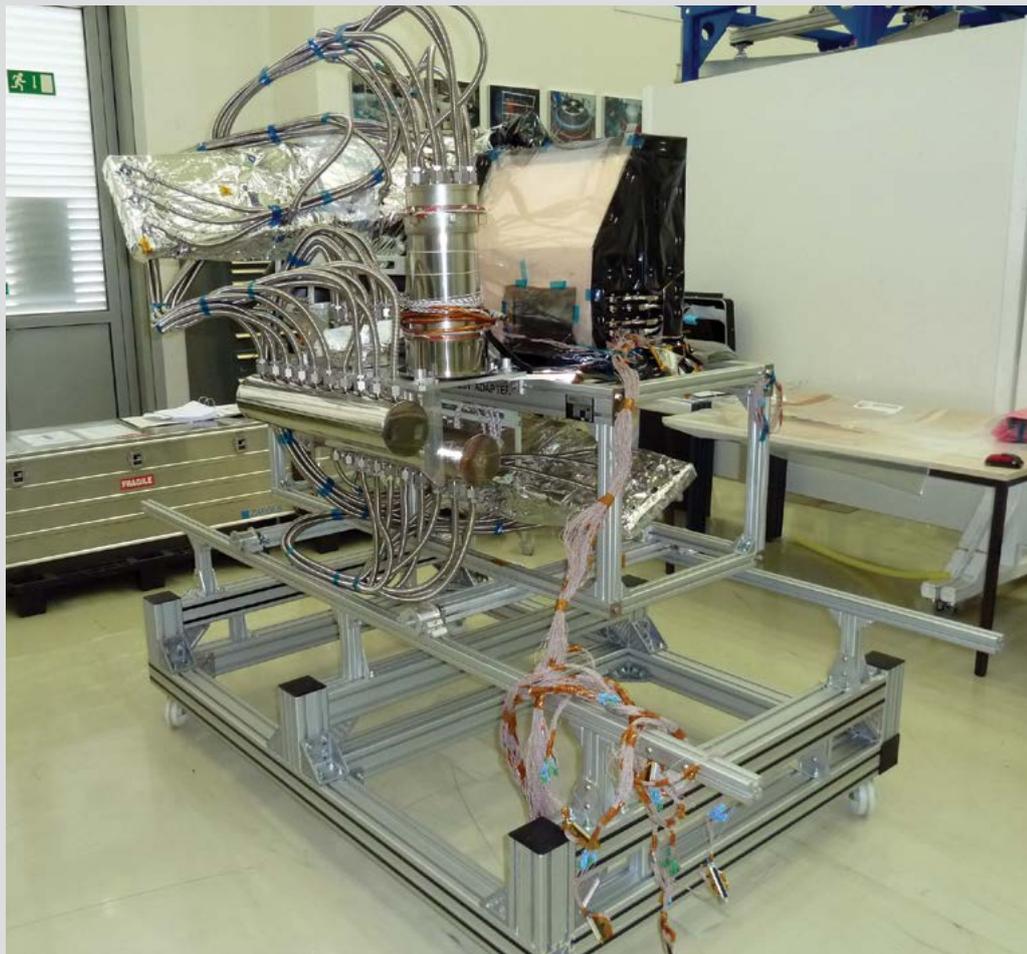
Sentinel-1A completed its Thermal Vacuum and Thermal Balance tests at Thales Alenia Space Italy. A series of System Verification Tests, commanded from ESOC, was performed to demonstrate the full compatibility with the Flight Operations Segment. Integration of the Synthetic Aperture Radar (SAR) antenna will take place in October, followed by the radiofrequency compatibility tests at the Thales Alenia Space in Cannes. The spacecraft will be integrated with the solar array wings prior to the mechanical vibration tests, the last stage of the Sentinel-1A environmental test campaign. An anomaly found during the qualification campaign obliged the Optical Communication Payload supplier (TESAT) to modify the Sentinel-1A flight unit. Launcher activities are progressing towards the first opportunity provided by Arianespace in March 2014 from Kourou.

## → SENTINEL-2

The payload instrument PFM is fully integrated at Astrium, Toulouse, and a VNIR and SWIR performance



Sentinel-2 Multispectral instrument Protoflight Model (Astrium SAS)



Sentinel-3 Microwave Radiometer Protoflight Model being prepared for calibration with the installation of the cold loads in the thermal chamber at IABG (EADS/CASA)

characterisation test campaign revealed excellent radiometric, geometric and spectral stability performance. Following the repair of six large inserts that needed mechanical reinforcement, the instrument will be functionally tested and undergo mechanical and thermal qualification before integration with the satellite in 2014.

