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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, Estonia, Finland, France, Germany, Greece, Hungary, 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.

The major establishments of ESA are:

ESTEC, Noordwijk, Netherlands.

ESOC, Darmstadt, Germany.

ESRIN, Frascati, Italy.

ESAC, Madrid, Spain.

EAC, Cologne, Germany.

ECSAT, Harwell, United Kingdom.

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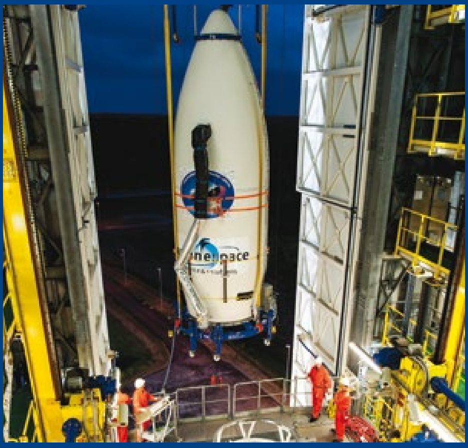
Chairman of the Council:
Harald Posch

Vice-Chairs:
Jean-Yves Le Gall and Bo Andersen

Director General:
Jean-Jacques Dordain



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On cover:
Integration of the complete fairing of Vega VV04, carrying ESA's Intermediate eXperimental Vehicle, at Europe's Spaceport in Kourou, French Guiana, on 30 January 2015 (ESA/M. Pedoussaut)

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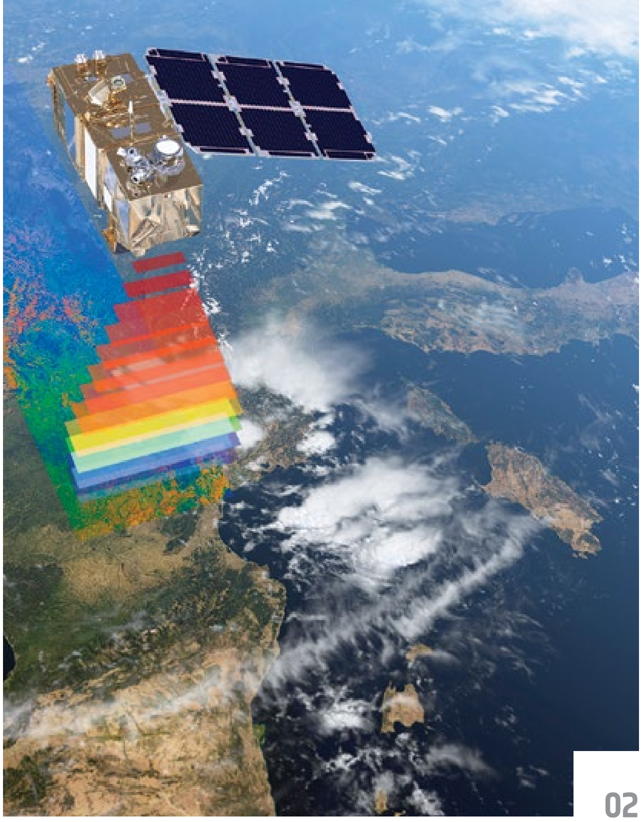

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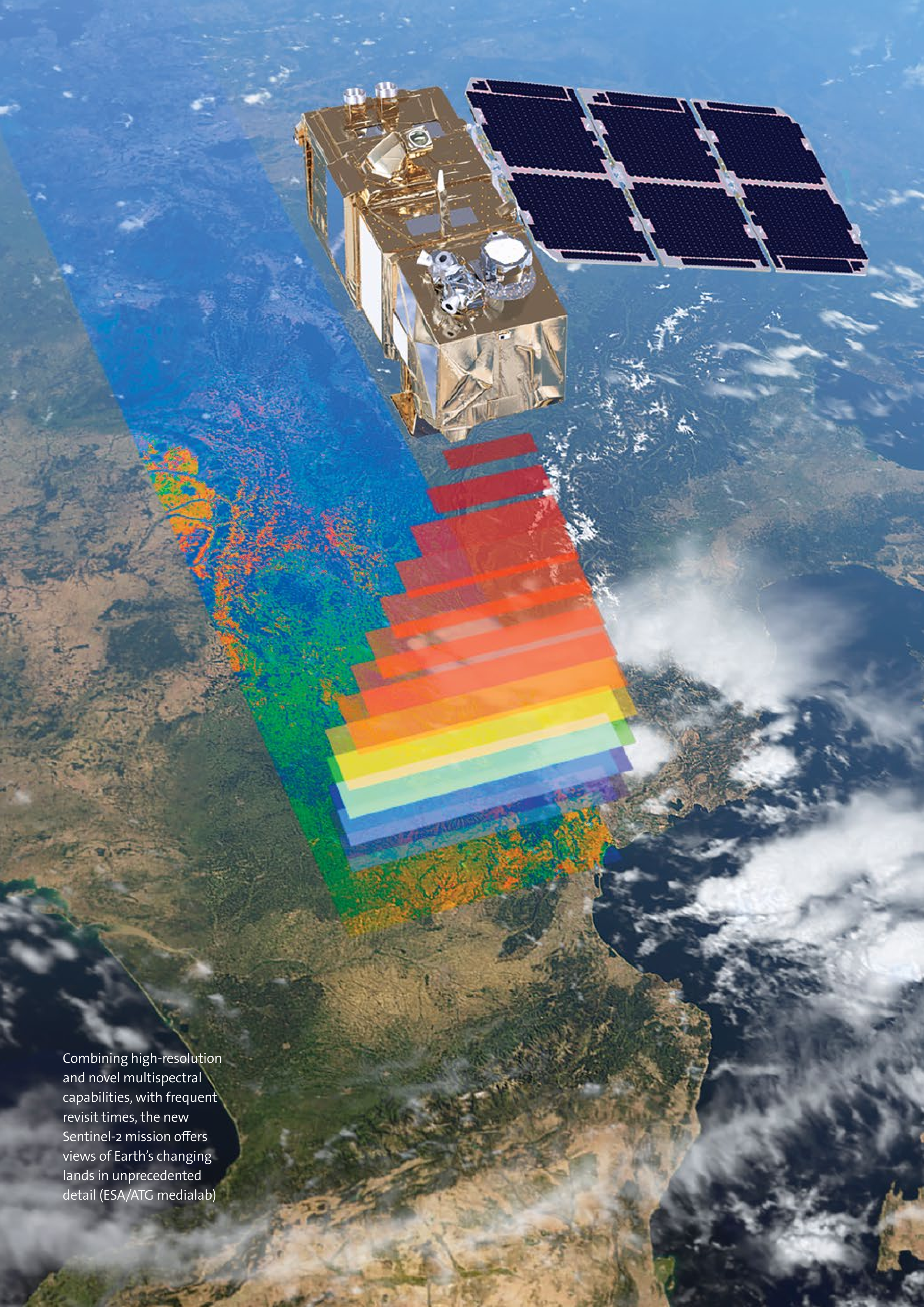


Combining high-resolution and novel multispectral capabilities, with frequent revisit times, the new Sentinel-2 mission offers views of Earth's changing lands in unprecedented detail (ESA/ATG medialab)

→ COLOUR VISION FOR COPERNICUS

The story of Sentinel-2

ESA's Sentinel-2 team
Directorate of Earth Observation, ESTEC, Noordwijk, the Netherlands & ESRIN, Frascati, Italy

Directorate of Human Spaceflight and Operations, ESOC, Darmstadt, Germany

↑ Sentinel-2A in the thermal vacuum chamber during testing at IABG in Munich, Germany (IABG)

The launch of the Sentinel-2A satellite in a few weeks is set to open a new chapter in our ability to monitor the health of Earth's vegetation and track changes in the way land is used.

Carrying a novel multispectral imager, this state-of-the-art mission will provide information that will not only help improve agricultural practices and map changes in land cover, but also monitor the world's forests and detect pollution in lakes and coastal waters. In addition, images of floods, volcanic eruptions and landslides will contribute to disaster mapping and help humanitarian relief efforts.

Following on from the Sentinel-1A radar satellite, Sentinel-2A is the next in ESA's fleet of satellites dedicated to Europe's Copernicus programme – the largest environmental monitoring programme in the world.

Managing Earth from space: a new era

The European Commission's Copernicus programme has been put in place to help manage the environment more effectively and help respond to the challenges of global change. This innovative global monitoring initiative offers a set of key information services for a wide range of practical applications.

Since the provision of accurate data is central to Copernicus, ESA has been tasked with coordinating the programme's 'space component', which includes developing six Sentinel missions, their ground segment and user interfaces. Each mission carries different technology to deliver a stream of complementary imagery and data tailored to the needs of Copernicus users. Importantly, these data are open to users worldwide and are available free of charge.

The first satellite in the series, Sentinel-1A, was launched into orbit in April 2014 and is now delivering operational radar images for numerous applications including the monitoring of ice in the polar oceans and tracking land subsidence.

In June 2015, it will be followed by Sentinel-2A, which carries a high-resolution multispectral optical imager with 13 spectral bands to offer a new perspective of our land and vegetation. The combination of high spatial resolution, advanced multispectral imaging capabilities, a very wide swath of 290 km and frequent revisit times make this mission exceptional.

As with most of the Sentinel missions, Sentinel-2 is based on a constellation of two identical satellites launched around a year apart. Orbiting 180° apart, they will cover all Earth's land surfaces, inland and coastal waters between 84°N and 56°S every five days.

In partnership

The Sentinel-2 mission has been made possible thanks to the close collaboration between ESA, the European Commission, industry, service providers and data users. Demonstrating Europe's technological excellence, its development has involved around 60 companies, led by Airbus Defence and Space in Germany for the satellites and Airbus Defence and Space in France for the multispectral instruments.

The mission has been supported in kind by the French space agency CNES to provide expertise in image processing and calibration, and by the German Aerospace Center DLR that provides the optical communication payload, developed by Tesat Spacecom GmbH.

This piece of technology allows the Sentinel-2 satellites to transmit data via laser to satellites in geostationary orbit carrying the European Data Relay System (EDRS). This new space data highway allows large volumes of data to be relayed very quickly so that information can be even more readily available for users.

Following completion of testing at the IABG test centre in Germany, Sentinel-2A will be ready for launch on a Vega rocket from Europe's Spaceport in French Guiana in June 2015.

Rising to the challenge

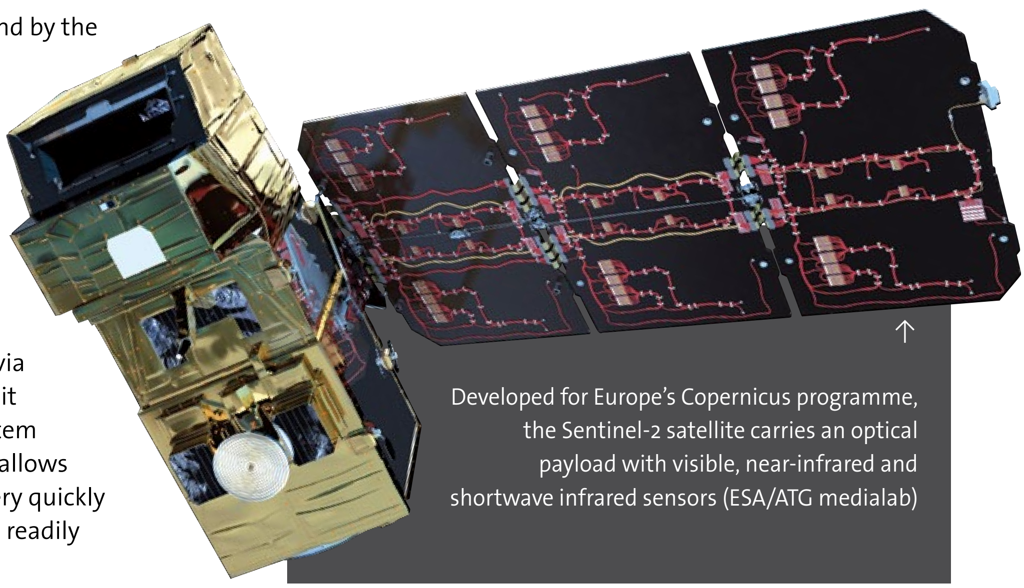
Seven years in the making, this novel mission has been built to operate for more than 20 years. Ensuring that it will meet users' exacting requirements has been a challenging task. Developing Sentinel-2 has involved a number of technical challenges, from early specification in 2007 to qualification and acceptance in 2015.

The satellite requires excellent pointing accuracy and stability and, therefore, high-end orbit and attitude control sensors and actuators. The multispectral imager is the most advanced of its kind, integrating two large visible near-infrared and shortwave infrared focal planes, each equipped with 12 detectors and integrating 450 000 pixels.

Pixels that may fail in the course of the mission can be replaced by redundant pixels. Two kinds of detectors integrate high-quality filters to isolate the spectral bands perfectly. The instrument's opto-mechanical stability must be extremely high, which has meant the use of silicon carbide ceramic for its three mirrors and focal plane, and for the telescope structure itself.

The geometric performance requires strong uniformity across the focal planes to avoid image distortion. The radiometric performance excluded any compromise regarding stray light, dictating a tight geometry and arrangement of all the optical and mechanical elements. The instrument is equipped with a calibration and shutter mechanism that integrates a large spectralon sunlight diffuser.

Each satellite has a high level of autonomy, so that they can operate without any intervention from the ground



↑

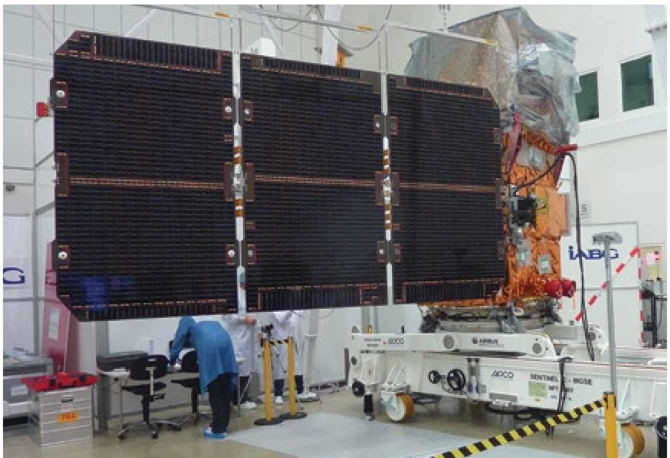
Developed for Europe's Copernicus programme, the Sentinel-2 satellite carries an optical payload with visible, near-infrared and shortwave infrared sensors (ESA/ATG medialab) for periods of up to 15 days. This requires sophisticated autonomous failure analysis, detection and correction on board.

The 'carpet mapping' imaging plan requires acquisition, storage and transmission of 1.6 terabytes per orbit. This massive data blast results from the combination of the 290 km swath with 13 spectral channels at a spatial resolution as high as 10 m.

In addition, the optical communication payload using the EDRS data link is a new technology that will improve the amount and speed of data delivery to the users. This was very recently demonstrated by Sentinel-1A, which also carries an optical communication payload.

Preparing the ground system to process the huge flow of data, including all the necessary geometric, radiometric and atmospheric corrections, in real time has also been no mean feat. And, being an operational mission, the ground system uses tight quality-monitoring functions and key performance indicators that will be made available to the users throughout the duration of the mission.

↑ Sentinel-2's multispectral instrument performance tests at Centre Spatial de Liège, Belgium (CSL)



↑ Solar array deployment tests at IABG in Munich, Germany (ESA)

Essential ground work

It is vital to make sure that the eventual data meets the users' exacting requirements, so efforts are put into field and airborne campaigns to assess the future performance of an instrument. This means that many airborne and ground measurements have to be made so that the final data products can be simulated and evaluated.

The field campaigns for Sentinel-2 involved taking measurements over fields and forests with an airborne imaging spectrometer. These data are complemented by coincident measurements taken from the ground to calibrate and validate those from the aircraft. The field campaigns formed an essential role in preparing the user community for Sentinel-2A's upcoming data products. Such campaigns will continue once Sentinel-2A is in orbit to help validate its data.

Land in focus

Ensuring that land is used sustainably, while meeting the food and wood demands of a growing global population – a projected eight billion by 2020 – is one of today's

↑ Scientists from the University of Milan taking part in a field campaign to support Sentinel-2 (ESA/D. Schuettemeyer)

↑ Sentinel-2 offers key information to optimise crop yield (A. Krappweis)

biggest challenges. The Copernicus land service provides information to help respond to global issues such as this, as well as focusing on local matters, or 'hotspots', that are prone to specific challenges.

However, this service relies on very fast revisit times, timely and accurate satellite data in order to make meaningful information available to users – hence, the role of Sentinel-2. Through the service, users will have access to information about the health of our vegetation so that informed decisions can be made – whether about addressing climate change or how much water and fertiliser are needed for a maximum harvest.

Sentinel-2 is able to distinguish between different crop types and will deliver timely data on numerous plant indices, such as leaf area index, leaf chlorophyll content and leaf water content – all of which are essential to accurately monitor plant growth. This kind of information is essential for precision farming: helping farmers decide how best to nurture their crops and predict their yield.

While this has obvious economic benefits, this kind of information is also important for developing countries where food security is an issue. The mission's fast geometric revisit of just five days, when both satellites are operational, and only 10 days with Sentinel-2A alone, along with the mission's range of spectral bands means that changes in plant health and growth status can be easily monitored.

Sentinel-2 will also provide information about changes in land cover so that areas that have been damaged or destroyed by fire, for example, or affected by deforestation, can be monitored. Urban growth also can be tracked.

The Copernicus services are managed by the European Commission. The five 'pan-European' themes covering 39 countries are addressed by the land service, including sealed soil (imperviousness), tree cover density, forest type, and grasslands. There is currently insufficient cloud-free satellite data in high resolution with all the necessary spectral bands that cover Europe fast enough to monitor vegetation when it is growing rapidly in the summer. Sentinel-2 will fill this gap.

This multi-talented mission will also provide information on pollution in lakes and coastal waters at high spatial resolution and with frequent coverage. Frequent coverage is also key to monitoring floods, volcanic eruptions and landslides. This means that Sentinel-2 can contribute to disaster mapping and support humanitarian aid work.

Leading edge

The span of 13 spectral bands, from the visible and the near-infrared to the shortwave infrared at different spatial resolutions ranging from 10 to 60 m on the ground, takes global land monitoring to an unprecedented level.

The four bands at 10 m resolution ensure continuity with missions such as SPOT-5 or Landsat 8 and address user requirements, in particular, for basic land-cover classification. The six bands at 20 m resolution satisfy requirements for enhanced land-cover classification and for the retrieval of geophysical parameters. Bands at 60 m are dedicated mainly to atmospheric corrections and cirrus-cloud screening.

In addition, Sentinel-2 is the first civil optical Earth observation mission of its kind to include three bands in the 'red edge', which provide key information on the vegetation state.

Thanks to its high temporal and spatial resolution and to its three red edge bands, Sentinel-2 will be able to see very early changes in plant health. This is particularly useful for the end users and policy makers to detect early signs of food shortages in developing countries.

Getting ready for launch

Following the completion of the test campaign at IABG in Germany, the Qualification and Acceptance Review will be held in April 2015 to assess the compliance

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This wide view of Lake Constance and part of southern Germany, eastern France and northern Switzerland simulates Sentinel-2's large swath width of 290 km. The four zoomed-in pairs of images focus on a 25 km-wide area east of Lake Constance at 10–20 m resolution in natural colour (left) and in infrared.

and completeness of the verification and qualification programme. In parallel, the Ground System Acceptance Review will be held to evaluate the ground system dedicated to mission operations and exploitation, and to review the status of operations preparations.

A positive outcome of these reviews will mean that the satellite and its ground support equipment can be packed and shipped to Europe's Spaceport in French Guiana.