Several tests were performed by Astrium on critical systems such as payload data handling, communications, and Attitude and Orbit Control. These complex tests already demonstrate the robustness of the onboard software and the performance of the satellite control algorithms that will provide attitude stability in orbit. In the meantime, the Sentinel-2B payload instrument and platform are under integration.

The Sentinel-2 Ground Segment PDR is ongoing, with an emphasis on ground segment system tests required before launch and Sentinel-2 in-orbit commissioning. NASA is supporting the characterisation the Sentinel-2 solar diffuser. These calibration activities pave the way to a better interoperability between European and US land-observing missions for the benefit of Sentinel-2 user communities.

## → SENTINEL-3

Sentinel-3A is ready to start instrument integration and satellite-level testing. The full topography payload, including DORIS (Doppler Orbitography and Radio positioning Integrated by Satellite), the SAR Radar Altimeter and Microwave Radiometer, has been delivered to the prime contractor after completing the protoflight test campaign at equipment level. The instruments are being integrated ready for their functional testing on the satellite.

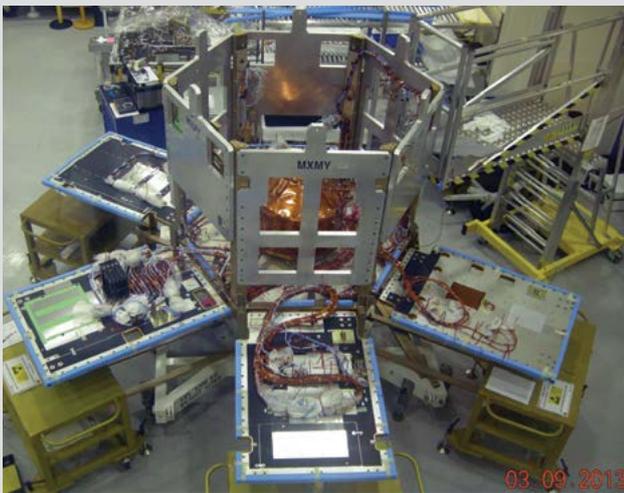
The delivery of all sub-assemblies for the optical payload is ongoing. Both OLCI (Ocean and Land Colour Instrument) and the SLSTR (Sea and Land Surface Temperature Radiometer) started integration in October, leading to a readiness for integration at satellite level in 2014. Integration of the Sentinel-3B platform was completed.

## → SENTINEL-4

Two subsystems PDRs were held: the Optical Modules Subsystem in July and the Detectors subsystem in

September. Ground segment activities continued in coordination with Eumetsat with focus on the definition of the Instrument Data Processing Facility and the preparation of the ITT for Level-2 data prototype and operational processor. The system PDR is planned for November.

## → SENTINEL-5 PRECURSOR



Sentinel-5 Precursor platform integration at Stevenage (Astrium Ltd)

The satellite/system CDR was concluded in July. Spacecraft integration activities continue at Astrium Ltd, Stevenage, on track for a fully mechanically integrated platform, apart from thermal blankets and solar array, by the year end.

The TROPOspheric Monitoring Instrument (TROPOMI) payload EFM is being readied for EMC testing. AIT started on the FM with the integration of main housing parts and telescope mirrors of the UVN Optical Bench module at TNO. A fully integrated SWIR was ready at SSTL in October for thermal vacuum test at MSSL. The main TROPOMI flight structure and all flight electrical units plus EGSE will be delivered to Leiden within this year.

Negotiations for an extension to the current basic Payload Data Ground Segment to full operational status have begun with DLR. Discussions are planned with NASA/NOAA on collaboration between Sentinel-5 Precursor and Suomi-NPP for receipt of cloud data from the Visible Infrared Imaging Radiometer Suite for enhancement primarily of the methane product from SWIR.

## → JASON-CS

Measurement of the ocean by altimeters carried on satellites was first proposed in 1969 and since then many



Seen on 8 November, only days before launch, the three Swarm satellites sit just centimetres apart on their tailor-made launch adapter. This novel system keeps the satellites upright within the fairing during launch and allows them to be injected simultaneously into orbit

missions have been flown which utilise this type of measurement. Since 1991, with the launch of ERS-1, ESA has maintained a continuous series of altimeters operating in orbit with the most recent launch being CryoSat-2 in 2010. These ESA missions have been intended for broader application than oceanography alone and, indeed, CryoSat-2 is primarily a mission to measure the Earth's ice in polar regions.