A five-week launch campaign will prepare Sentinel-2A for launch in June 2015. ESA's European Space Operations Centre will operate both Sentinel-2 satellites, with CNES joining forces to complete the full commissioning of the satellite and instrument in three months. Sentinel-2 is expected to be operating routinely before the launch of the second satellite in June 2016. ■

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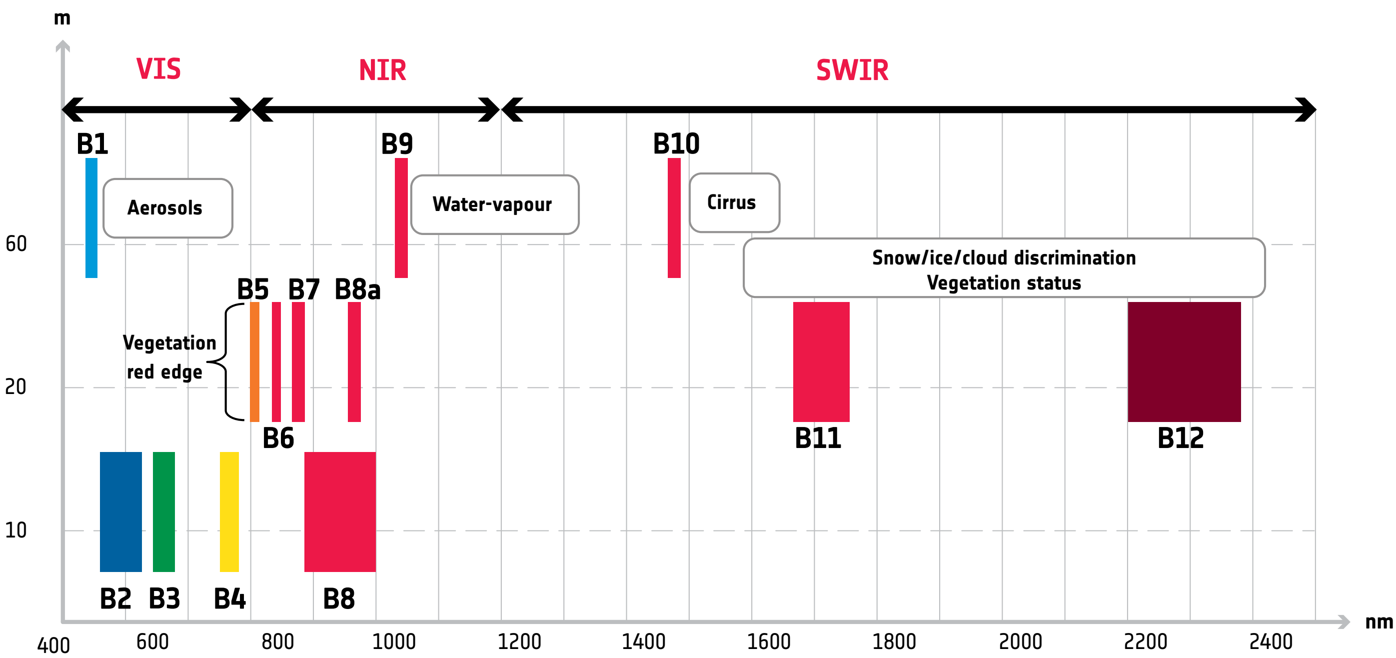
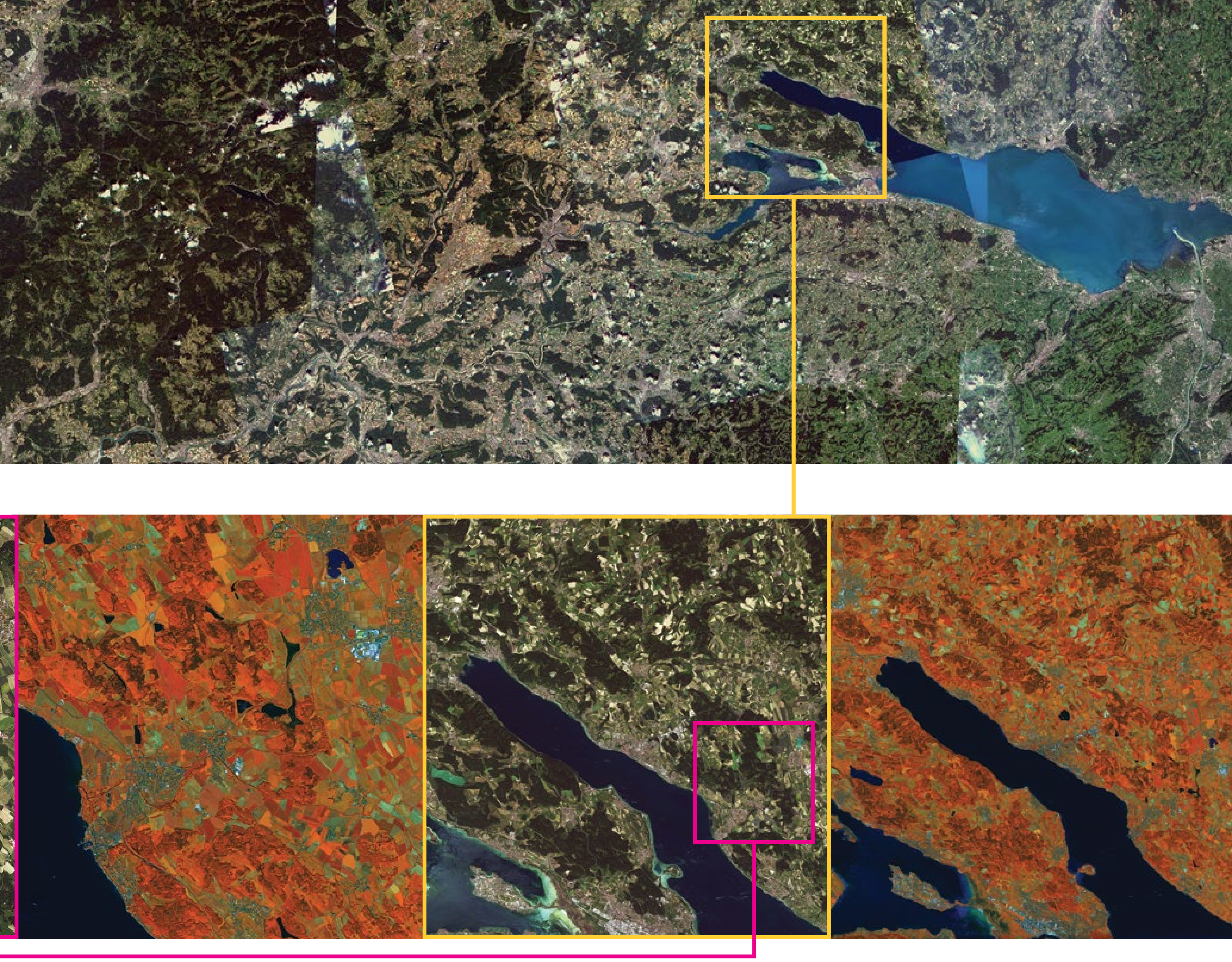
The infrared view on the right of each pair shows bodies of water, such as smaller lakes, in greater detail and allows us to better see differences in vegetation, with dark red to light green depicting high to low chlorophyll content, respectively (Blackbridge)



↑ Spatial resolution versus wavelength: Sentinel-2's span of 13 spectral bands, from the visible and the near-infrared to the shortwave infrared at different spatial resolutions ranging from 10 to 60 m on the ground, takes land monitoring to an unprecedented level



→ FACTS AND FIGURES

Sentinel-2A launch	June 2015, by Vega from Kourou, French Guiana
Sentinel-2B launch	July 2016, by Rockot from Plesetsk, Russia
Orbit	Polar, Sun-synchronous at altitude 786 km Mean Local Solar Time at descending node: 10:30 (optimum Sun illumination for image acquisition)
Geometric revisit time	Five days from two-satellite constellation (at equator)
Life	Seven years (carries consumable for 12 years: 123 kg of fuel including end of life deorbiting)
Multispectral instrument (MSI)	Multispectral imager covering 13 spectral bands (443–2190 nm), with a swath width of 290 km and a spatial resolution of 10 m (four visible and near-infrared bands), 20 m (six red edge and shortwave infrared bands) and 60 m (three atmospheric correction bands).
Receiving stations	MSI data: transmitted via X-band to core Sentinel ground stations and via laser link through EDRS. Telecommand and telemetry data: transmitted from and to Kiruna, Sweden
Main applications	Agriculture, forests, land-use change, land-cover change. Mapping biophysical variables such as leaf chlorophyll content, leaf water content, leaf area index; monitoring coastal and inland waters; risk and disaster mapping
Mission	Managed, developed, operated and exploited by various ESA establishments
Funding	ESA Member States and the European Union
Prime contractors	Airbus Defence & Space Germany for the satellite, Airbus Defence & Space France for the instrument
Cooperation	CNES: Image quality optimisation during in-orbit commissioning DLR: Optical Communication Payload (provided in kind) NASA: cross calibrations with Landsat-8

Devastation in L'Aquila,
Italy, April 2009
(Thales Alenia Space)

→ RISE TO RECOVERY

Rebuilding a space facility after the L'Aquila earthquake

Wolfgang Veith and Tommaso Ghidini
Directorate of Technical and Quality Management, ESTEC, Noordwijk, the Netherlands

Sean Blair
Communications Department, ESTEC, Noordwijk, the Netherlands

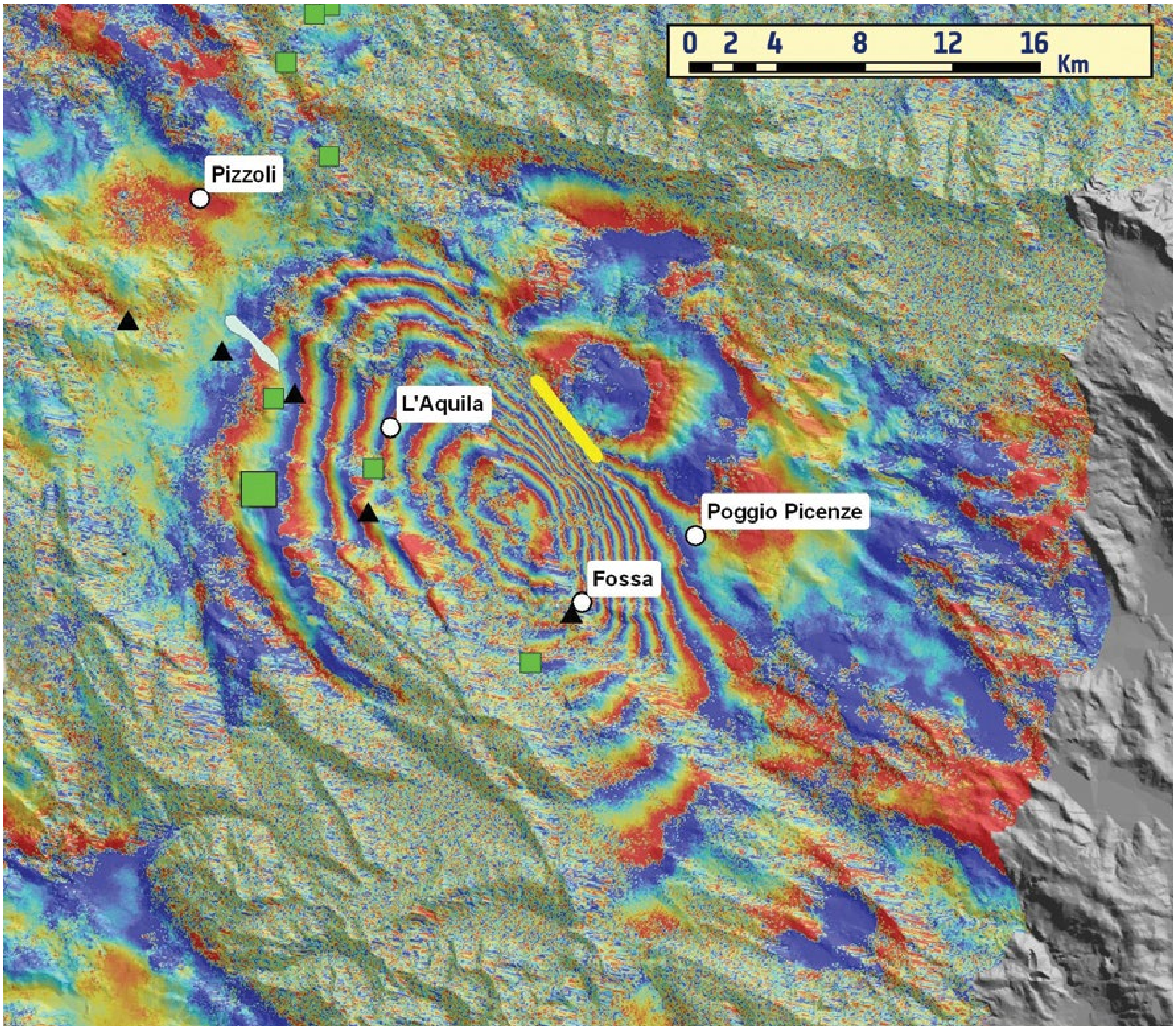
Supporting Europe's space industry is one of ESA's fundamental goals. Never was that support more literal than in the aftermath of Italy's L'Aquila earthquake of 6 April 2009.

This earthquake left a major town devastated – and a yawning hole in the European space sector. An entire Thales Alenia Space facility, producing critical electronic components and composite materials for a multitude of ESA and commercial space missions, was severely damaged.

ESA stepped in to help, first in salvaging and restarting manufacturing, then in creating a replacement facility. It was an engineering challenge with both a technical and humanitarian dimension.

ESA's Product Assurance and Safety Department lent its expertise to a workforce whose homes had been largely destroyed, many of them commuting to work, from tents or far-distant hotel rooms, for months on end. Without this support and ESA stamp of quality, the facility might have faced closure, bringing a further economic blow to the already battered Abruzzo region.

ESA's product assurance engineers were able to help in bringing the situation back from the brink. A joint team was established with the company providing maximum support to first restart production and then revalidate all necessary industrial processes – lending the company's customers vital reassurance that rigorous space quality standards had not been compromised.



↑ An Envisat Advanced Synthetic Aperture Radar interferogram interpretation by Italy's Istituto Nazionale di Geofisica e Vulcanologia. The large green square shows the magnitude 6.3 main shock, the smaller green squares are aftershocks (INGV)

But the Thales Alenia Space management demonstrated strong commitment to their stricken employees, and pledged a brand new state-of-the-art facility would be built for L'Aquila. Five years on, that facility is in place – again with significant ESA technical support – and its relocated production lines are set to start rolling. This is the story of the L'Aquila plant's rise from the ruins.

One day in April

In the early hours of 6 April 2009, some 8.8 km under the heart of Italy's Apennine mountain range, one microplate of Earth's crust ground under another. The result on the surface was a magnitude 6.3 earthquake. There had been brief, minor tremors since the start of the year, but this one, the 'big one', lasted 20 seconds.

L'Aquila is the hilltop capital of the Abruzzo region, and much of its historic centre had been rebuilt following an earthquake in 1703. This time around, its centre was levelled with many modern structures proving just as susceptible to tremors as their age-old equivalents. Around 100 000 buildings were damaged in the quake and the violent aftershocks that followed, with more than 300 people killed and around 67 000 inhabitants left homeless.

One of those buildings, located less than 200 metres from the medieval walls of L'Aquila, held a special significance

← Part of the Thales Alenia Space plant destroyed by the earthquake (Thales Alenia Space)

to the European space industry, as well as being the town's leading private employer. A Thales Alenia Space facility, operational since 1983 and employing 300 people, was producing electronic equipment, hybrid packages, antennas and composite materials for various ESA and commercial customers, including the electronic front end of the radar-based Earth-observing Sentinel-1.

"I was scheduled to go to the facility the following morning for a meeting of the Component Technology Board Hybrid Working Group," recounted Remo Cirone of ESA's Product Assurance and Safety Department. "Once we heard the news I tried to call my friends – I myself had worked at the site for 20 years – but for that first day all communications were unavailable.

"The following day we learned that one employee had been killed during the earthquake when her downtown home collapsed. Michela Rossi, who worked in the composites section of the plant, had visited us at ESTEC often. Other employees had lost relatives in the disaster, and the plant itself was almost completely destroyed."

Offices on the west side of the plant had nearly collapsed. Luckily, the cleanroom manufacturing, testing and storage areas on the east side remained structurally intact – they had once been a state mint, and survived bombing during the Second World War. But what sort of state was it in on the inside? Cleanrooms are known for their isolated environments, with filtered air and regulated temperature and humidity. But what would happen after such a major external shock?

"In the wake of the earthquake – when the city itself remained in an emergency situation – some employees went to the plant to check its systems," recalls Fabio Occhioni, the plant's Production Manager. "By doing this, we guaranteed the minimum operation of certain systems, such as nitrogen flushing – keeping sensitive items bathed in the neutral gas – which subsequently allowed the recovery of the industrial equipment and flight hardware." And fortunately, the emergency generator had kicked in once the mains power had failed.

For nearly two weeks, Italian civil protection officials forbade access inside the plant itself, considering it an unacceptable risk as aftershocks rumbled on. In the meantime, Thales Alenia Space management reassured employees their salaries would continue to be paid, donated 100 000 euros to local authorities in an emergency contribution, and reassured its 14 space project customers – six from outside Europe – that manufacturing of their 39 active programmes would be restarted as soon as possible.

Plans were laid to shift production to other Thales Alenia Space facilities across Italy, France and Belgium, once all the necessary manufacturing equipment could be salvaged from L'Aquila. ESA's Product Assurance and Safety Department – part of the Directorate of Technical and Quality Management – pledged the strongest possible support for this process. They set up a joint task force with Thales Alenia Space to collaborate on relocation, verification and validation planning, helping to anticipate problems before they arose.

Wolfgang Veith, Head of ESA's Product Assurance and Safety Department, explains, "This joint ESA-Thales Alenia Space post-earthquake relocation team was put together with the goal of ensuring a rebirth of the company – and fresh hope for the employees. We sought to provide maximum support for the relocation and revalidation effort and ensure the restart of production in the shortest time possible.

"The main challenge was to do this while proving to the company's customers that the disruption had in no way compromised their rigorous technical requirements or their top quality. In addition, the work had to be performed without interrupting the assembly of flight hardware – including those destined for ESA projects."

"So ESA, as the European authority on manufacturing for space, would be at hand to provide them with an authoritative and independent stamp of quality."

"It would be a long process all the same, involving the detailed testing of sample batches through a complete mission profile, plus on-the-spot environmental audits, but we worked as closely as possible to advise and expedite on issues arising."

Determination was equally strong on the Thales Alenia Space side, recalled Elisio Prette, President and CEO of Thales Alenia Space Italy. "The customers who had come to us during the first few weeks after the earthquake thought there might still be an uncertain, inoperative situation," said Elisio.

"On the contrary, they found an active, competent and motivated team following clear, well-defined operational plans, and it was quite evident we were proceeding in the right direction. And our plans for redeployment and restarting of production lines were shared with customers in a completely transparent manner, creating the necessary relationship of mutual trust to ensure the success of the endeavour."

Tommaso Ghidini, Head of ESA's Materials Technology section, oversaw the ESA side of the joint team. He said, "Normally, if a company has an ESA customer we would then begin work to qualify them, showing that they were able to perform a given task to an actual space standard – placing ten components on a circuit board, for instance. That is their 'perimeter of qualification', and if they seek to go beyond it, with added components, or a switch in materials in processes, or even a move of equipment from one building to another, then the whole qualification process has to start again from scratch."

"In this case, we were talking about much more than a move between buildings, but transfers of equipment and production lines to entire new facilities. And, at the same time, the stakes were much higher. There was always the possibility that the plant would be closed entirely and business lost."

"But we could see the will of the Thales workforce to recover from the tragedy, coming in to do great work every morning, even though many of them were living in tents for months afterwards, their old homes destroyed, and unsure what the future held. So of course we empathised. Our multidisciplinary team was keen to help them through this difficult moment, and then go on to rebuild."

The recovery process began on 19 April, when the civil protection officials permitted the first access within the ruined plant, escorted by firemen. The first priority was to inspect the cleanrooms. They were largely intact on the inside, although internal cladding and fittings had given way, with their raised flooring having helped 'cushion' much of the force of the quake.

A lot of effort had gone into defining dedicated procedures for the salvagers to rescue flight hardware in a very short time, while following the safety constraints required by the Civil Protection authorities.

Thales Alenia Space engineers worked like archaeologists entering an ancient site. Wearing anti-static gloves and bracelets, they started by documenting everything with video footage and hundreds of photos, while also compiling temperature and humidity readings to assess any potential damage or contamination to flight unit items

> **The earthquake that struck us was a tragic yet significant event in the history of our company.**
>
> Elisio Prette, CEO of Thales Alenia Space Italy

←

Members of ESA's Product Assurance and Safety Department received commemorative plaques from Thales Alenia Space for their assistance in relocating production after the L'Aquila earthquake. Left to right: Roberto Ciaschi, Wolfgang Veith, Ramon Torres, Christopher Semprimoschnig, Remo Cirone and Patrizia Secchi

and manufacturing and test equipment. Next they removed everything they could, in a mammoth salvage effort.

"I recall that Sunday – when we entered the plant to retrieve – as if it were yesterday. We were all focused on what we had to do; we were well aware that we were about to do something important for the company, for our customers and therefore for ourselves," said Fabio Occhioni.

"On some of the faces you could see the fear of what they had experienced on that night in 6 April. Yet, during the recovery operation, when aftershocks were felt, these people looked at each other and then continued to work on, even more determinedly than before.

"All in all, the cleanrooms were in an extremely good condition. While some heavy machinery had moved from its original position and some equipment had fallen, the flight hardware – thanks to compliance with the standard handling and storage procedures implemented at the end of the shift prior to the earthquake itself – had been put away in cabinets, permitting it to be safely salvaged.

"All the flight hardware was retrieved on that day, which started at 7 am and ended at midnight, after its transfer to our cleanrooms in Rome. Having been carefully packed for its redeployment, it was then thoroughly inspected by personnel from our quality department who then issued an appropriate incoming report."

By the end of June, the upwards of 4300 recovered flight unit items had been joined by the last of the test and manufacturing equipment. The very largest items to be extracted were one-of-a-kind test benches or machinery: one antenna measuring device measured in at around 10 cubic metres.

Dozens of reviews were carried out to guarantee the quality of this salvaged equipment to customers. Meanwhile a parallel effort on the office side had recovered computers and hard drives. Recovery of equipment was followed by its relocation, in the short term to Thales Alenia Space sites in Rome, Turin and France, in order to restart production lines to deliver critical hardware to waiting customers – including ESA's Sentinel-1. In the longer term, production restarted in L'Aquila itself, based in a temporary rented site, coupled with the Thales facility in Rome, about 100 km away.

The quality approach defined in the first few days after the quake was continuity: to reproduce previously qualified processors using the same operators employing the same manufacturing, inspection and test machines, the same manufacturing tools, the same materials and parts amid precisely the same environmental conditions – controlled temperature, relative humidity and cleanliness.

ESA performed regular reviews of all the relocation and validation planning and reports, with regular exchanges of comments and recommendations between the two sides. By June 2010, 15 months after the quake, all relocated processes had been successfully reverified.

Roberto Ciaschi, Remo Cirone, Patrizia Secchi, Christopher Semprimochnig and Wolfgang Veith of ESA's Product Assurance Department received commemorative plaques as thanks for their support in revalidating the L'Aquila production lines.

But this was not the end of the story – or ESA's involvement. The relocated production in Rome and the temporary L'Aquila site were only intended to be a stop-gap solution. On 21 July 2009, Thales Alenia Space committed to building a new state-of-the-art plant in L'Aquila.

"The decision to rebuild the plant was made in order to safeguard the strategic assets and expertise here in L'Aquila, developed over decades of work carried out in space. The

L'Aquila facility has always been a key plant in terms of technologies as well as the manufacturing of hybrid systems, composite structures and antennas," said Elisio Prette.

"And for some employees, who had lost all their belongings and had no more reference points, the news that their company was continuing to count on them by investing in a new plant was welcomed with enthusiasm. It strengthened the sense of belonging even more so, and multiplied the energy and effort that was needed in the months and years ahead, to reach what were difficult objectives."

"It was a dramatic decision, one that didn't have to happen," added Wolfgang. "It amounted to a reaffirmation of the professional quality and dignity of the workforce, and the future of their families. Again we were pleased to support it."

The first stone was laid on the €42 million building on 11 December 2011, and it was inaugurated just short of two years later, on 3 December 2013. As before, all processes had to be fully revalidated once they were moved.

In practice, this meant all the processes previously carried out at the old L'Aquila plant. In addition, the company took the opportunity to transfer new production lines from Turin, a facility in the process of closure – dedicated in particular to the development of large, lightweight satellite radar antennas.

"Starting in 2013, the relocation involved lots of work," said Liam Murphy of ESA's Components Technology section, overseeing the revalidation of hybrid production lines. "On the hybrid side, the documentation covered around 35 processes – covering varied disciplines such as soldering, adhesive bonding, wire bond interconnections and hermetic sealing – plus associated sub-processes."

"Each process required detailed documentation and testing to prove that the work could be performed to the very same standard or better at the new location. Finally samples of production lines end up at ESTEC for 'destructive physical analysis' – taking them apart to ensure the finished product does indeed meet space specifications."

Carol Villette of ESA's Materials Technology section, responsible for printed circuit board (PCB) production line revalidation, said, "The revalidation process required very close collaboration. It included weekly teleconferences that lasted half a day, and frequent testing and micro-sectioning of PCB samples to search for any problems.

"To ensure assembly could continue while the production lines were transported, work was divided into two lines – so one could be moved first, then revalidated, after which the second could be moved as well."

←

Construction of the new plant began 2011 (Thales Alenia Space)

→

Thales Alenia Space's new plant has a total surface area of 16 000 m^2, comprising 10 000 m2 of labs and cleanrooms, 4500 m^2 of offices and a 1500 m^2 energy centre (Thales Alenia Space)

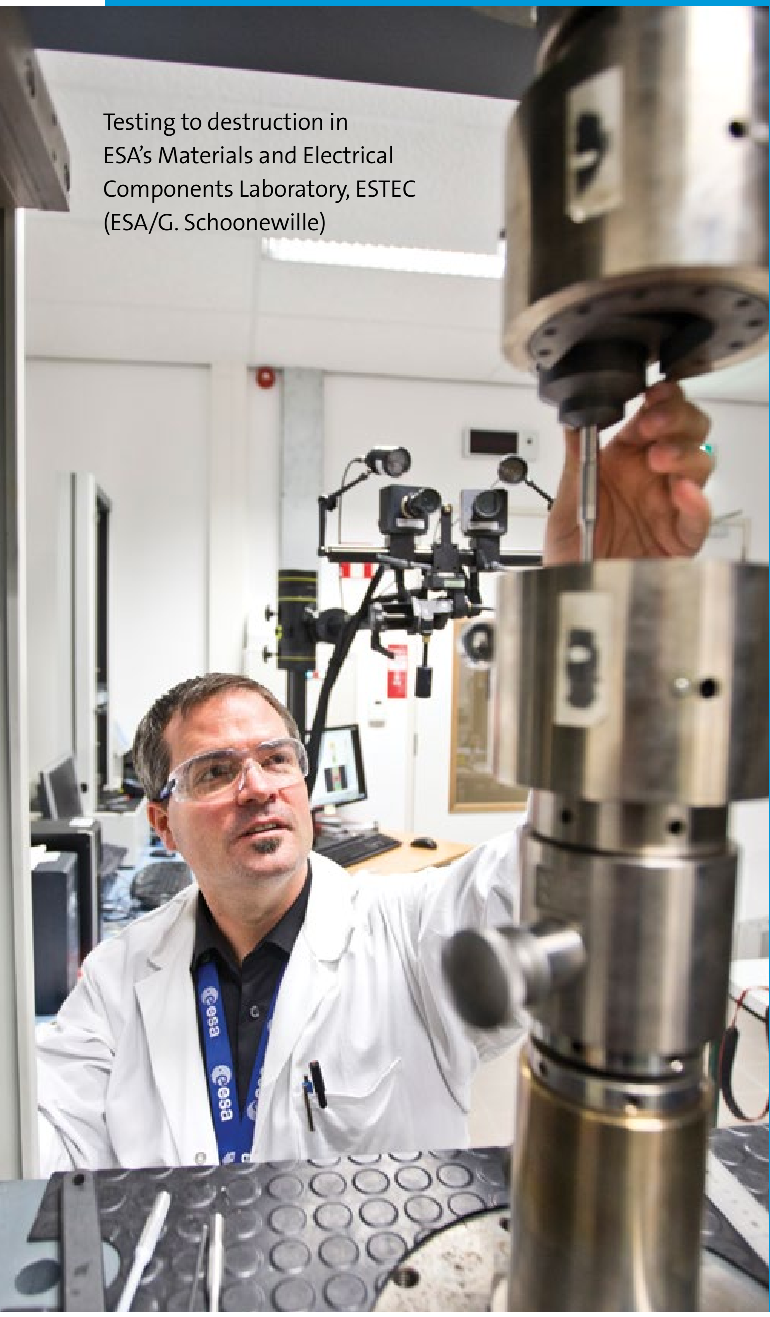
The new facility was constructed to the strongest modern earthquake safety standards, resting atop 150 pillars that can absorb seismic shakes to keep the facility isolated, flexing up to 30 cm on each side (Thales Alenia Space)

↑ The new building in L'Aquila (Thales Alenia Space)

"The aim of ensuring identical manufacturing quality involved audits of the premises, ensuring compliance with the relevant ECSS (European Cooperation for Space Standardisation) standards – checking everything from suitable lighting and appropriate tools to the appropriate materials and prevention of electrostatic discharge.

Transplanted manufacturing equipment – such as vapour phase machines – have to operate in exactly the same way as before, even down to their temperature profile."

Last year, more than a hundred separate items of equipment were validated, more than 30 separate meetings were held with Thales Alenia Space and 19 'flash



Testing to destruction in ESA's Materials and Electrical Components Laboratory, ESTEC (ESA/G. Schoonewille)

→ Quality control

ESA's Product Assurance and Safety Department is active in producing and promoting common quality and engineering standards for use in all European space activities through the European Cooperation for Space Standards (ECSS), including manufacturing and testing. "The aim is to have common verifiable standards in place all across Europe," stated Wolfgang Veith.

Skilful handcrafting remains much more central to the manufacture of space components and satellites than might otherwise be imagined. Soldering is a central, essential skill for instance, required to perform the reliable surface-mounting and interlinking of electronic components on circuit boards. A poor solder joint could fail to stand up to the environmental extremes of space and lead to the failure of a subsystem, or even the entire mission.

"How do we ensure that a low-level operator in one country carries out soldering tasks to the same standard as others all across Europe?" asks Wolfgang. "We've set up a network of schools all over the continent, so technicians can receive detailed training in their own language. In addition we train inspectors in techniques to perform independent inspections, and also instructors, to go on expanding the network."

When it comes to qualifying a new company in the production of particular components, batches of parts will be received for detailed testing at ESA's Materials and Electrical Components Laboratory – based at the ESA ESTEC technical centre in Noordwijk, the Netherlands.

"We want to demonstrate their quality throughout the intended mission profile, to answer the question: would they really survive the mission?" explained Tommaso.

audits', or walkthrough inspections, were carried out across the course of the transfer phase.

Years on from the quake, its effects were still being felt by the joint team. Some Thales Alenia Space employees are still commuting after losing their homes, and the city centre remains shrouded in scaffolding with roads sealed to traffic. Yet marked progress has been made.

"The earthquake that struck us was a tragic yet significant event in the history of our company," stated Elisio Prette. "Since that moment we have embarked on a journey, a path consisting of concrete stages, challenges won and objectives that we have reached, which has brought us to the present, and the celebration of an innovative, state-of-the-art plant along with the intense, excellent technological activities being carried out within the plant itself."

The end of October 2014 saw the validation of all the equipment installed in the plant for manufacturing and testing space-quality parts, set to serve forthcoming ESA missions including BepiColombo, ExoMars, Solar Orbiter and Sentinel-3, along with some other notable customers. The plant is producing most of the radar systems for the Italian COSMO-SkyMed Second Generation constellation, plus transmission/reception modules, onboard computers and control electronics for the main mission antennas of the US 70-satellite IridiumNEXT. ■

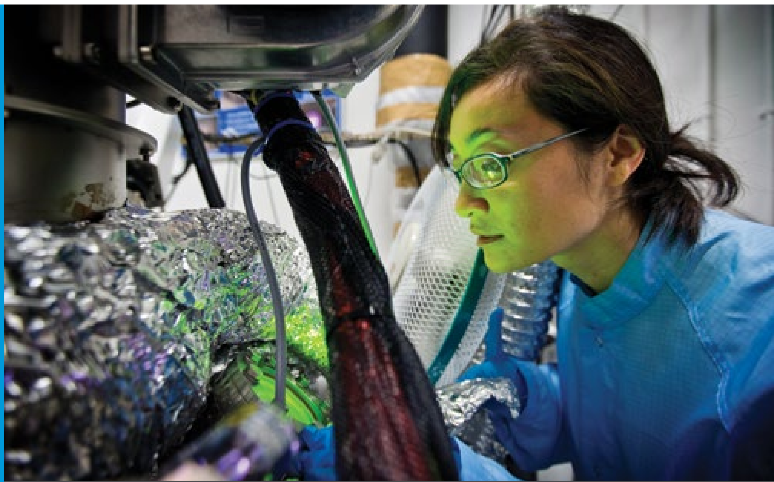
The resulting test campaign would include 'thermal vacuum testing', where the components are placed within a space-quality vacuum and subjected to the kind of extreme temperatures experienced during orbital flight, sometimes with those temperatures raised higher to perform 'accelerated lifetime testing'.

The parts are placed onto industrial shakers to undergo shock and vibration testing, reproducing the violent forces experienced during a rocket launch and stage separations. Afterwards, the question is how well have the components weathered the stress? Has soldering cracked or given way? Have components fallen off their circuit board? Has a hybrid component been pulled apart during shear testing as its adhesive gives way?

Follow-up functional testing or visual inspections can answer a lot of questions, but might not be sufficient by themselves. The components can then be cut into micro-sections for detailed examination by an array of optical or electron microscopes, peering down to a few millionths of a millimetre in scale. An X-ray tomography machine – the equivalent of a medical CT scanner – can create detailed high-resolution models of a component for a subsequent flythrough by engineering teams.

Product assurance and safety engineers also inspect the manufacturing facility of the candidate components, seeking to audit the suitability of the work environment.

"We would be looking at factors like cleanliness, the appropriate training and certification of the people involved, and the potential for cross-contamination, for instance with other materials or parts stored nearby. The aim is to demonstrate that the candidates can perform a task to a given level of quality again and again," concluded Wolfgang.



↑ The CROSS1 VUV-UV high-vacuum chamber at ESA's ESTEC facility in the Netherlands. This is used to recreate a space environment, subjecting test items to space-quality vacuum, temperature extremes and ultraviolet solar radiation – up to 13 times the sunlight experienced by satellites in Earth orbit (ESA/G. Schoonewille)

↑ Using an electron microscope to check for damage in micro-components in ESA's Materials and Electrical Components Laboratory, ESTEC (ESA/G. Schoonewille)

Launch of IXV on Vega flight VV04 on 11 February from Europe's Spaceport in Kourou, French Guiana

→ THE 100-MINUTE MISSION

The flight of the Intermediate eXperimental Vehicle

Giorgio Tumino and the IXV team
Directorate of Launchers, ESA Headquarters, Paris, France

ESA's experimental 'spaceplane' has completed its mission: showcasing the latest technologies and critical systems to extend Europe's capability for space exploration.

In a world first, Europe launched and landed its unmanned Intermediate eXperimental Vehicle (IXV), a spaceplane that has no wings but instead features an aerodynamic shape that produces enough lift to fly through the atmosphere.

IXV lifted off on 11 February from Europe's Spaceport in Kourou, French Guiana, on a Vega rocket. It separated from its Vega at an altitude of 340 km and continued up to 412 km. Reentering from this suborbital path, it recorded a vast amount of data from more than 300 advanced and conventional sensors.

IXV's entry speed of 7.5 km/s at an altitude of 120 km created the same conditions as those for a vehicle returning from low Earth orbit. As it descended, the spacecraft manoeuvred, using flaps and thrusters, to decelerate from hypersonic to supersonic speed. IXV glided through the atmosphere before deploying parachutes to slow the descent further for a safe splashdown in the Pacific Ocean, just west of the Galapagos Islands.

IXV was kept afloat by its flotation balloons while the recovery vessel *Nos Aries* hurried to pick it up. The vehicle will be returned to Europe for detailed analysis at ESA's ESTEC technical centre in the Netherlands.

Catching up in a strategically important area

Mastering reentry opens a new chapter for ESA. Most of our reentry knowledge comes from capsules and winged bodies developed in Russia and the USA in the 1960s and 1970s. But ESA has come a long way since its first experiments with the conical Atmospheric Reentry Demonstrator, or ARD, flown in 1998.

Such a capability is a cornerstone for reusable launcher stages, sample return from other planets and crew return from space, as well as for future Earth observation, microgravity research, satellite servicing and disposal missions. The IXV results will feed into the 'Programme for Reusable In-orbit Demonstrator for Europe' (PRIDE), a reusable spaceplane that would be launched on a Vega, orbit Earth and land automatically on a runway.

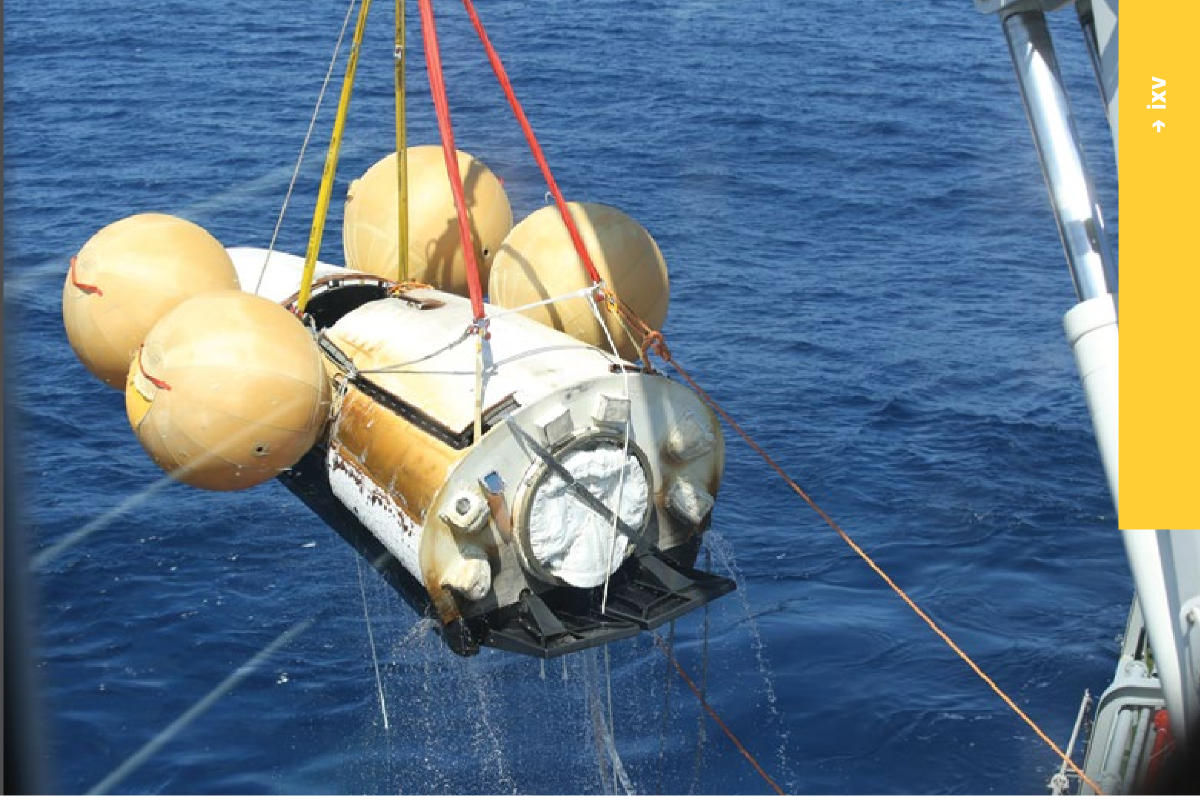
↑

Giorgio Tumino, ESA's IXV Programme Manager with Davide Nicolini, ESA Vega Operational Launch System Project Manager

> **This was a short mission with big impact**
>
> Giorgio Tumino, IXV Project Manager

→

Recovery of a heat-scarred but otherwise intact IXV in the Pacific Ocean (ESA/T. Javidi)



←

IXV kept afloat by its flotation balloons while awaiting recovery

The mission in depth

The IXV mission has pioneered a series of system and technological capabilities. On the system side, this was the first time that a full atmospheric reentry was performed from orbital speed using a 'lifting body' (a vehicle without wings, having the simplicity of quasi-ballistic capsules while exhibiting the performance of winged bodies with high controllability and manoeuvrability for precision landing).

On the technological side, this was the first time that in-flight verification had been performed for most of the advanced thermal protection materials and concepts, the advanced guidance navigation and control techniques, and of the advanced aerothermodynamics experiments.

Activities before launch

The IXV mission was based on an integrated space and ground segment design, able to perform the mission autonomously from launch, through operation in flight, to its recovery in the Pacific Ocean.

Six streams of activities were put in place to ensure the timely implementation of the IXV mission, namely:

- space and ground segments qualification and acceptance;
- space segment launch campaign;
- ground segment operations;
- recovery operations;
- logistics and transportation; and safety compliance.

The space and ground segment design, development, integration, qualification and acceptance activities were completed with the ESA review system. These highlighted the completeness of the verification programme, as well as the unknowns that would need in-flight qualification because of the experimental nature of the mission.

The space segment launch campaign activities began with the arrival of the IXV spacecraft in Kourou on 24 September 2014. These progressed smoothly for about five weeks, and then combined operations for Vega and IXV took place for approximately three weeks up to the launch, original scheduled for 18 November.