In parallel to these and other missions that have operated in high-inclination Sun-synchronous orbits, there has been a series of missions dedicated to oceanography, operating in a mid-inclination orbit. The forerunner was TOPEX/Poseidon, a NASA/CNES mission, and this has been succeeded by the Jason-1 and -2 satellites with Jason-3 due to launch in 2015. The combination of high-inclination and mid-inclination missions is able to provide optimal space-time sampling and serve operational ocean forecasting. This operational system will be ensured into the future with the launch of the Sentinel-3 satellites to provide the high-inclination component, and Jason-CS (for Continuity Service) to provide the mid-inclination part. In order to ensure continuity into the 2030s, two Jason-CS satellites will be built.

The Jason-CS payload consists of a set of instruments dedicated to the primary ocean topography measurement, and another instrument that will make measurements of atmospheric composition for operational meteorology. The height above the ocean surface will be measured by the Poseidon-4 radar altimeter, which is a significant evolution of the SRAL altimeter on Sentinel-3. The altimeter measurements need to be corrected to compensate for the excess path delay caused by water vapour in the atmosphere; this is measured by the Advanced Microwave Radiometer, AMR-C (C indicating that this enhanced version of the instrument is upgraded to climate quality), and a new High Resolution Microwave Radiometer operating at high frequencies is also under investigation.

To convert the altimeter measurements into surface elevation it is necessary to have highly precise knowledge of the orbit. This is enabled by tracking measurements with several instruments: a GNSS receiver which uses navigation signals from satellites such as GPS, a DORIS receiver which uses signals from a network of ground beacons and a laser retro-reflector array (LRA) which enables ground-based laser tracking stations to make ranging measurements.

The secondary atmospheric mission is achieved with a GPS Radio-occultation receiver called TriG. This, together with the AMR-C and LRA is built by JPL, under NOAA funding as part of the US contribution to the mission. NOAA also provides the launcher and tracking station support.

The satellite is based on CryoSat, making use of the latter's design features optimised for orbits with constantly changing local solar time. Inevitably some changes are necessary to accommodate more payload instruments, and a further change is required to provide a very significant propulsion capability: Jason-CS's orbit is at 1336 km and to remove it from the protected zone extending from Earth's surface up to 2000 km altitude, at the end of its life, requires substantial amounts of fuel.

The ground segment will be developed by Eumetsat. Because Jason-CS is part of the GMES Copernicus programme, the EU will also be contributing funding to the mission, including the operations. CNES, which has been centrally involved in the earlier TOPEX/Poseidon and Jason series, also contributes to the mission. Phase-B2 began in mid-2013, planned to last until mid-2014. Assuming that all of the partner agencies are able to secure funding as planned, the first satellite will be ready for launch towards the end of 2019, with the second about five years later.

## → EDRS

EDRS consists of two independent nodes in geostationary orbit – EDRS-A and EDRS-C – as well as a dedicated ground segment.

The PDR was held in October 2012. The CDR, however, will be held separately for the EDRS-A and EDRS-C missions because of their different development schedules and launch dates.

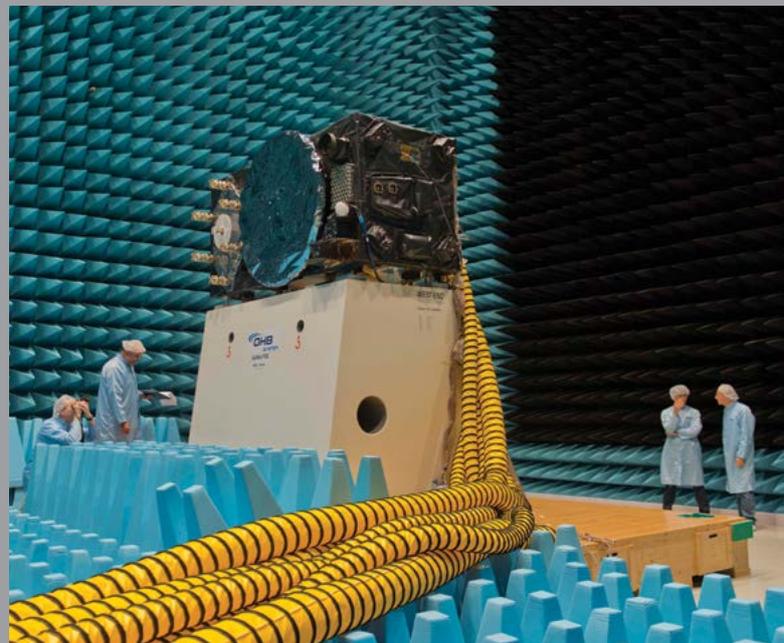
The EDRS-A payload – comprising a Laser Communication Terminal and a Ka-band inter-satellite link – will be carried on Eutelsat's EB9B satellite, built by Astrium and positioned at 9°E. This first of the two EDRS nodes will be launched in early 2015.