←

IXV being encapsulated in the Vega fairing at Kourou

Joint Vega and IXV operations culminate with the mating of the IXV/fairing composite with the launcher on 2 February

↑ The ESA team joins the *Nos Aries* recovery and tracking vessel in Panama

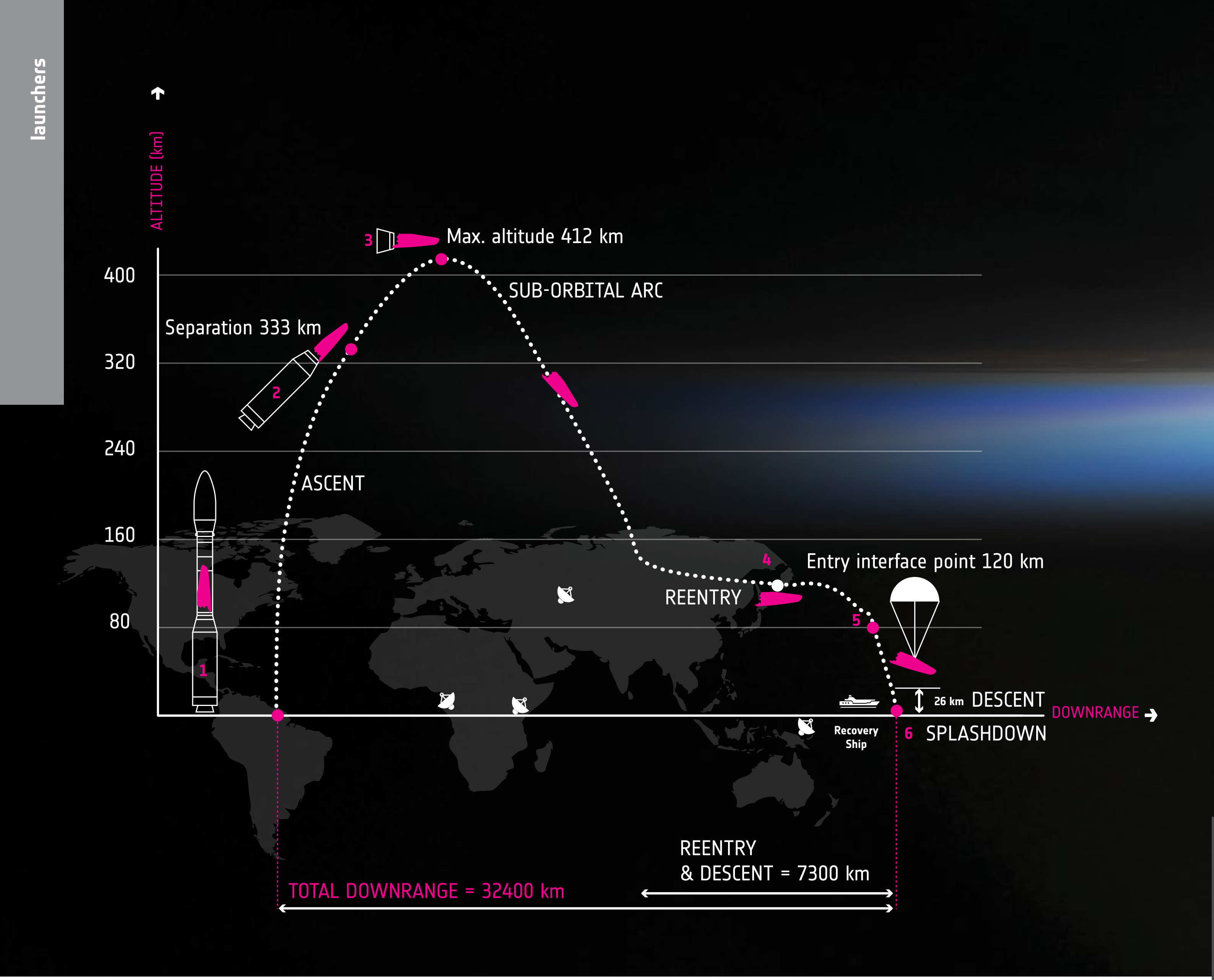
The ground segment operations activities began with the system simulations and an operational readiness review in Europe, progressing smoothly through the various system simulation campaigns, including dry-run dress rehearsals.

Recovery operations had started in June 2014 with the installation of the tracking equipment and the testing of the recovery systems on the recovery ship, the *Nos Aries*. The vessel departed from Genoa, Italy, on the 5 October, sailing across the Atlantic Ocean, to pick up the operational crew in Panama. On 23 October, a decision to postpone the launch was taken by the launch authorities as a result of safety concerns that required additional analysis.

A new launch date was announced and ESA's recovery team boarded the *Nos Aries* on 25 January while it was stationed in the Flamenco Island Anchorage in Panama. The ship then continued its long journey across the Pacific Ocean to arrive in the predicted splashdown area.

The logistics and transportation activities, the safety compliance activities and remaining mission preparatory activities progressed at speed towards the launch day. At the end of January, the ground segment side declared operational readiness, as did the space segment side, declaring final launch readiness.

↓ Fisheye view of the Vega VV04 vehicle, ready for launch



100 thrilling minutes for Europe

The IXV operational team deployed to different sites around the world, with the mission being coordinated from two centres: the Vega Launch Control Centre at Europe's Spaceport at Kourou, French Guiana, and the IXV Mission Control Centre at ALTEC (Advanced Logistics Technology Engineering Centre) in Turin, Italy.

In Kourou, from the Jupiter Room, the IXV Mission Director was in contact with the IXV Launch Campaign Manager in the Local Banc de Contrôle, also in Kourou, the IXV Operations Director in Turin and with the IXV Recovery Manager in the Pacific Ocean.

In turn, the IXV Operations Director was in contact with the Station Managers for the ground stations in Libreville (Gabon), Malindi (Kenya) and the tracking station on board the *Nos Aries* in the Pacific Ocean.

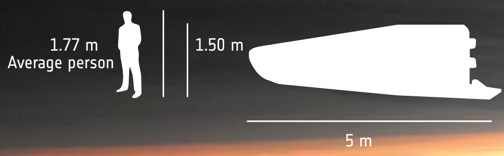
The mission lasted end-to-end approximately 102 minutes, including about 20 minutes from Vega liftoff to IXV separation over Libreville station, and 80 minutes from IXV separation until landing.

Among the most exciting moments were the successful separation of the spacecraft from the launcher and the acquisition of spacecraft telemetry from the ground stations in Libreville and in Malindi, confirming the

↓ ESA IXV tracking teams at Libreville, Gabon, and Malindi, Kenya

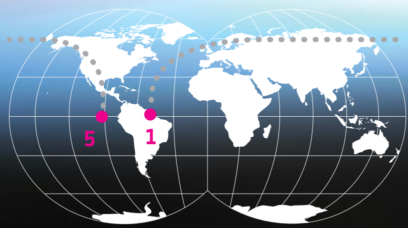
1
IXV lifts off on 11 February from Europe's Spaceport in Kourou, French Guiana

2
IXV separates from its Vega at an altitude of 333 km



3
IXV continues up to 412 km

4
Entry speed of 7.5 km/s at an altitude of 120 km – same conditions for a vehicle returning from low Earth orbit



5
IXV glides through the atmosphere before deploying parachutes.

6
Splashdown

> **IXV has opened a new chapter for ESA in terms of reentry capabilities and reusability.**
>
> Jean-Jacques Dordain, ESA Director General

correct execution of the in-orbit operations for the experimental phase.

But possibly the most thrilling moment was the receipt of spacecraft telemetry by the tracking station on the recovery ship, confirming that the spacecraft had survived the reentry phase and had begun downloading experimental data. This was followed by the successful deployment of the parachute, and the splashdown with buoyancy aids working perfectly.

↑ Liftoff of IXV on 11 February

Exploitation of flight data

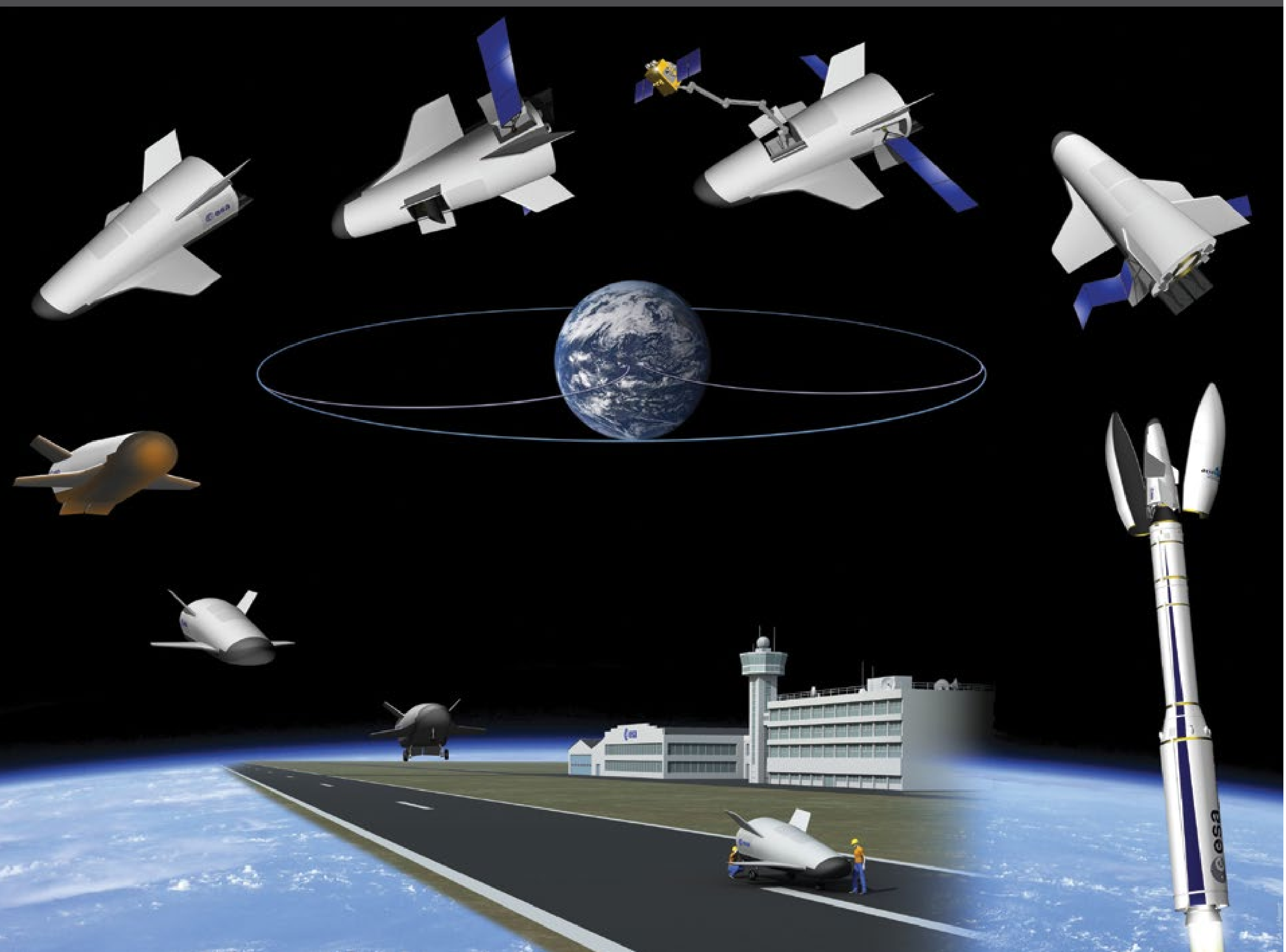
The mission has an extremely high technological and scientific return, thanks to the objective of reducing qualitatively and quantitatively the current uncertainties in our knowledge of the critical atmospheric reentry disciplines and technologies.

The corresponding in-flight experimentation plan included a large number of experiments, each one requiring a specific set of measurements.

With synergies found among the various experiments and corresponding measurement locations around the spacecraft, the number of sensors required to fulfil the inflight experimentation requirements was reduced. This included 37 pressure ports, 194 thermocouples, 12 displacement sensors, 48 strain gauges and one infrared camera.

An extensive post-flight data exploitation analysis will be performed, giving us a better understanding for future atmospheric reentry systems design.

↓ The future PRIDE project will focus on system and technology performance verification in all flight conditions (i.e. hypersonic, supersonic, transonic and subsonic) in an end-to-end European orbital mission with landing on a conventional runway (ESA/J. Huart)



←

IXV flight control team at ALTEC, Turin (ESA/P. Shlyaev)

→

A pensive-looking IXV Spacecraft Operations Manager, Stephane Dussy, in Turin (ESA/P. Shlyaev)

High technological return on investment

The mission has an extremely high technology return on the investment, thanks to technological synergies between IXV and other launcher developments, such as Vega and Ariane.

Specifically, the space segment development benefited in the field of the avionics by building on Ariane and Vega inertial measurement unit and batteries, the flap control used the design of Vega thrust vector control actuators, the reaction control was based on the Ariane 400 N thruster and the ablative thermal protection system was based on Vega P50 solutions.

The ground segment development has benefited from synergies in the field of the telemetry by using the Ariane and Vega S-band radio-frequency reception system and the auto-tracking capabilities of the seaborne antenna.

Such synergies were possible thanks to similarities in the real-time nature of the missions and their atmospheric environments, which are governed by the same disciplines (for example, aerodynamics and aerothermodynamics) even though in different operating conditions.

This meant that we could concentrate the financial resources of the programme on the experimental objectives at system, subsystem and technologies levels, while maximising the reuse of the available launcher technologies, upgrading them when required for IXV's specific operating conditions.

European cooperation

The IXV mission can be considered to be an extraordinary example of European cooperation. From the industry side, it has brought together competences from several European countries (Italy, France, Spain, Switzerland, Belgium, Ireland and Portugal, with the support of Germany and the Netherlands).

It harmonised the teamwork of about 40 companies, research centres and universities for an experimental mission that required industrial, technological and scientific expertise.

The mission also brought together competences from ESA and national agencies for the day-by-day follow-up of the industrial activities, as well as for the review of the industrial activities results at the completion of each critical design, development and qualification phase.

The future

The next step is the PRIDE programme, with its objective now refocused towards the definition and development of an affordable reusable European space transportation system. This would be launched by Vega and be able to perform multiple future application missions in low Earth orbit, benefiting from existing launcher technologies, and addressing where relevant the technological challenges with limited risks and minimal financial effort for Europe.

→ THE HUBBLE STORY

Celebrating 25 years in orbit with the Hubble Space Telescope

Carl Walker
Communications Department, ESTEC,
Noordwijk, The Netherlands

Hubble in orbit as seen by the crew of STS-125 (NASA)

On 24 April 1990, the Space Shuttle *Discovery* lifted off carrying a precious cargo. The following day, it released into orbit the Hubble Space Telescope, an observatory that would open our eyes to the wonders of space beyond the shores of our cosmic ocean.

The NASA/ESA Hubble Space Telescope is one of the greatest scientific projects of all times. Although not the first telescope in orbit, at launch Hubble was one of the largest and most versatile, and is well known as both a vital research tool for astronomers and a powerful ambassador for astronomy for the public at large.

Since its launch, Hubble has been greatly expanded in its scientific powers through new instrumentation installed during five servicing missions with the Space Shuttle. Its primary mirror is 2.4 m in diameter, not large by today's ground-based standards, but giving amazing performance in space.

↑ Edwin Hubble, after whom the Space Telescope was named (Carnegie Inst. for Science)

Why a telescope in space?

Since the dawn of civilisation, we have been limited in our understanding of the Universe by our vision. Telescopes enhanced this vision as observations by European astronomers in the 16th and 17th centuries, such as Copernicus, Galileo and Kepler, spearheaded the Scientific Revolution.

By the 18th century, telescopes had become indispensable instruments for studying the Universe. Telescopes became bigger and more effective, and technological advances in spectroscopy and photography increased their versatility, sensitivity and power.

However, astronomers still faced a major obstacle between them and a clear view of the Universe: Earth's atmosphere. Our planet's atmosphere is a fluid, a mix of gas, vapour and dust that blurs visible light, causing stars to twinkle and making it difficult to see faint objects.

Earth's atmosphere hinders or even totally absorbs some wavelengths of light, making observations in wavelengths such as infrared, ultraviolet or gamma rays difficult or totally impossible. Many of our best telescopes today are situated on mountains and away from sources of light pollution. But, even with the best optics and image processing techniques, the effects of the atmosphere cannot be totally eliminated.

Putting a telescope in space is one way of avoiding this problem. From its vantage point 575 km above Earth, Hubble can detect light with 'eyes' five times sharper than the best ground-based telescopes under normal conditions. As well as collecting visible light from its orbit high above the atmosphere, Hubble can also observe the infrared and ultraviolet wavelengths that are filtered out by the atmosphere.

→ History of Hubble

1920s

German rocket scientist Herman Oberth suggests a space-borne telescope as early as 1923 in his book *Die Rakete zu den Planetenräumen* (The Rocket into Planetary Space)

This view of the coil-shaped Helix Nebula is a composite of ultra-sharp Hubble images combined with a wide view from the 0.9-m telescope of Kitt Peak National Observatory (NASA/NOAO/ESA/STScI/NRAO)

1940s

US astrophysicist Lyman Spitzer writes about the scientific benefits of a telescope in space, above Earth's turbulent atmosphere, in 1946

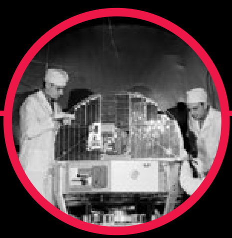
1960s

A report in 1962 by the US National Academy of Sciences recommends the development of a space telescope as part of the US space programme

The Cat's Eye Nebula (NGC 6543) was discovered by William Herschel in 1786. Hubble observations revealed it to be one of the most complex nebulae known of its kind, with 11 rings of gas making up the Cat's Eye and remarkable structures such as knots, jets and bubbles (NASA/ESA/STScI/AURA)

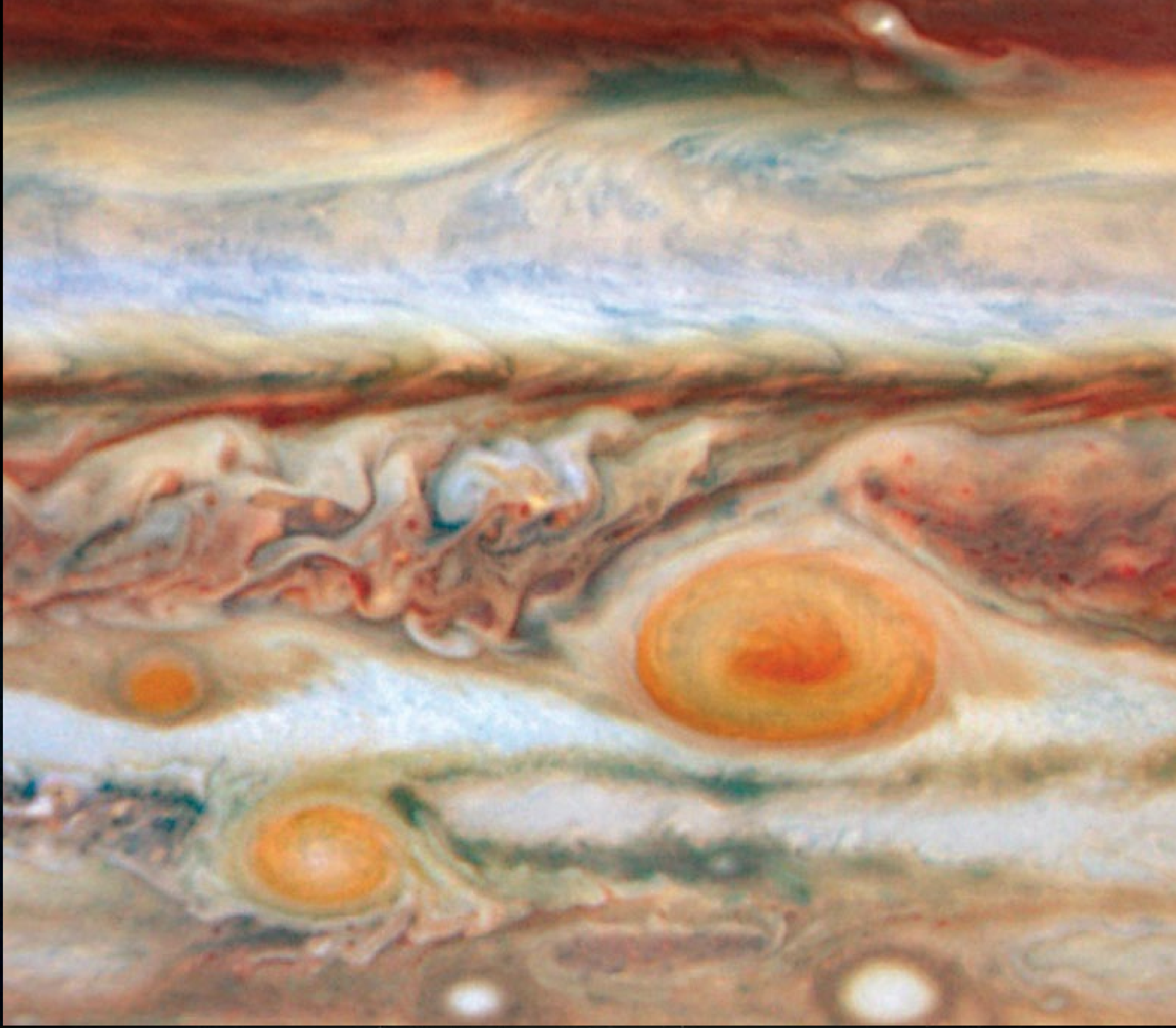
March 1962

NASA launches its Orbiting Solar Observatory OSO-1 satellite



1965

Lyman Spitzer appointed to head a NASA committee to define the scientific objectives for a large space telescope



← Hubble's 2008 view of a third red spot that appeared alongside the Great Red Spot (and Red Spot Jr., which appeared on 2006) in the turbulent atmosphere of Jupiter (NASA/ESA/Univ. Calif., Berkeley)

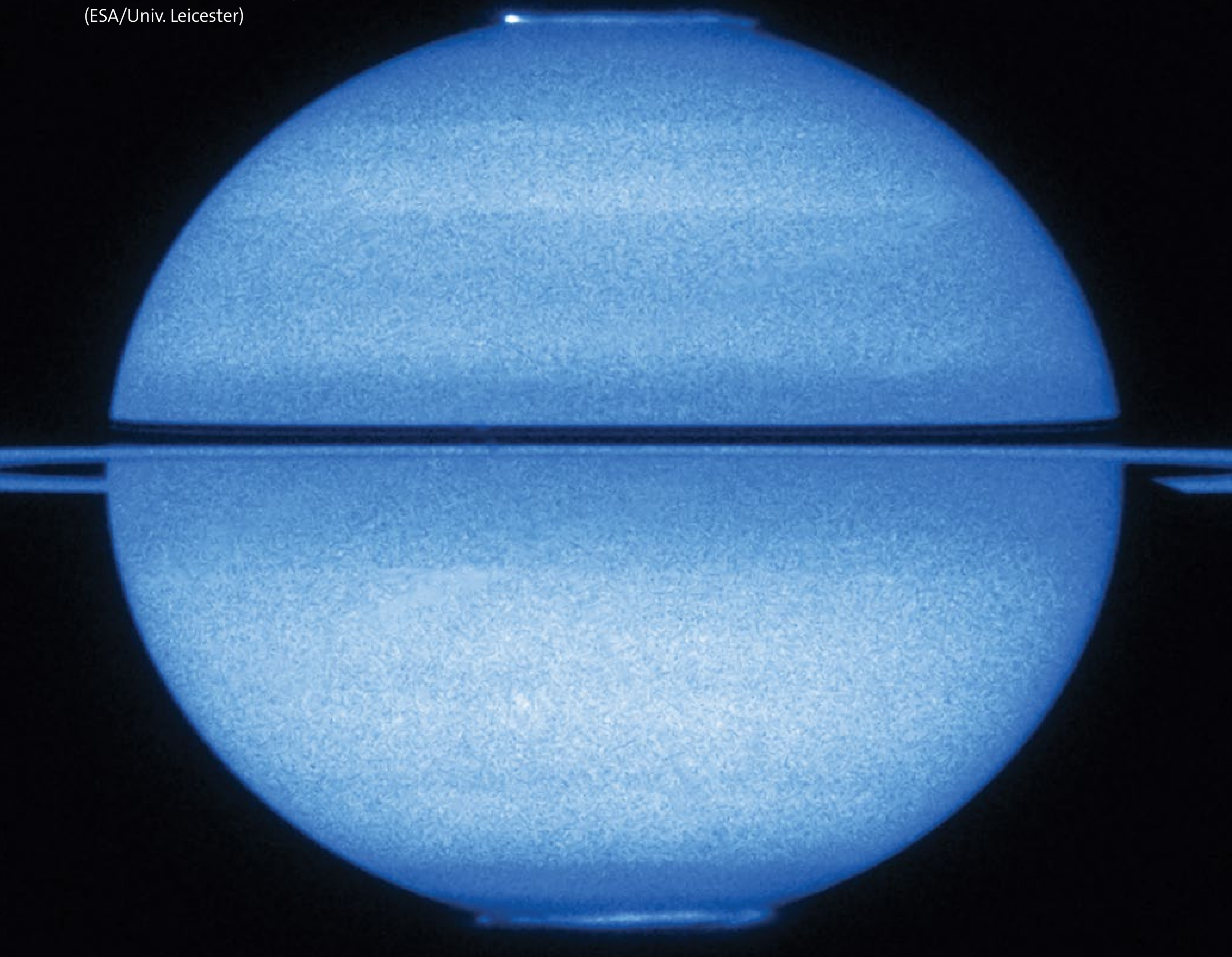
← One of the Universe's most stately and photogenic galaxies, the Sombrero galaxy, M104 (NASA/ESA/STScI/AURA)

1966

NASA launches the first Orbiting Astronomical Observatory

1968

NASA announces plans for a space-based reflecting telescope, provisionally known as the Large Space Telescope (LST)



A unique image from 2009 features Saturn with its rings edge-on and both poles in view, offering a stunning view of its almost symmetrical aurorae, Saturn's own 'northern' and 'southern lights' (ESA/Univ. Leicester)

1969

US National Academy of Sciences approves the LST with a mirror 3 m in diameter and a slated launch date of 1979

April 1974

NASA invites ESRO to contribute to the LST project


The planetary nebula NGC 6302 taken by Hubble after Servicing Mission 4 (NASA/ESA/ERO)

May 1975

European Space Agency created

June 1975

ESA/NASA joint working group set up to pursue negotiations between agencies and manage the LST project, now called 'Space Telescope'

→ The NGC 2070 star cluster is only a few million years old and resides in 30 Doradus, the 'Tarantula' Nebula, the largest stellar nursery in our local galactic neighbourhood. Taken by Hubble after Servicing Mission 4 (NASA/ESA/ERO)

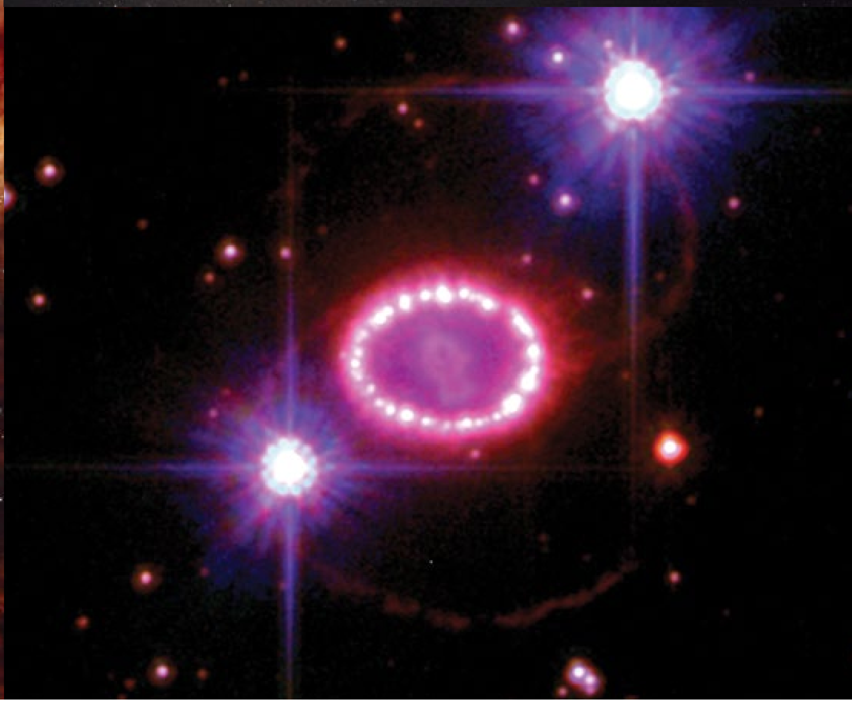
1977

US Congress approve funding for 1978, allowing the design of the Space Telescope to begin, with a launch date of 1983

October 1977

NASA/ESA Memorandum of Understanding signed, committing both organisations to building one of the most sophisticated satellites ever constructed

← Blobs of cold cosmic dust lie around the giant elliptical galaxy NGC 1316 (NASA/ESA/STScI/AURA)



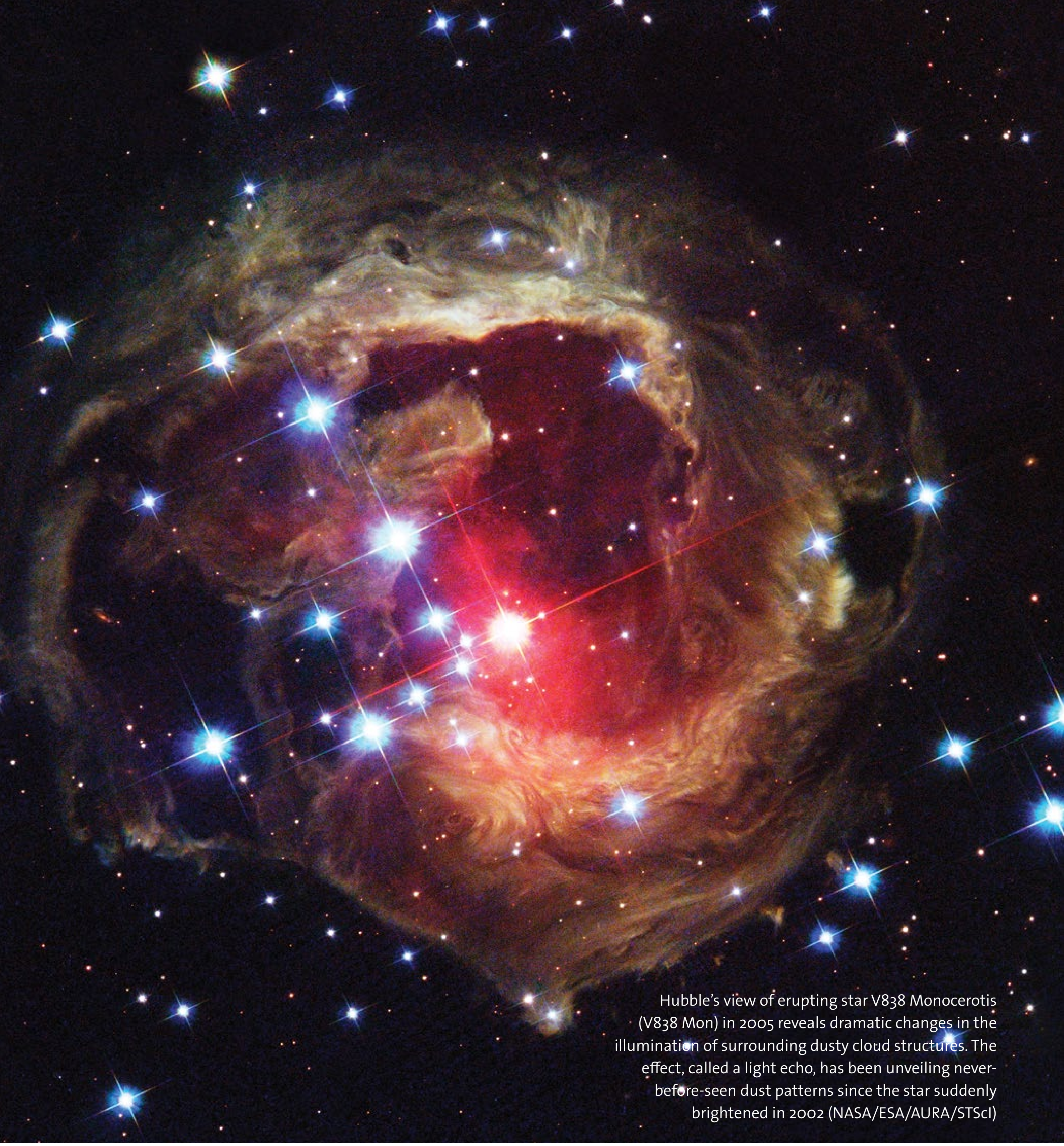
← The doomed star, Supernova 1987A, spotted two decades ago, was one of the brightest exploding stars in more than 400 years. This Hubble image shows a ring with dozens of bright spots in the region around the supernova in 1996 (NASA/ESA/Harvard-Smithsonian Center for Astrophysics)

1979

Construction of Hubble main 2.4 m mirror begins at prime contractor Perkin-Elmer

1981

The Space Telescope Science Institute (STScI) opens in Baltimore, Maryland, with staff including European astronomers



Hubble's view of erupting star V838 Monocerotis (V838 Mon) in 2005 reveals dramatic changes in the illumination of surrounding dusty cloud structures. The effect, called a light echo, has been unveiling never-before-seen dust patterns since the star suddenly brightened in 2002 (NASA/ESA/AURA/STScI)

1983

Renamed the Hubble Space Telescope (HST), after the renowned astronomer Edwin P. Hubble

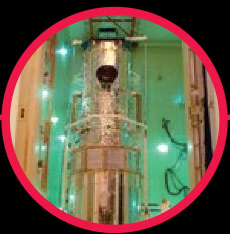
1984

Space Telescope European Coordinating Facility (ST-ECF) begins operations in Garching, Munich

← The Horsehead Nebula, part of the Orion Molecular Cloud, seen in infrared light in 2013 (NASA/ESA/STScI/AURA)

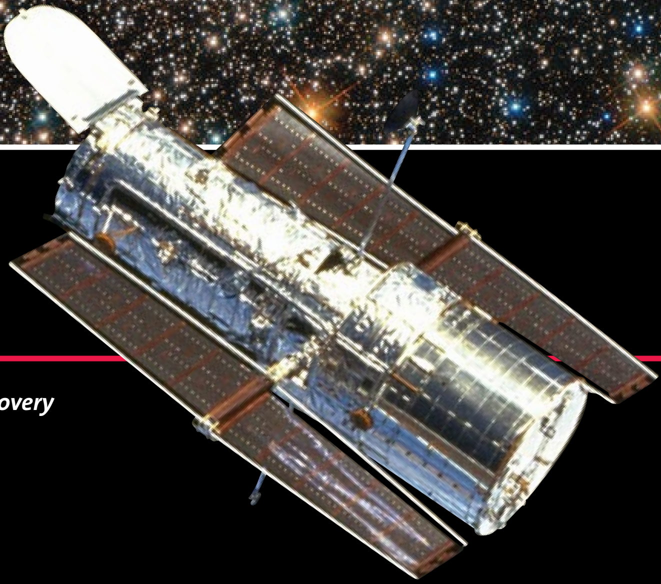
1985

Telescope assembly and integration is completed at Lockheed-Martin, USA



January 1986

The *Challenger* accident puts Shuttle launches on hold for two years



April 1990

The Hubble Space Telescope is launched on STS-31 *Discovery*

Hubble was finally launched by the Space Shuttle *Discovery* on 24 April 1990, and that date marked the beginning of a very successful collaboration between NASA and ESA that lasted more than two decades.

It laid the foundation for future collaborations with NASA, such as the one on the James Webb Space Telescope, and the close partnership that was necessary for cooperating in the future development of the International Space Station.

Although floating silently above us, Hubble still depends on its teams of engineers and scientists working together on both sides of the Atlantic. Over 25 years, the beauty of its images alone has been enough to inspire and fascinate people all over the world, but is also a constant reminder that we should be celebrating the spirit of endurance and cooperation that started decades ago and continues as strong today.

Launch on 24 April 1990 by Space Shuttle *Discovery*, STS-31 (NASA)

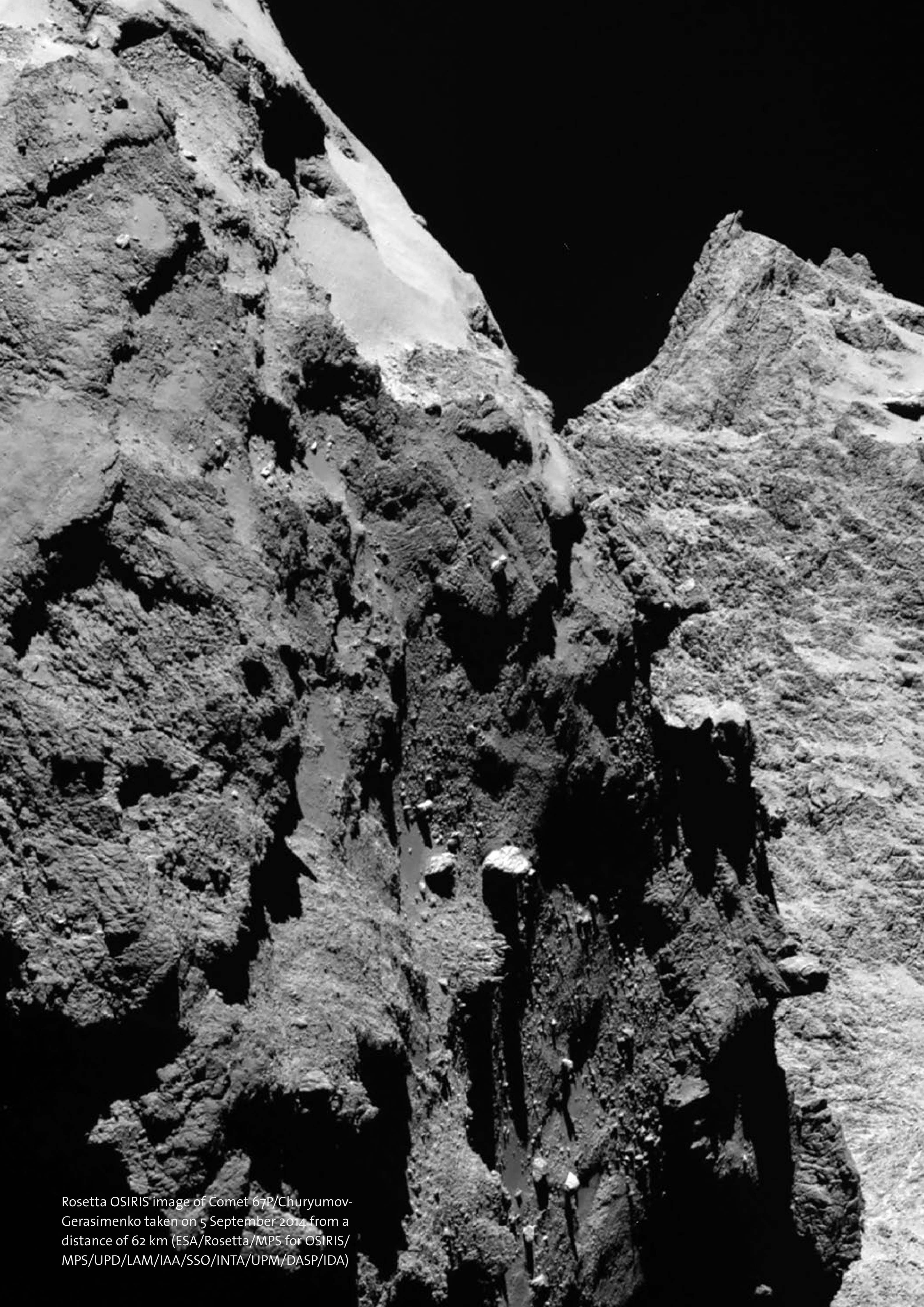
Further reading

- **The history of the Hubble Space Telescope and ESA's involvement**, by R.J. Laurance, *ESA Bulletin* 61, February 1990
- ***A History of the European Space Agency (1958–1987) Vol. II The story of ESA, 1973 to 1987***, by J. Krige, A. Russo and L. Sebesta, SP-1235, April 2000
- **The Hubble Story** http://www.nasa.gov/mission_pages/hubble/story/the_story.html
- **A Brief History of the Hubble Space Telescope**, by G. Okolski, http://history.nasa.gov/hubble/
- ***Fifty years of European cooperation in space: Building on its past, ESA shapes the future***, by J. Krige, Les Editions Beauchesne, June 2014

← This is Messier 15, one of the oldest globular clusters known, with an age of around 12 billion years. This view from Hubble was taken in 2013

←

Hubble away! The telescope is released by the Shuttle's robot arm on STS-31 (NASA)



Rosetta OSIRIS image of Comet 67P/Churyumov-Gerasimenko taken on 5 September 2014 from a distance of 62 km (ESA/Rosetta/MPS for OSIRIS/MPS/UPD/LAM/IAA/SSO/INTA/UPM/DASP/IDA)