The EDRS-A CDR has started with the completion of the payload CDR in June, and the space segment CDR in July. The mission CDR began in October, and will conclude in January 2014. Payload integration has started at Astrium Ltd, Portsmouth, and the first payload integration activities at satellite level will start in February 2014.

The second EDRS node, carrying the EDRS-C payload which includes a second LCT, will be launched into its geostationary slot at 31°E in the first half of 2016 on a dedicated satellite built by OHB based on the SmallGEO platform; it will also carry Avanti's Hylas-3 as a 'hosted payload'. The CDR started with the payload CDR in October.

## → SMALLGEO

Repeater Module testing is being completed at TESAT, including the Redsat elements. Delivery to OHB for integration on the Platform Module is planned for the end of December. The PFM first Functional Performance Tests are progressing



The first flight model Galileo Full Operational Capability satellite, FM1, being prepared for testing inside the Maxwell electromagnetic test facility at ESTEC's Test Centre in August



ESA astronaut Luca Parmitano works inside the ISS to install the Centreline Berthing Camera System in preparation for the arrival of the Cygnus cargo spacecraft in September (ESA/NASA)

well at OHB. The Propulsion Module was shipped from AVIO to OHB in September. The Electrical Propulsion Sub-system has been integrated on the Propulsion Module and tests are in progress. The Qualification Acceptance Review preparation continues with Subsystem Qualification Reviews.

## → ADAPTED ARIANE 5 ME & ARIANE 6

The Frame Contract covering the three work orders were negotiated and signed between July and September.

### Adapted Ariane 5 ME

Besides the Work Order 1 for Adapted Ariane 5 ME specific activities, fairing XL industrialisation activities started in July. The Tender Evaluation Board for Ariane 5 ME ground segment took place in June. Negotiations took place during summer and the contract is ready for notification in October. The first contractual coverage for Phase-C implementation of the cryogenic test facility P5.2 was granted in August.

### Upper Stage and Commonalities

The Work Order 2 related to Common Upper Stage specific activities was signed in July. Both work orders (1 and 2) include a Verification Key Point in December to check the status with respect to mission requirements. The commonalities assessment activities were completed. The generation of an Adapted Ariane 5 ME/Ariane 6 Integrated Development Plan was issued and the activities listed in this document will be implemented through Work Orders 1 and 2. The final areas of commonalities are: Vinci and Functional Propulsive System, the fairing, the engine thrust frame, the thrust vectoring and actuation system, some buildings located at Bremen, some jigs and tools. The Vinci M5 campaign is progressing. Tests 1 and 2 took place

in September, test 3 is planned for October (14 tests are planned in total, the last scheduled for April 2014). The Final Post-test Review is planned for May 2014.

### Ariane 6

Work Order 3 for Ariane 6 specific activities was signed. This covers Phase-A and selected Phase-B1 activities, and in particular a first Design Analysis Cycle (DAC-1) with technical activities up to December. The Ariane 6 Launch System Preliminary Requirements Review, marking the end of Phase-A, began in October. The Tender Evaluation Board for the Ariane 6 ground segment took place in July.

## → VEGA

Both on the launch vehicle and ground segment, activities are focusing on the close-out of main development contracts, planned by the end of 2013. The generic qualification tests the Flight Programme Software for mission type 2 were completed. The Vega generic qualification loop started and Qualification Review is expected in January 2014. The Vega Consolidation and Evolution Preparation (VECEP) programme Phase-0 was completed and Request for Quotation was issued to Industry. Activities are focused on analyses of synergies between Ariane 6 and VECEP.

## → IXV

Development, qualification, integration and acceptance activities for the IXV flight and ground segments are progressing, including preparation of the Vega launch campaign following the completion of the Preliminary Mission Analysis Review.



At the window of Cupola, Luca Parmitano uses a laser rangefinder during rendezvous, capture and docking operations for Cygnus (ESA/NASA)

The first Cygnus commercial cargo spacecraft built by Orbital Sciences Corp., in the grasp of the Canadarm2, on 29 September (ESA/NASA)

For PRIDE (Programme for Reusable In-orbit for Demonstrator in Europe), the Request for Quotation for the PRIDE-ISV Phase-A/B activities was issued in June, and the industrial proposal was submitted in August, including the in-kind documentation and data produced by the Italian USV-3 national programme. The consolidation of the PRIDE-ISV mission and system requirements is planned to take place by mid-2014.

## → FUTURE LAUNCHERS PREPARATORY PROGRAMME

**System, demonstrators, technologies – Next Generation Launcher**

The final report for PPH-type concepts is under evaluation and a final presentation will be made in October.