→ 2014 IN PICTURES

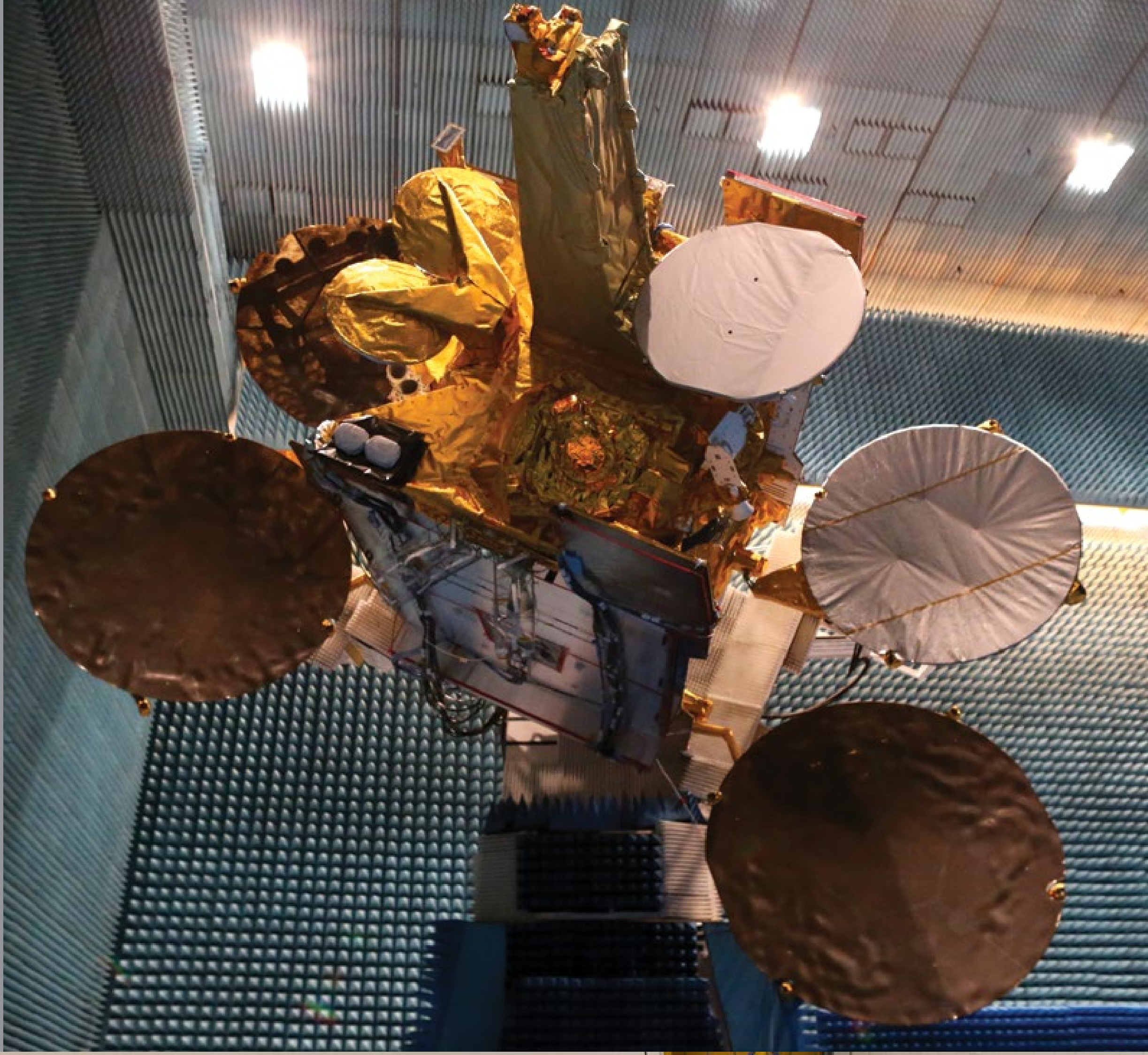
Some of the most memorable moments and inspirational images taken last year

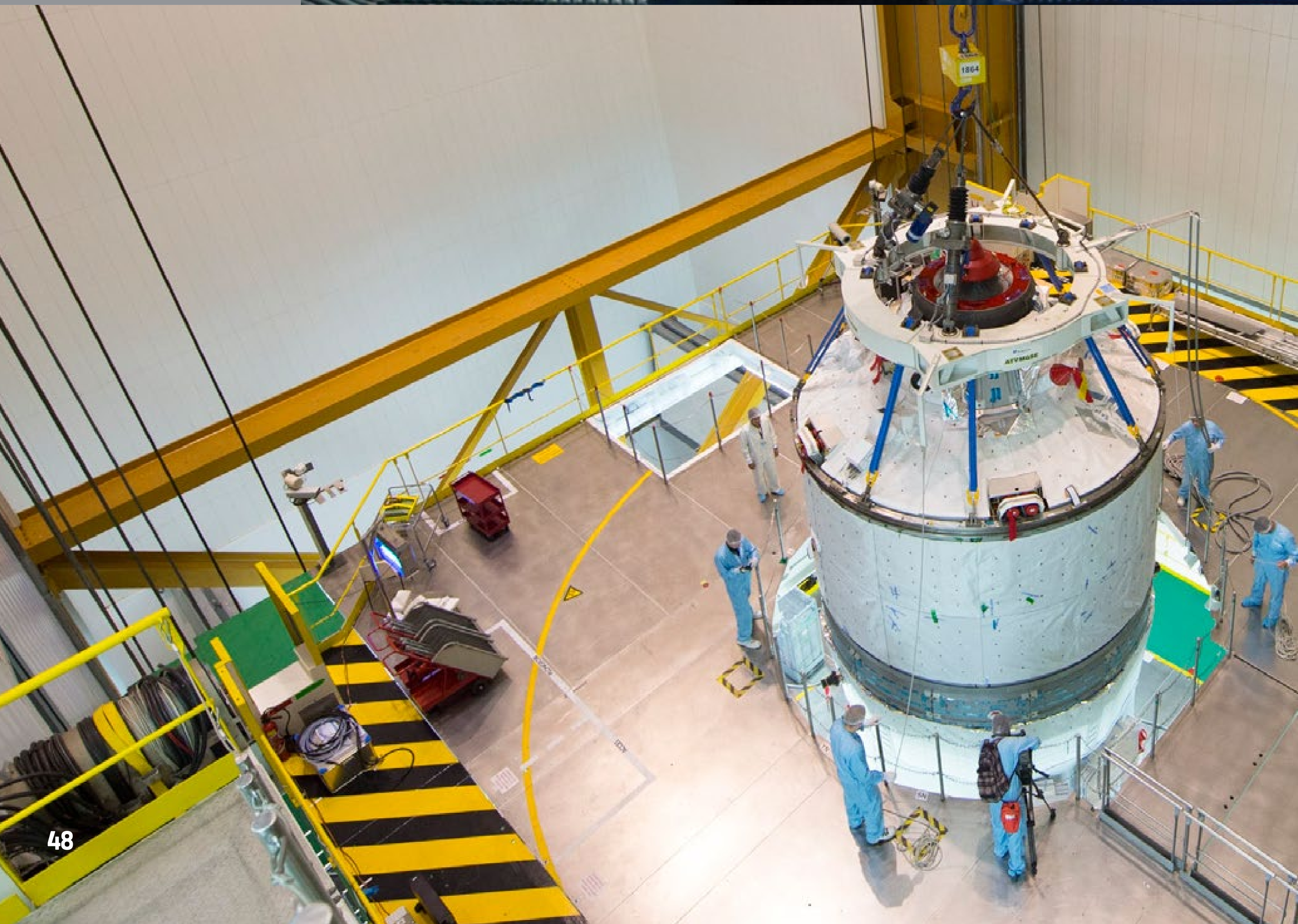
Launch of ATV *Georges Lemaître*, ESA's fifth and last Automated Transfer Vehicle, on 29 July 2014 (ESA/S. Corvaja)

ESA's CAVES team preparing the 2014 underground astronaut training course. CAVES – short for Cooperative Adventure for Valuing and Exercising human behaviour and performance Skills – offers astronauts, trainers and planners a chance to test space-like procedures while exploring uncharted caverns (ESA/A. Romeo)

→

The Eutelsat-9B satellite with its EDRS-A payload is shown in the anechoic test chamber of Airbus Defence & Space in Toulouse, France, having completed its final antenna pattern tests in November 2014 (Airbus Defence & Space)





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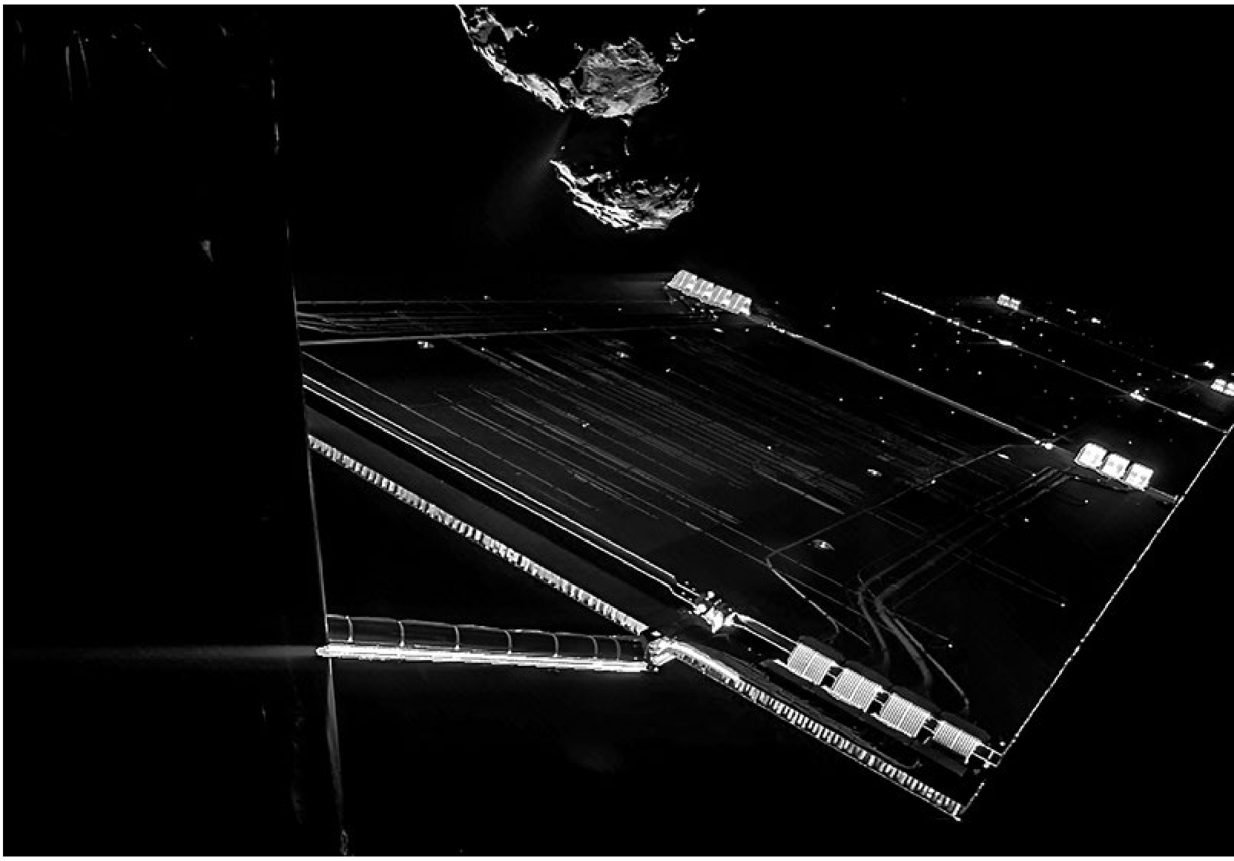
On 30 October 2014, the Mercury Planetary Orbiter, one of the two spacecraft of ESA's BepiColombo mission, was installed in the Large Space Simulator at the ESTEC technical centre in Noordwijk, the Netherlands (ESA/A. Le'Floch)

←

On 26 June 2014, the ATV *Georges Lemaître* spacecraft is integrated on its Ariane 5 launcher in the BAF (Final Assembly Building) at Europe's Spaceport in Kourou, French Guiana (ESA/S. Corvaja)

→

Mission controllers cheer the first signal received from the Rosetta spacecraft on 20 January 2014. Rosetta had woken up 807 million km away after 31 months of deep-space hibernation (ESA/J. Mai)



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Rosetta's Philae lander snapped a 'selfie' at Comet 67P/Churyumov–Gerasimenko from a distance of about 16 km from the comet. This image was taken on 7 October and shows one of Rosetta's solar wings with the comet in the background (ESA/Rosetta/Philae/CIVA)

→

ESA Director General Jean-Jacques Dordain and Director of Human Spaceflight & Operations Thomas Reiter react after the signal from Rosetta is received at ESOC (R. Orlowski/Reuters)

←

Ukrainian astronomer Klim Churyumov at ESA's mission control in Darmstadt, Germany, during the landing on Comet 67P/Churyumov-Gerasimenko (ESA/J. Mai)

←

Svetlana Gerasimenko, holding a 3D model of 'her' Comet 67P/Churyumov-Gerasimenko, at the German Aerospace Center event for the comet landing in November 2014 (DLR)

→ NEWS IN BRIEF

The fifth and final Automated Transfer Vehicle, ATV Georges Lemaître, burns up harmlessly in a controlled reentry over the Pacific Ocean on 15 February (NASA/ESA)

New Member States

Estonia and Hungary signed Accession Agreements to the ESA Convention earlier this year, to become the 21st and 22nd ESA Member States respectively.

Above: Estonia's signing ceremony on 4 February at ESA Headquarters.
Below: Hungary's signing ceremony on 24 February in Budapest

Estonia's signing ceremony took place on 4 February at the ESA Headquarters in Paris with the participation of ESA Director General Jean-Jacques Dordain, Estonian Minister of Economic Affairs and Communications Anne Sulling, Head of the Estonian Space Committee Ene Ergma and the Estonian Ambassador in France, Sven Jürgenson.

For Hungary, the signing ceremony took place on 24 February at the Palace of Arts in Budapest with Jean-Jacques Dordain and Ákos Kara, Minister of State for Infocommunication and Consumer Protection, and Fruzsina Tari, Head of the Hungarian Space Office.

Estonia has a long tradition in astrophysics research and has contributed to several ESA scientific and technology projects. The country participated in the Plan for European Cooperating States (PECS). Estonia's first satellite, ESTCube-1, was launched on a Vega flight in 2013.

Hungary was the first central European state to sign a Cooperation Agreement with ESA in 1991. The country also became the first European Cooperating State (ECS), signing the ECS Agreement on 7 April 2003 in Budapest. Hungary's first satellite, MaSat-1, a cubesat-type satellite, was launched on the Vega maiden flight in 2012.

Later this year, the governments of both countries will conclude their ratification processes to become officially ESA Member States.

Biomass selected

The green light has been given for full implementation of Biomass, ESA's seventh Earth Explorer mission, for launch in 2020.

The mission was initially selected in 2013 and addresses one of the most fundamental components in the Earth system: the status and dynamics of tropical forests. Its primary scientific objectives are to determine the distribution of above-ground biomass in these forests and to measure annual changes in this stock over the period of the mission.

The amount of biomass and forest height will be measured at a resolution of 200 m, and forest disturbances such as clear-cutting at a resolution of 50 m, providing an important tool for sustainable forest management.

The mission will provide the first opportunity to explore Earth's surface at the 'P-band' radar frequency from space. In addition to studying forests, the data are expected to be used for monitoring the ionosphere, glaciers and ice sheets, and for mapping subsurface geology in deserts and surface topography below dense vegetation.

Integral orbit adjusted

Integral, one of ESA's longest-serving and most successful space observatories, began a series of manoeuvres carefully designed to balance its scientific life with a safe reentry in 2029.

Since 2002, ESA's Integral spacecraft has been observing some of the most violent events in the Universe, including gamma-ray bursts and black holes. While it still has years of life ahead, its fuel will certainly run out one day.

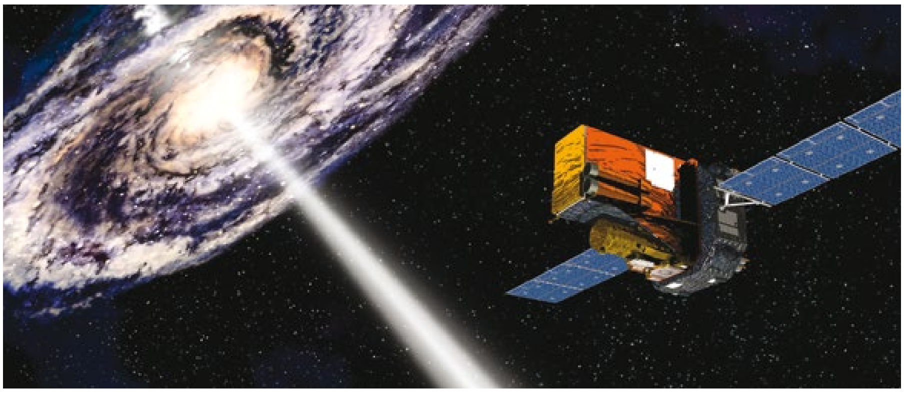
This is the first time that a spacecraft's orbit is being adjusted, after 12 years in space, to achieve a safe reentry 15 years in the future, while maximising valuable science return for the subsequent seven to eight years.

That seems far off, but detailed planning and teamwork now will ensure that the satellite's eventual entry into the atmosphere will meet ESA's guidelines for minimising space debris.

Making these disposal manoeuvres so early will also minimise fuel usage, allowing ESA to exploit the valuable satellite's lifetime to the fullest.

The latest ESA debris guidelines require that a satellite must be disposed of in such a way that it poses no risk to other satellites in protected orbital regions for more than 25 years. Although Integral's early launch date, in 2002, means it is not required to stick to the guidelines, they were followed for planning the disposal.

The mission celebrated its 10th anniversary in orbit in 2012, and is currently extended until December 2016. With the burns complete, Integral will continue scientific observations until its fuel runs out in the early 2020s.



Cooperation widens

Slovakia and Bulgaria became the ninth and tenth countries to sign European Cooperating State (ECS) Agreements with ESA.

These agreements strengthen the countries' relations with ESA. Slovakia signed the ECS agreement in Bratislava on 16 February, after signature of its first Cooperation Agreement in April 2010. Bulgaria signed the ECS agreement in Sofia on 8 April.

The selection of the potential Plan for European Cooperating States (PECS) projects starts soon after the signatures, and the PECS Charter should be signed by Slovakian and Bulgarian governments not later than later than 16 February and 8 April 2016 respectively.

Pesquet mission announced

The next crews to visit the International Space Station, including ESA astronaut Thomas Pesquet, were announced in February.

It was announced March 2014 that Thomas would be assigned to a long-duration mission on the ISS. Now his crew has been selected, and Thomas will fly on Soyuz with NASA astronaut Peggy Whitson and Roscosmos cosmonaut Oleg Novitsky. They will join Expedition 50 crewmates Shane Kimbrough, Andrei Borisenko and Sergei Ryzhikov.

Peggy is one of NASA's most experienced astronauts, having already completed two missions totalling 192 days in space and completing six spacewalks lasting more 39 hours. Oleg has a military background and is an experienced pilot, diver and parachute instructor.

Thomas said: "I'm thrilled to fly to space with such a talented crew. Oleg is the best pilot-cosmonaut Russia has to offer, and Peggy knows the International Space Station inside out. I will have to keep up with the pace and learn as much as possible."