### Propulsion

In solid propulsion, the complete test specimen of the Pressure Oscillation Demonstrator (POD-X) was integrated and its test campaign started in September. The first hot firing test was planned for November. In hybrid propulsion, the contract for an integrated demonstrator design was placed, and manufacture and testing progressed as planned.

### Technologies

Implementation of integrated demonstrators is progressing, with the Cryotank Demonstrator (incorporating sandwich common bulkhead) where the Request for Quotation was released to industry. In parallel, technology activities are progressing in different topics, such as the Gas Port Phase Separator, the Jettisonable Fluid Ground Connector and Functional System Analysis Software.

## → HUMAN SPACEFLIGHT

Expedition 36 returned to Earth, and Fyodor Yurchikhin (Roscosmos) took over as Commander of Expedition 37 (with ESA's Luca Parmitano (IT), Oleg Kotov and Sergei Ryazanski (Roscosmos), and Karen Nyberg and Michael Hopkins (NASA). Luca has been continuing with his detailed research activities for ESA on the European Volare mission, as well as participating in ISS partner research activities. As part of his mission, Luca made two US Orbital Segment based spacewalks in July along with NASA astronaut Chris Cassidy. The second of these spacewalks was cut short because of a critical water leak in Luca's EVA suit. Two Russian-based spacewalks (by Yurchikhin and Misurkin) took place in August. A majority of the EVA work was in preparation for the arrival of the Russian Multipurpose Laboratory Module 'Nauka' together with the European Robotic Arm (ERA), the last major ISS elements to be launched to the ISS in April 2014. Luca assisted with robotic berthing procedures of the fourth Japanese H-II Transfer Vehicle (HTV-4) and in September he was the principal robotic arm operator during the berthing of the Orbital Sciences' Cygnus spacecraft (one of NASA's commercial ISS resupply spacecraft) during its first demonstration flight.

## → ISS TRANSPORTATION

### ATV *Albert Einstein*

The Orbit Correction System thrusters of ATV-4 were used to carry out reboosts of the ISS on 10 July, 31 August and 15 September. ATV water and fuel transfer operations were also completed. Fuel and oxidiser were transferred from ATV-4 tanks to the Russian Zarya module, while the last supplies

ATV *Georges LeMaitre* seen during integration at Astrium, Bremen, in August (Astrium/I. Wagner)



of ATV water were transferred from ATV-4 to the Russian module. ATV's supplies of oxygen were also used to refresh and repressurise the ISS cabin atmosphere. ATV-4 undocked from the ISS on 28 October, removing with it 1.6 tonnes of waste.

#### ATV *Georges LeMaitre*

ATV-5 was shipped to Kourou on 5 October for a launch in June 2014.

#### Multi-Purpose Crew Vehicle European Service Module (MPCV-ESM)

The PDR began in September. The PDR board will be conducted in November. The updated MPCV-ESM contract proposal will be presented in November. The second financial slice of the MPCV-ESM project will be part of the third Financial Binding Commitment to be approved at the Ministerial Council in 2014. Technical exchanges were made with NASA to identify concrete options for the extension of

the cooperation in Transportation Systems for Exploration beyond the initial MPCV-ESM contribution, as foreseen by the barter for the ISS Common Systems Operations Costs (CSOC) compensation.

## → ISS DEVELOPMENT/EXPLOITATION

#### European Robotic Arm (ERA)

Electrical integration with the Multipurpose Laboratory Module EM started in Russia in August according to plan. Because of the Proton launch failure on 2 July, the ERA launch will be delayed from December to not earlier than 25 April 2014.

#### Multi-Purpose End-To-End Robotic Operation Network (METERON)

Eurobot was tested at ESTEC in preparation for the

ESA's fourth Automated Transfer Vehicle, ATV *Albert Einstein*, burnt up on 2 November over the Pacific Ocean. This image was taken by astronauts on the ISS when ATV was around 100 km below (ESA/NASA)



OPSCOM2 experiment (tele-operation of Eurobot from the ISS). Preparatory tests of interfacing the Eurobot with ESOC's software are ongoing. Preparation continues for the next flight experiments of the METERON suite planned for 2013 and 2014 (standalone test of a single Exoskeleton joint and tele-operation of Eurobot at ESTEC from ISS).

## → ISS UTILISATION

Utilisation activities were at a reduced level in the past few months because of the extensive spacewalk preparations and activity on top of a busy period for ISS logistics traffic.

### Human research

Samples from the last test subjects Roman Romanenko, Oleg Novitski and Yevgeny Tarelkin (Roscosmos) for the IMMUNO experiment were returned to Earth on 11 September. The IMMUNO experiment is determining changes in stress and immune responses, during and after a stay on the ISS.