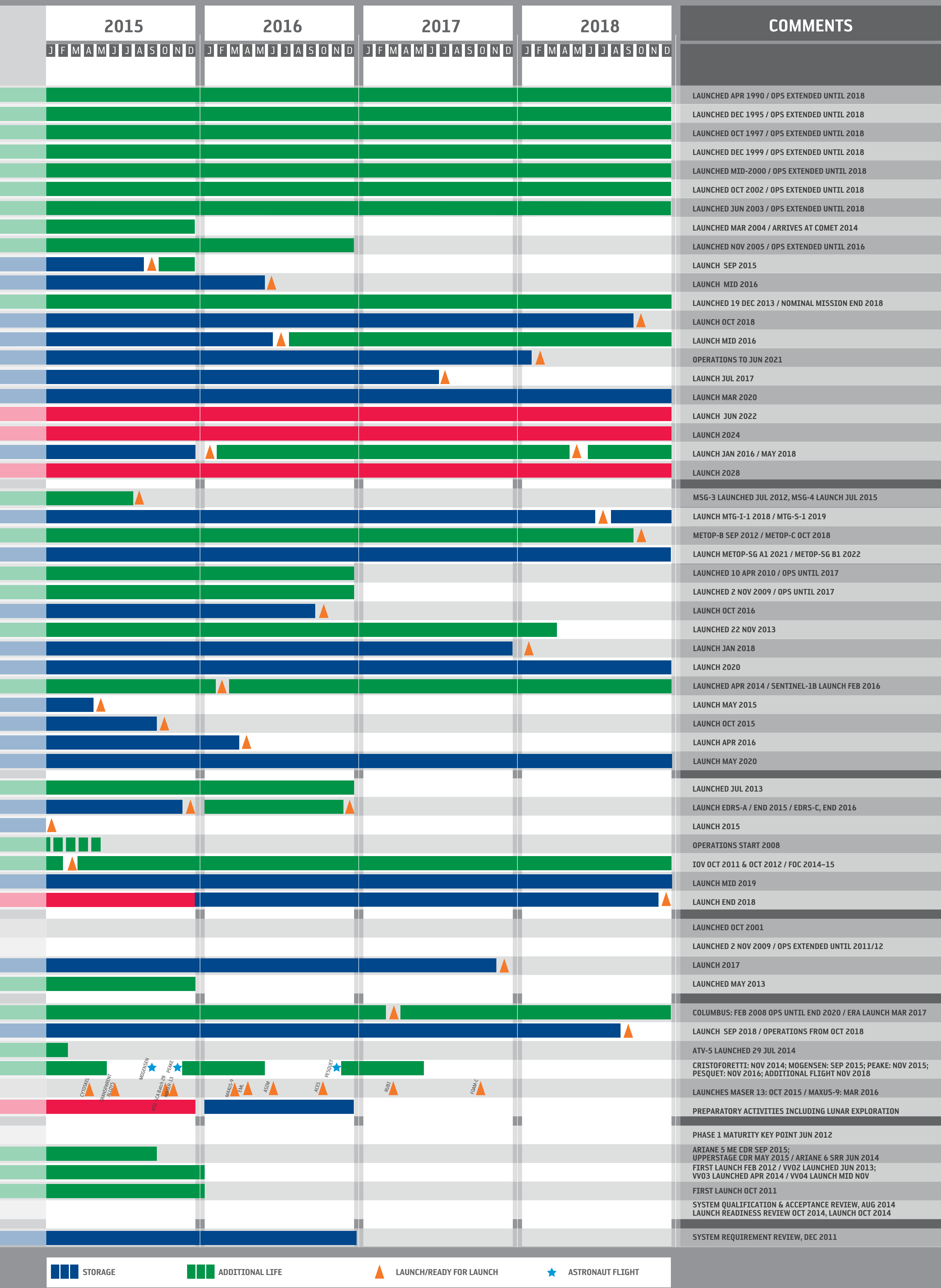
→ PROGRAMMES IN PROGRESS

Status at end January 2015

ESA-sponsored medical doctor Beth Healey who begins her stay at Concordia station in Antarctica in March (ESA/IPEV/PNRA–B. Healy)


Rab


2011
2012
2013
2014
J F M A M J J A S O N D
SCIENCE & ROBOTIC EXPLORATION PROGRAMME
HUBBLE
SOHO
CASSINI-HUYGENS
XMM-NEWTON
CLUSTER
INTEGRAL
MARS EXPRESS
ROSETTA
VENUS EXPRESS
LISA PATHFINDER
MICROSCOPE
GAIA
JWST
BEPICOLOMBO
CHEOPS
SOLAR ORBITER (M1)
EUCLID (M2)
JUICE (L1)
PLATO (M3)
EXOMARS
ATHENA (L2)
EARTH OBSERVATION PROGRAMME
MSG
MTG
METOP
METOP-SG
CRYOSAT
SMOS
AEOLUS
SWARM
EARTHCARE
BIOMASS
SENTINEL-1
SENTINEL-2
SENTINEL-3
SENTINEL-5 PRECURSOR
SENTINEL-6
TELECOMMS/NAVIGATION PROGRAMMES
ALPHASAT
EDRS
SMALLGEO
GNSS-1/EGNOS
GALILEO
ELECTRA
NEOSAT
TECHNOLOGY PROGRAMME
PROBA-1
PROBA-2
PROBA-3
PROBA-V
HUMAN SPACEFLIGHT PROGRAMME
COLUMBUS & ERA
MPCV-ESM
ATV
ASTRONAUT FLIGHTS
ELIPS PAYLOADS
TRANSPORTATION & HUMAN EXPLORATION
VITTORI
KUIPERS
PARMITANO
GERST
MASER-12
FASES
FASTER
EML
PK-4
LAUNCHER PROGRAMME
ARIANE 5 POST-ECA
ARIANE 5 ME & ARIANE 6
VEGA
SOYUZ AT CSG
IXV
SSA
PERIOD 2
DEFINITION PHASE
MAIN DEVELOPMENT PHASE
OPERATIONS


2015
2016
2017
2018
J F M A M J J A S O N D
COMMENTS
LAUNCHED APR 1990 / OPS EXTENDED UNTIL 2018
LAUNCHED DEC 1995 / OPS EXTENDED UNTIL 2018
LAUNCHED OCT 1997 / OPS EXTENDED UNTIL 2018
LAUNCHED DEC 1999 / OPS EXTENDED UNTIL 2018
LAUNCHED MID-2000 / OPS EXTENDED UNTIL 2018
LAUNCHED OCT 2002 / OPS EXTENDED UNTIL 2018
LAUNCHED JUN 2003 / OPS EXTENDED UNTIL 2018
LAUNCHED MAR 2004 / ARRIVES AT COMET 2014
LAUNCHED NOV 2005 / OPS EXTENDED UNTIL 2016
LAUNCH SEP 2015
LAUNCH MID 2016
LAUNCHED 19 DEC 2013 / NOMINAL MISSION END 2018
LAUNCH OCT 2018
LAUNCH MID 2016
OPERATIONS TO JUN 2021
LAUNCH JUL 2017
LAUNCH MAR 2020
LAUNCH JUN 2022
LAUNCH 2024
LAUNCH JAN 2016 / MAY 2018
LAUNCH 2028
MSG-3 LAUNCHED JUL 2012, MSG-4 LAUNCH JUL 2015
LAUNCH MTG-I-1 2018 / MTG-S-1 2019
METOP-B SEP 2012 / METOP-C OCT 2018
LAUNCH METOP-SG A1 2021 / METOP-SG B1 2022
LAUNCHED 10 APR 2010 / OPS UNTIL 2017
LAUNCHED 2 NOV 2009 / OPS UNTIL 2017
LAUNCH OCT 2016
LAUNCHED 22 NOV 2013
LAUNCH JAN 2018
LAUNCH 2020
LAUNCHED APR 2014 / SENTINEL-1B LAUNCH FEB 2016
LAUNCH MAY 2015
LAUNCH OCT 2015
LAUNCH APR 2016
LAUNCH MAY 2020
LAUNCHED JUL 2013
LAUNCH EDRS-A / END 2015 / EDRS-C, END 2016
LAUNCH 2015
OPERATIONS START 2008
IOV OCT 2011 & OCT 2012 / FOC 2014–15
LAUNCH MID 2019
LAUNCH END 2018
LAUNCHED OCT 2001
LAUNCHED 2 NOV 2009 / OPS EXTENDED UNTIL 2011/12
LAUNCH 2017
LAUNCHED MAY 2013
COLUMBUS: FEB 2008 OPS UNTIL END 2020 / ERA LAUNCH MAR 2017
LAUNCH SEP 2018 / OPERATIONS FROM OCT 2018
ATV-5 LAUNCHED 29 JUL 2014
CRISTOFORETTI: NOV 2014; MOGENSEN: SEP 2015; PEAKE: NOV 2015; PESQUET: NOV 2016; ADDITIONAL FLIGHT NOV 2018
LAUNCHES MASER 13: OCT 2015 / MAXUS-9: MAR 2016
PREPARATORY ACTIVITIES INCLUDING LUNAR EXPLORATION
PHASE 1 MATURITY KEY POINT JUN 2012
ARIANE 5 ME CDR SEP 2015; UPPERSTAGE CDR MAY 2015 / ARIANE 6 SRR JUN 2014
FIRST LAUNCH FEB 2012 / VV02 LAUNCHED JUN 2013; VV03 LAUNCHED APR 2014 / VV04 LAUNCH MID NOV
FIRST LAUNCH OCT 2011
SYSTEM QUALIFICATION & ACCEPTANCE REVIEW, AUG 2014 LAUNCH READINESS REVIEW OCT 2014, LAUNCH OCT 2014
SYSTEM REQUIREMENT REVIEW, DEC 2011
MOGENSEN
PEAKE
PESQUET
MAXUS-9
EML
ASIM
ACES
RUBI
FOAM-C
STORAGE
ADDITIONAL LIFE
LAUNCH/READY FOR LAUNCH
ASTRONAUT FLIGHT

KEY TO ACRONYMS

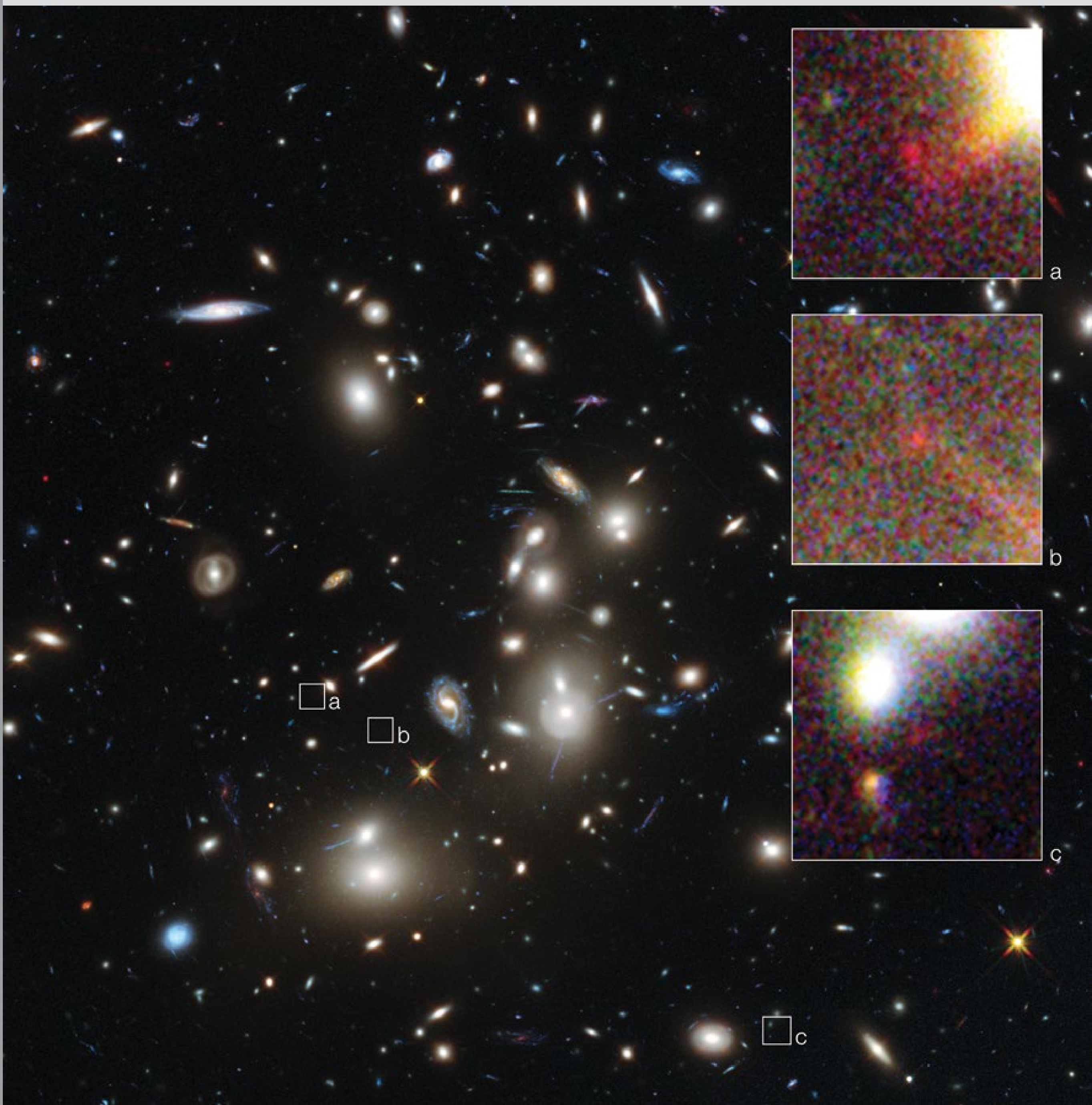
AM - Avionics Model	ITT - Invitation to Tender
AO - Announcement of Opportunity	LEOP-Launch and Early Orbit Phase
AIT - Assembly, integration and test	MoU- Memorandum of Understanding
AU - Astronomical Unit	PDR - Preliminary Design Review
CDR - Critical Design Review	PFM- Proto-flight Model
CSG - Centre 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

→ HUBBLE SPACE TELESCOPE

Hubble has made what may be the most reliable distance measurement yet of an object that existed in the early Universe. The distance to one of the faintest, smallest and most distant galaxies ever seen has been measured with an accuracy that is only possible because of the incredibly detailed mapping of how giant galaxy clusters warp the space-time around them.

Astronomers often use gravitational lensing — the magnifying power of galaxy clusters — to find distant galaxies. However, when it comes to the very

The huge galaxy cluster Abell 2744, seen by Hubble's Wide Field Camera 3 and Advanced Camera for Surveys. The three marked areas show three images of a single, very distant galaxy whose light has taken 13 billion years to reach us. The galaxy has been magnified and multiplied by gravitational lensing from Abell 2744 (NASA/ESA)



early Universe, distance measurements can become inaccurate because the objects are so faint. Now, a team of astronomers has combined a traditional method of distance measurement with some clever reverse engineering to vastly improve accuracy.

The lensing power of the giant galaxy cluster Abell 2744, nicknamed Pandora's Cluster, focused the light from the faraway galaxy, making it appear about ten times brighter than usual and visible to astronomers. The lensing also produced three magnified images of the same galaxy.

By analysing the colour of the faraway galaxy, the team could estimate its distance. Since the light left the galaxy, the Universe's expansion has stretched its wavelength, shifting its colour towards red in the spectrum. This colour change can be measured and quantified as a redshift. For this galaxy, the team estimated a redshift of 10, almost a record-breaking value, which means that its light has taken over 13 billion years to reach us.

To verify the accuracy of their measurement, the team used the multiple images produced by the lens, measuring the angular distance of the galaxy and comparing them to those for less distant galaxies also lensed by the cluster — the greater the angular separation, the further away the object is.

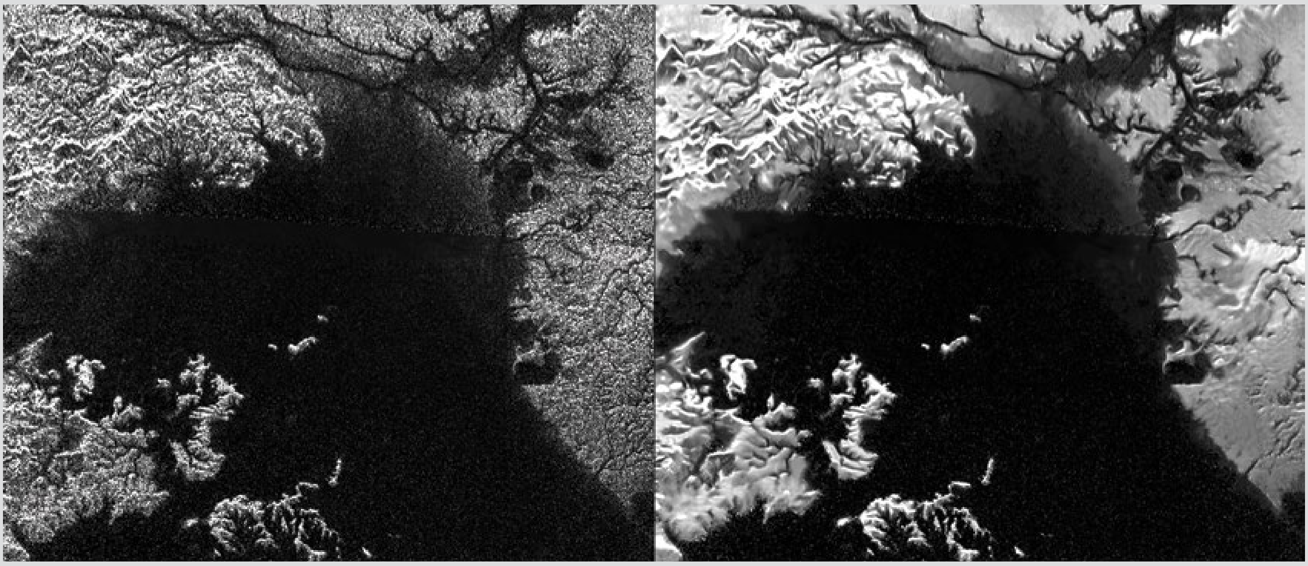
The astronomers had already characterised the cluster and the distorting effects of its gravitational lens so well that they could then tell how far the remote galaxy was behind the lensing cluster.

By combining a traditional analysis of the colours with the reverse engineering of the lens, the team calculated a robust distance measurement at a redshift of about 10. The galaxy appears as a tiny blob only a small fraction of the size of the Milky Way when the Universe was only about 500 million years old, roughly three percent of its current age of 13.8 billion years. While about ten other galaxy candidates have been uncovered from this early era, this newly found galaxy is significantly smaller and fainter than most of those other remote objects.

Analysis of the galaxy shows that it measures 850 light-years across and is estimated to have a mass of 40 million times that of the Sun – tiny when compared to our own galaxy, which spans more than 100 000 light-years. It also creates about one star every three years. Although this is only a third of the star formation rate in the Milky Way, it is prolific for a galaxy this small, showing that the galaxy is rapidly evolving and efficiently forming stars.

→ CASSINI-HUYGENS

Greatly enhanced images, taken by the Cassini Radar, have been produced of regions of Titan that have been observed during the mission. These new images allow better interpretation of small-scale geological and hydrological features on Titan's surface, including possible changes over time. The high resolution enables lakes' shorelines, fluvial features and their connection with the lakes to be seen with better accuracy. Analysis of the dunes' distribution orientation and shape is also greatly facilitated by these



A comparison of a traditional Cassini Synthetic Aperture Radar view and one made using a new technique for handling electronic noise that results in clearer views of Titan's surface. The technique, called 'despeckling', produces images that can be easier for researchers to interpret (NASA/JPL-Caltech/ASI) enhanced radar images. They will also be used to create improved Digital Terrain Models of Titan's surface.

→ XMM-NEWTON

Using data from NASA's Wide-field Infrared Survey Explorer (WISE), hundreds of dwarf galaxies have been discovered that display evidence for accreting massive black holes at their cores. XMM-Newton's observation of one of these galaxies, irregular dwarf galaxy J132932.41+323417.0, revealed an X-ray source one hundred times brighter than expected. Its combined X-ray and infrared properties can only be explained by the presence of a supermassive black hole. Supermassive black holes are normally found only at the centre of large galaxies and little is known about their presence in smaller galaxies. Understanding the fraction of small galaxies that have black holes at their centres and how massive these black holes are is very important because it could tell us how supermassive black holes form – something astronomers still don't fully understand.

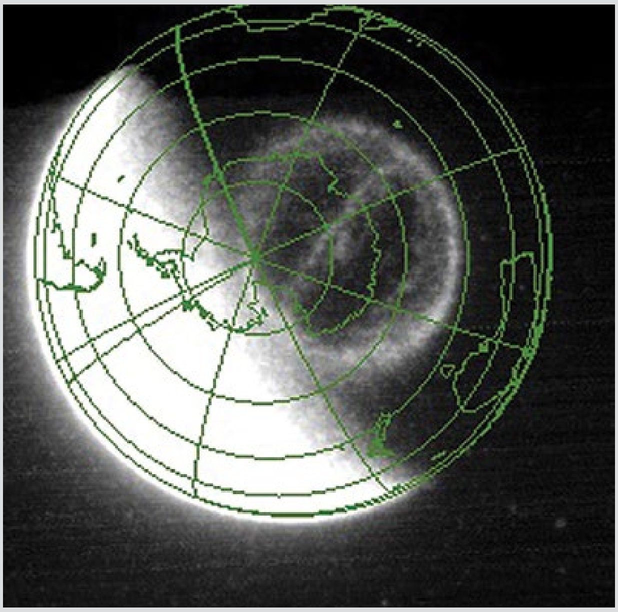
→ CLUSTER

Auroras are the most visible manifestation of the Sun's effect on Earth, but many aspects of these spectacular displays are still poorly understood. For the first time, another aspect of the Sun–Earth connection has now been revealed: the origin of a particular type of high-latitude aurora, called the theta aurora. Thanks to a combination of in situ measurements from ESA's Cluster satellites and the wide-field view from NASA's IMAGE satellite, this phenomenon has been explained.

Although separated by some 150 million km, the Sun and Earth are connected by the solar wind. This stream of plasma – electrically charged atomic particles – is launched by the Sun and travels across the Solar System, carrying its own magnetic field. When this interplanetary magnetic field arrives near Earth, there can be various results, depending on how it aligns with Earth's magnetic field. When the interplanetary magnetic field points northward, auroras can occur at higher latitudes than usual. One such type is known as a 'theta aurora' because seen from above it looks like the Greek letter theta – an oval with a line crossing through the centre.

While the genesis of the auroral oval emissions is reasonably well understood, the origin of the theta aurora was previously unclear. This mystery has now been solved after studying data collected simultaneously by the Cluster and IMAGE satellites on 15 September 2005. While the four Cluster satellites were located in the southern hemisphere magnetic lobe, IMAGE had a wide-field view of the southern hemisphere aurora. When one Cluster satellite observed uncharacteristically energetic plasma in the lobe, IMAGE saw the arc of the theta aurora cross the magnetic footprint of Cluster.

It was found that the energetic plasma signatures occur on high-latitude magnetic field lines that have been 'closed' by the process of magnetic reconnection, which then causes the plasma to become relatively hot. Because the field lines are closed, the observations are incompatible with direct entry from the solar wind. By testing this and other predictions about the behaviour of the theta aurora, these observations provide strong evidence that the plasma trapping mechanism is responsible for the theta aurora.