Activities continued with three experiments in the area of 'Nutrition, Sleep and Additional Wellbeing': the Circadian

Rhythms experiment (with Luca Parmitano as a subject, undertaking two 36-hour sessions for the experiment in July and September); the 'Space Headaches' experiment (Luca continued filling in weekly questionnaires, which will be analysed on the ground to help determine the incidence and characteristics of headaches occurring in astronauts, a common complaint); and the third and fourth sessions of ESA's Skin-B experiment (this experiment will help to develop a mathematical model of aging skin and improve understanding of skin-aging mechanisms, which are accelerated in weightlessness, and will provide a model for the adaptive processes for other tissues in the body).

### Biology research

No research activities took place from July to September, though extensive facility maintenance activities have taken place. Luca Parmitano installed two Life Support Modules and the refurbished microscope in ESA's Biolab facility in July.

### Fluids Research

The Fundamental and Applied Studies of Emulsion Stability (FASES) experiment investigates the effect of surface tension on the stability of emulsions. Results of

ESA astronaut Luca Parmitano installing the FASES experiment on the ISS (ESA/NASA)



the FASES experiment hold significance for applications in oil extraction processes, and the chemical and food industries. The science programme of FASES, installed in the Fluid Science Laboratory, was impacted by thermal control and sample transfer problems. After troubleshooting on the FASES experiment container, science operations resumed and additional experiment runs were carried out in September.

#### Materials research

Batch 2a experiments study different aspects of the solidification process in metal alloys that will help to optimise industrial casting processes. Following engineering analysis, Batch 2a solidification experiments (CETSOL-2, MICAST-2, SETA-2) in the Materials Science Laboratory (MSL) resumed after a problem in May. Luca exchanged the SETA-2 cartridge in the MSL for a CETSOL-2 cartridge on 21 August with the sample being processed in September.

#### Radiation research

The Dose Distribution inside the ISS 3D (DOSIS-3D) experiment continued using both active radiation detectors located in the European Physiology Modules facility and a new set of passive radiation detectors that were installed in different locations around Columbus on 3 April. Luca collected all of the passive detector packages on 6 September, and they were returned to Earth for analysis.

The results related to how the radiation levels in Columbus vary with the solar cycle, altitude of the ISS and location inside Columbus. This includes the first results of the period from 24 to 29 May when the active detectors were used for the very first time in a higher frequency mode (due to an increase of the solar proton flux). The active detectors make time-dependent cosmic radiation measurements for the experiment, while the passive detectors are used for 'area dosimetry', measuring the spatial radiation gradients inside Columbus.

#### Technology research

The Vessel Identification System (also Automatic Identification System, AIS) tests the means to track global maritime traffic from space by picking up signals from standard AIS transponders carried by all international ships over 300 tonnes, cargo vessels over 500 tonnes and all types of passenger carriers. It has been functioning on the ISS for three years with telemetry being received by the Norwegian User Support and Operation in Trondheim via ESA's Columbus Control Centre in Germany. During reentry of the fourth Japanese H-II Transfer Vehicle in September VIS data was used to refine knowledge of the position of the reentering spacecraft as part of an overall strategy for ensuring a safe deorbiting of the ISS at the end of its life.



Alexander Gerst, serving on the Expedition 38/39 backup crew, took part in a dress rehearsal fit check in Soyuz at the Baikonur Cosmodrome in Kazakhstan in October



Samantha Cristoforetti, NASA astronaut Terry Virts (centre) and Russian cosmonaut Anton Shkaplerov (right) during survival training near Star City, Russia, in June (GCTC)

Luca Parmitano used part of his free time on 20 July to perform the Education Payload Operations (EPO) 'Slinky' education activity. This is a demonstration covering wave dynamics and behaviours, recorded in space for use in ESA educational products. 'EPO Slinky' forms part of ESA's 'EPO Parmitano' series of education activities.

## → NON-ISS RESEARCH

The latest Concordia winter-over season is due to finish in November. The campaign includes eight ESA experiments and 15 crewmembers. The preparation of experiment complement for the next winter-over crew in 2014 is ongoing. A research Announcement of Opportunity (AO) for future Concordia studies (2015 onwards) was published in October.

The third and final campaign of the medium (21-day) bedrest study started at MEDES (FR) in September. The study builds on previous campaigns, testing nutritional supplements. The campaign is testing a nutritional supplement together with resistive vibration exercise to determine if the supplement improves the effect of the exercise as a countermeasure for the effects of (simulated) weightlessness on the human body. An AO for the next bedrest study was published in October.

A new experiment campaign on Diffusive Wave Spectroscopy Measurements on Granular Media was approved with 32 drops/catapult shots planned to start in December. The Drop-Your-Thesis 2013 candidate has also

been selected with a project based on mechanisms of stripe formation in vibrated granular materials. The drop tower campaign is scheduled for November/December.

Projects with the European Commission (ThermoMag, Accelerated Metallurgy, ExoMet, COLTS, AMAZE) are progressing well. Close links with ELIPS projects are exploited in terms of science team members and flight experiments.

## → ASTRONAUTS

Alexander Gerst (DE) had Columbus Specialist training at EAC in July. In September, he participated in ATV Rendezvous and Docking as well as Payload training at EAC. In addition, Alex took a three-day purpose-built medical course at the Uniklinik Köln in Germany in close cooperation with EAC.

Samantha Cristoforetti (IT) received one week of training for ATV Rendezvous and Docking together with her crew mate Alexander Samokutyaev at EAC in September. She also participated in Columbus Specialist training at EAC with US astronaut Barry Wilmore.

Tim Peake (UK) was involved in Luca Parmitano's mission as lead Eurocom after the launch in May. Tim has also been in training in the USA and Canada. Astronauts Andreas Mogensen (DK) and Thomas Pesquet (FR) completed Extravehicular Mobility Unit EVA Novice Flow and ISS US Orbital Segment Operator training in the USA. Andreas and Thomas also took part in a five-day underwater exercise in Florida to test tools

Thomas Pesquet took this photo of Andreas Mogensen 20 m under the sea on a simulated spacewalk, as part of the Seatest mission to test and practise ways of collecting samples during spacewalks on future space exploration missions



and practise spacewalks as part of the Space Environment Analog for Testing EVA Systems and Training (Seatest) mission.

## → TRANSPORTATION/EXPLORATION

Technical exchanges are continuing with NASA to identify concrete options for cooperation in Transportation Systems for Exploration related to Space Launch System upper stage and cryogenic propulsion technologies.

### Advanced Re-entry Vehicle (ARV)

The aerodynamic static test campaign for the ARV capsule shape (Apollo-type) was completed. The capsule dynamic model was also completed and tested during the summer. Breadboard elements, for large power solar panels, as required for exploration crew vehicles, are being tested. A simulator for advanced rendezvous sensors is being developed, avoiding the use of targets during docking manoeuvres.

### International Berthing Docking Mechanism (IBDM)

Design work for the Evolved Engineering Development Unit to bring the system design to SRR is progressing, in particular with the completion of the trade-off for the avionics architecture. Several alternative configurations for the accommodation of the magnets for vehicle soft capture in the selected narrow ring soft-docking system configuration have been defined for discussion with the international partners. Dynamic simulations of various vehicle docking cases were completed in support of the decision between magnets or more traditional mechanical latches.

Sierra Nevada Corporation (SNC) confirmed their interest to evaluate the use of the IBDM on their Dream Chaser vehicle. An initial agreement for a preparatory phase was finalised between ESA and SNC.

### International Docking Standard System (IDSS)

Discussions for the Revision C of the IDSS started with ISS partners. It was agreed to maintain the Androgynous Peripheral Attach System (APAS) soft-docking ring dimensions with the use of mechanical latches and reserve an option for the potential future adoption of capture by magnets. Cooperation with NASA, on the Block II version of the US mechanism tailored for exploration missions, has been agreed in principle. The cooperation aims at using the IBDM actively controlled soft-docking system in combination with the NASA hard-docking system.

### Operation Avionics Subsystem (OAS)

This project will prepare a demonstrator of operations avionics technology for later flight opportunity. The ongoing Phase-2 is building on the results of Phase-1 to consolidate, design and develop a set of highly configurable OAS building blocks, following the philosophy of ESA's onboard software reference architecture (SAVOIR), as follows: an On-Board Control Procedure engine that supports mission management and vehicle configuration functions by means of reconfigurable automated procedures; a generic Cockpit Display System (CDS) that can be configured to support the crew interaction needs for different missions (manned or teleoperated).

In parallel, Phase-3 has been carried out to develop a mock-up providing a representative environment of a cabin system, with sufficient elements to test, demonstrate and evaluate onboard systems with representative users, such as astronauts, crew members and instructors. OAS technology may find roles in other vehicles such as the MPCV-ESM and other ATV derivatives, or in the cockpits of the Russian NG-CTV (or PTK), the Sierra Nevada Dream Chaser crew vehicle or the S3 suborbital spaceplane.

### European Experimental Reentry Testbed (EXPERT)

Investigation of launch options as alternatives to Volna continues. Discussions took place with Orbital Sciences to study two different launch systems (Pegasus Lite and Minotaur). The two options are feasible. Talks took place with NASA and the US Army for the possible use of a new small launch system, SWORDS, jointly developed by NASA Marshall and the Army. A Technical Assistance Agreement is being prepared with Thales Alenia Space and Lockheed Martin to study the possibility of aerial recovery for the test bed.

### Lunar exploration

Discussions with Russia to define an incremental participation with ESA in their lunar exploration programme are progressing. Possible ESA contributions will aim to: prepare technologies and capabilities for future exploration missions; and gain knowledge to plan safe, effective and efficient human exploration beyond low-Earth orbit.

### International Exploration Framework

The International Space Exploration Coordination Group has released two documents: an update of the Global Exploration Roadmap in August and a White Paper on Space Exploration Benefits in September. Both documents may serve as reference for the preparation of the International Space Exploration Forum (ISEF) meeting, to be held in Washington DC on 9 January 2014. ISEF discussions will focus on international cooperation, space exploration and utilisation, public commitment and support to exploration.

## → SSA (SPACE SITUATIONAL AWARENESS)

### Space Surveillance and Tracking (SST)

The observation campaign was completed and the data are being analysed by AIUB (CH). This campaign was designed to start and maintain an independent catalogue of Earth-orbiting manmade objects within the geostationary orbit area. It will provide valuable information for the challenges involved in putting together a federation of sensors for a future SST system.

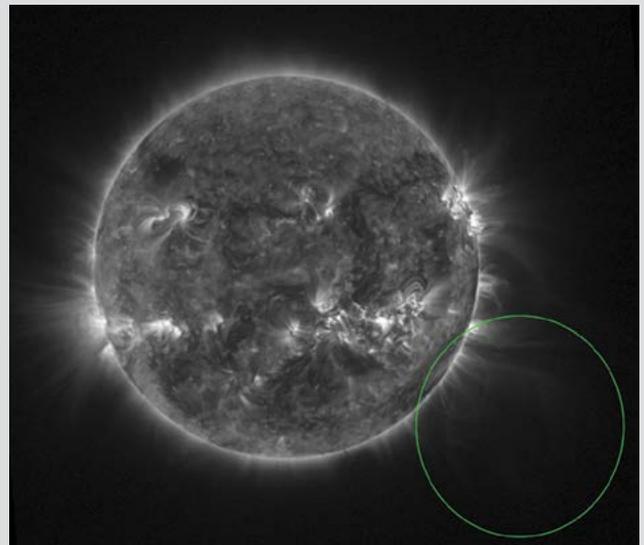
### Space Weather (SWE)

New space weather capabilities are becoming available to the end users as the developments started during the SSA Preparatory Programme are being completed. The SWE Web Portal was updated to provide more user-friendly access to the available tools and federated functions. One of the new capabilities available for users through the Solar Weather Expert Service Centre (ESC) is subscription to an automatic solar flare detection alert, based on the ground-based H-alpha images. This capability is provided by the Kanzelhöhe Observatory, University of Graz. An updated AVIDOS tool to estimate the cosmic background radiation dose at aircraft

altitudes has been fully integrated into the SWE system. This tool is provided by Seibersdorf Laboratories GmbH.

### Proba-2

Management responsibility of the Proba-2 mission was handed from ESA's Science and Robotic Exploration Directorate to the SSA Programme in June. Responsibility over the Proba-2 Science Centre remains with the Directorate. The spacecraft is in good health and continues to provide data from the 'Sun Watcher using APS detectors and image Processing' (SWAP) and Large Yield Radiometer (LYRA) instruments. An off-pointing campaign was carried out in July to allow the SWAP imager to observe a large on-disk filament. A partial filament eruption generating a coronal mass ejection on 26 July was captured by SWAP during this campaign. Proba-2 SWAP and LYRA data are used routinely in the SSA Solar Weather ESC coordinated by the Royal Observatory of Belgium.



Partial filament eruption on the Sun generating a coronal mass ejection on 26 July seen by Proba-2 (ROB)

### Near-Earth Objects (NEO)

In August, the number of known near-Earth asteroids increased over 10 000. The NEO Coordination Centre is active in the European asteroid community. An example was the observation of a very close object discovered by an American survey telescope. It turned out to be a defunct rocket stage.

A workshop, 'Dissemination of information on space-related hazards to national civil protection authorities', was held at ESOC in September with representatives of European emergency response agencies, and provided valuable input to the NEO segment for preparing the international coordinated response to a possible asteroid impact threat. Roadmaps for future activities related to both impact effect tools and asteroid deflection missions have been finalised.

# → ESA PUBLICATIONS

## Brochures

### Towards A Science-led One ESA (November 2013)

BR-315 // 92 pp  
E-book online

### Mars Express: A Decade of Observing the Red Planet (June 2013)

BR-312 // 8 pp  
E-book online

### Alphasat: Europe's Largest Telecommunications Satellite

(May 2013)  
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