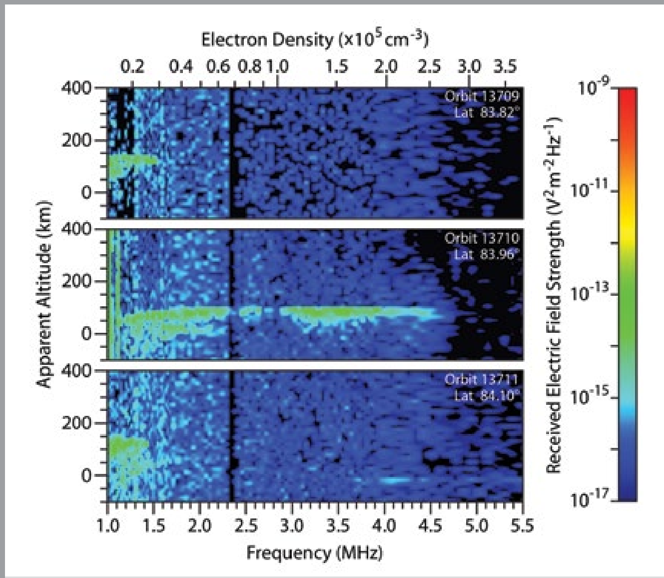
The theta aurora as seen by NASA's IMAGE satellite on 15 September 2005. The green lines are latitude and longitude lines and outlines of continents: Australia to the right, South America to the left and Antarctica in the middle. The theta aurora is visible slightly off-centre, above the right-hand side of Antarctica. The bright region to the left is the sunlit atmosphere (NASA/R. Fear *et al.*)

→ INTEGRAL

In August 2011, a new hard X-ray source, IGR J17361-4441, was discovered in the globular cluster NGC 6388 by Integral. This cluster lies at about 13.2 kpc from Earth (about 40 000 light years). Excitement arose because this emission could have been a result of the intermediate-mass black hole in the centre of NGC 6388 tidally disrupting a star. Previous observations with the Chandra X-ray observatory, however, revealed that the position of IGR J17361-4441 is not consistent with the gravitational centre of the cluster, and the source of hard X-rays could not have been the intermediate-mass black hole.

Integral: artist impression of a planet ripped apart by gravitational forces (A. Nucita)

Various observations (including from Integral) and theoretical considerations now show that the disrupting object is most likely a massive (about 1.5 solar mass) white dwarf, while the disrupted object is most likely a terrestrial planet with a mass of about one third of that of Earth. Half of the planet's mass was thrown out of the system at high velocity, while the remaining debris was accreted onto the white dwarf. The resulting flare showed up in hard X-rays. It is speculated that such a planetary tidal disruption event by a white dwarf can happen once every 20 years at most.



The dramatic rise of an ionised layer in the martian atmosphere, caused by a vast number of small dust particles from the coma of Comet Siding Spring. Each dust particle causes a 'meteor' when it hits the atmosphere, just like those seen in Earth's atmosphere, and leaves a trace of ionised gas. The collective effect of all these meteors is an ionised layer. The upper panel shows the state of the atmosphere a few hours before the passing of the comet; the middle panel is just after the comet has passed; the lower panel is seven hours later, when the situation is back to normal (ASI/NASA/ESA/JPL/Univ. of Rome/Univ. of Iowa)

→ MARS EXPRESS

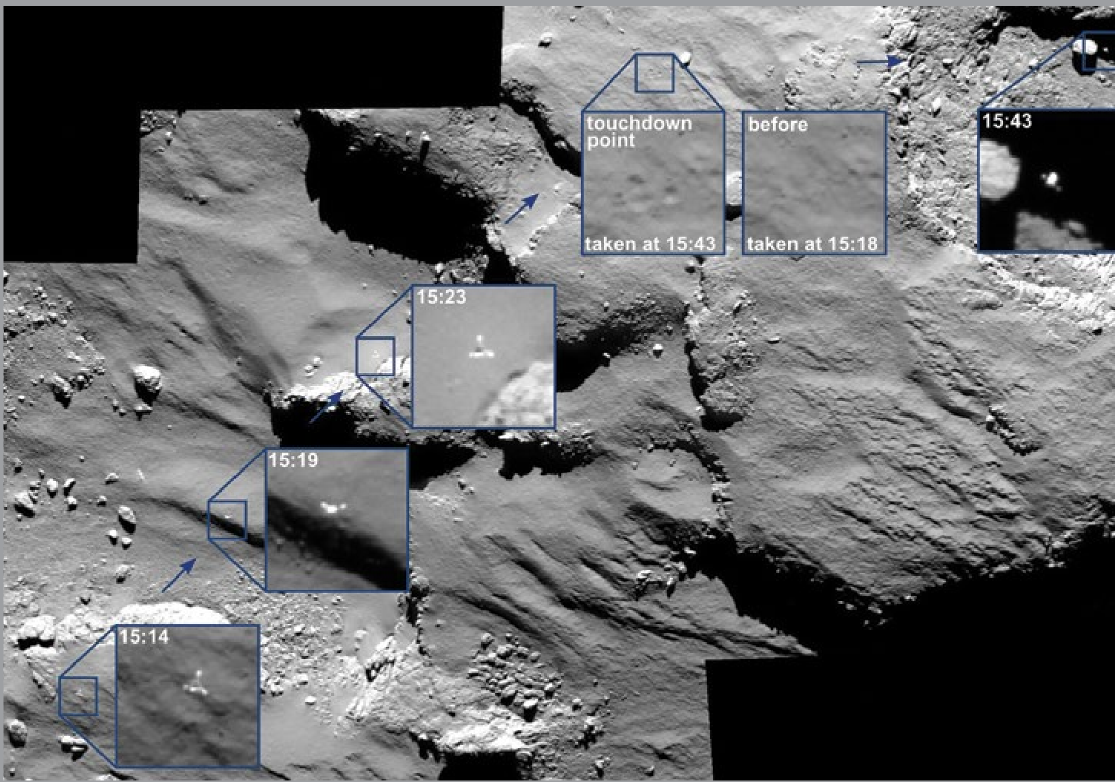
One of the major events in 2014 was the flyby of an Oort cloud comet, Comet Siding Spring, on 19 October. The shortest distance from the martian surface to the comet nucleus was only 136 000 km and the relative velocity was an amazing 56 km/s. After its discovery in 2013, the comet was estimated to become very bright and active at closet approach, with possibly substantial effects on Mars and potential significant risks for the various spacecraft in orbit. As often with comets, and in particular with Oort cloud comets, the brightness and the activity turned out to be somewhat disappointing. Nevertheless, several Mars missions, including Mars Express, obtained important observations.

Marsis discovered very strong enhancement of the ion density in the ionosphere shortly after the closest approach, much higher than the highest value measured during the mission so far. This is believed to be caused by the dust particles of the cometary coma, resulting in meteor phenomena and the corresponding ionisation of these dust particles and atmospheric molecules in the upper martian atmosphere (at 90–100 km altitude). The Super Resolution Channel the High Resolution Stereo Camera obtained a good sequence of images in the orbit after the closest approach, but at a distance about 1 million km, resulting in an unresolved nucleus and no sight of the cometary coma. Aspera data is still under investigation. SpicaM, Planetary Fourier Spectrometer and Omega instruments also made observations but did not detect any signature of the event.

→ ROSETTA

The mission is now in its full science phase following the deployment of its lander Philae on the surface of Comet 67P/Churyumov-Gerasimenko on 12 November 2014. Dispatched some 23 km from the comet, the lander touched down on the surface within 120 m of its target 'Agilkia'. Unexpectedly, the lander subsequently rebounded and travelled some 1 km across the 'head' of the comet, finally coming to rest after a third touchdown. As a result we obtained very good measurements from multiple sites on the comet's surface from magnetic and gas spectrometric analysers, which would not have been possible with a single landing site. Philae's final landing site is a highly diverse location with a number of interesting features.

The Rosetta orbiter science continues and was showcased, along with preliminary Philae measurements, at a meeting of the American Geophysical Union last December.



Images from Rosetta's OSIRIS narrow-angle camera, taken at roughly 15.5 km from the surface of Comet 67P/Churyumov-Gerasimenko over a 30-minute period, show the journey of the Philae lander as it rebounded from its first touchdown site (ESA/Rosetta/MPS for OSIRIS Team MPS/UPD/LAM/IAA/SSO/INTA/UPM/DASP/IDA)

Measurements made by the Rosina instrument following comet rendezvous in August 2014 have revealed that the comet has a particular 'flavour' of water (given by measuring the deuterium/hydrogen (D/H) ratio), which is distinctly different to that of Earth. This result is similar to those from Giotto but, unlike the more recent results from Herschel, indicates a diverse origin for Jupiter-family comets, which formed over a wider range of distances in the young Solar System than previously thought. These results rule out the idea that Jupiter-family comets contain solely Earth ocean-like water, and add weight to models that place more emphasis on asteroids as the main delivery mechanism for Earth's oceans.

→ VENUS EXPRESS

The mission has now ended. The spacecraft ran out of fuel during a sequence of pericentre rise manoeuvres on 28 November 2014. It had been known for a long time that the fuel level was low but, because a precise fuel estimate was not possible, it could not be predicted exactly when this would happen. After autonomous onboard systems detected that the thrust was not as expected during this manoeuvre, the spacecraft attempted to go into safe mode, with solar panels pointing towards the Sun and the High Gain Antenna (HGA) pointing towards Earth. This was only partially successful, because the thrusters did not operate properly through lack of fuel.

For two weeks, ESOC attempted to reestablish communications but this was impossible with the HGA not pointing towards Earth so it was very hard to command the spacecraft to do anything. Owing to the very large distance to Earth, the signal in S-band through the isotropic (low gain) antennas was too weak to be used. During the first week, sporadic lock was achieved through signals from sidelobes of the HGA in X-band, and a limited set of information from the critical event log and some housekeeping parameters could be downloaded – just about enough to determine the likely cause of the problem. During the latter part of December and in January the signal was too faint and, even if the X-band carrier could be detected, no telemetry could be read. The carrier is still visible (as of 20 January) and will be monitored until it disappears.

The pericentre altitude is rapidly being reduced due to natural forces and it is expected that the spacecraft will enter the atmosphere and disintegrate sometime late January or early February, when the altitude has reached below 120 km. The carrier signal may however be lost before that due to loss of attitude and/or power, induced by atmospheric drag.

The mission, which was originally foreseen to last 500 days, operated for more than 8.5 years and has now formally been declared ended and the post-mission phase has started. A treasure of data on the atmosphere, surface and plasma environment of Venus has been collected that will keep scientists busy for years to come. During its extended life, Venus Express has sent more data to Earth than all previous missions to Venus combined.

→ HERSCHEL

The post-operations phase continues, with activities that support the community performing data exploitation, including data processing software (HIPE) improvements, repopulation of the archive (HSA) with reprocessed data products and ingestion of user-provided data products, as well as (online) workshops and an active Helpdesk.

The 'Star Formation Across Space and Time' symposium was held in ESTEC, Noordwijk, in November 2014. A joint ALMA/Herschel Archival Workshop will take place at ESO in Garching on 15–17 April.

→ PLANCK

In its post-operational phase, the latest scientific results derived from this mission were presented in December at two conferences: the first in Ferrara, Italy (Planck 2014: The Microwave Sky in Temperature and Polarisation); and the second in Paris (The Primordial Universe after Planck). The highlight was the presentation of the first analysis of polarised CMB data, which confirm and extend the results presented in 2013 that were based on temperature data only.

→ GAIA

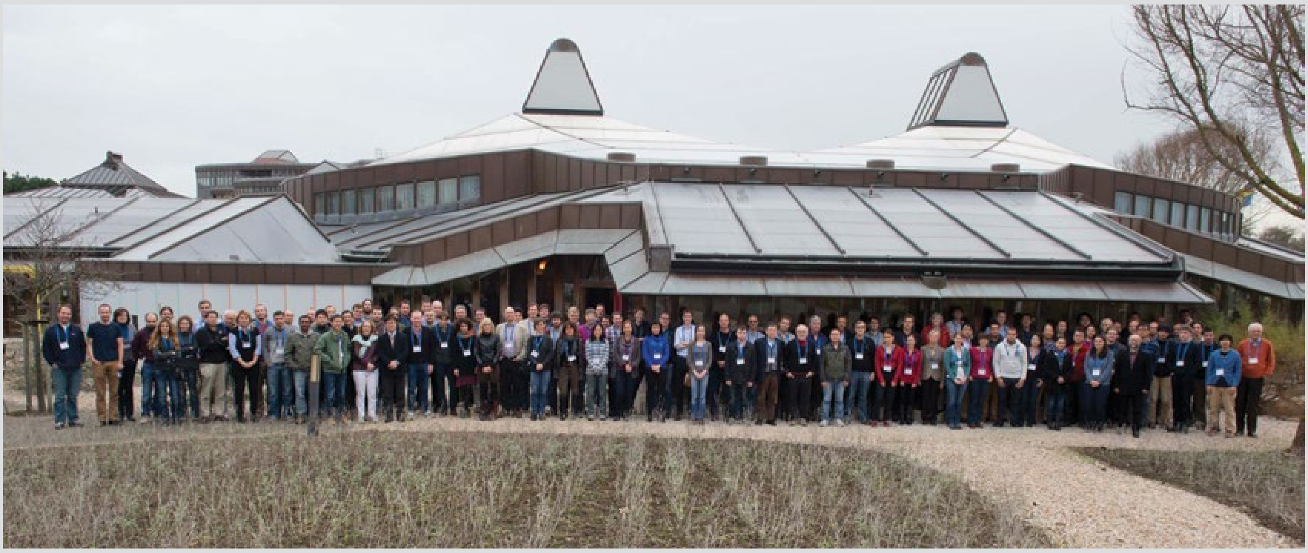
Routine operations continue. On average some 40 million stars cross the focal plane every day triggering astrometric, photometric and spectroscopic measurements. Owing to the nature of the astrometric measurements, no early data release is possible, but science alerts are issued regularly. In the meantime, the user community has been kept up to date with news items and data demonstrating the performance of Gaia.

The ground segment activities turning toward an onboard software change where the remaining modifications are implemented to take into account all inflight findings. The new software will specifically address the spectroscopic instrument with improvements for faint objects. In the meantime, tests have been conducted with brightness limits set to very faint objects. Gaia has been performing very well and additional ground station time was booked to receive all observations for analysis.

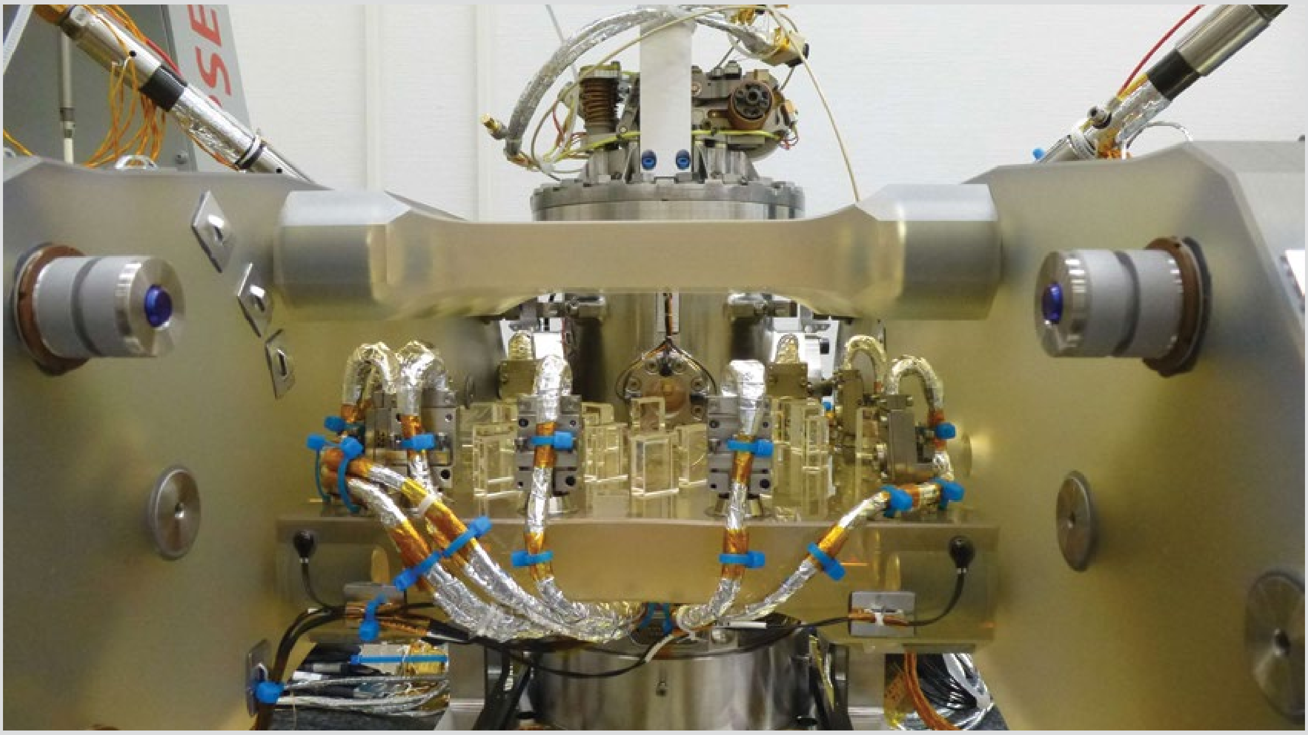
→ LISA PATHFINDER

The last remaining electronics unit of the main instrument, the LISA Technology Package (LTP), was integrated onto the spacecraft in December 2014. The sixth integrated system test was performed in this final configuration and the spacecraft is ready for shipment to IABG for acceptance environmental testing. The spacecraft carries two sets of six cold-gas thrusters; the first set was delivered in 2014, whereas the second set, being for redundancy purposes, is well into acceptance testing.

The two Inertial Sensor Head (ISH) flight units were delivered in 2014 after acceptance testing. Following incoming inspection and cleaning, their integration on the LTP Core Assembly (LCA) has commenced in an ultra-clean room (class 100). The LCA includes an optical interferometry ultrastable bench on its support frame, both ISHs,



Attendees at the Herschel 'Star Formation Across Space and Time' symposium



The LTP Core Assembly is ready to accept the Inertial Sensor Heads. In the background, ISH-1 with its window and the gold/platinum test mass in the centre. In front, inserts where ISH-2 will be aligned and fixed (Airbus D&S)

diagnostics equipment and support equipment. The Ground Segment readiness review takes place between January and March. The formal System Operation Validation Test will be performed in February. The baseline launch vehicle is Vega, on one of the VERTA launches.

→ BEPICOLOMBO

The Mercury Planetary Orbiter (MPO) PFM thermal vacuum and thermal balance test with high-intensity solar radiation simulation (10 solar constants) was run. Initial spot checks confirm an overall thermal performance in line with predictions. This represents a major achievement for the BepiColombo project, confirming that design improvements made after the thermal tests on the STM will work during the mission. System integration and testing activities are progressing with alignment activities on the MPO and will then continue further with the exchange of some QM units with their FMs.

Mercury Transfer Module (MTM) integration activities continued. The thermal test under high-intensity Sun illumination is planned for the end of 2015. The Mission CDR is being prepared for early February. The Mercury Magnetospheric Orbiter has almost completed the environmental test campaign and is planned for shipment to ESTEC in April.

→ MICROSCOPE

Testing of the Electronic Control Module (ECM) QM with two thruster QMs, delivered by ESA and integrated into the CNES fluidic system, took place in Toulouse. Manufacturing of the ECM FMs started. Two lots of thruster Mass Flow Sensors 23 units in total, were delivered by Thales Alenia Space Italy and are undergoing screening at Selex-ES. Production of ECM software is in progress.

→ EXOMARS

The ESA/Roscosmos programme is proceeding as planned with milestones for both 2016 and 2018 missions. Integration of the flight avionics and first models of the instruments rounded off last year's system-level integration and test activities for the 2016 mission. The 2018 mission System PDR was held on 6 November with a fully integrated ESA/Roscosmos team.

System AIT activities for the 2016 mission Trace Gas Orbiter (TGO) and the Schiaparelli Mars entry and landing vehicle continued at Thales Alenia Space France and Italy respectively. The FM spacecraft are now being prepared for system environmental testing, with instrumentation for the tests being added and the test preparations under way for EMC, mechanical vibration and thermal vacuum testing. Several

System Verification Tests with the Mission Control Centre in Darmstadt have been accomplished, proving commandability of the spacecraft as well as end-to-end data flow.

In the 2018 mission, the System PDR Board meeting was a very important event where both agencies co-chaired the proceedings. Although the review was not complete, and required a further step, significant progress was made by confirming interfaces and allowing procurement to proceed. The Rover Analytical Design Laboratory Sample Preparation and Distribution Sub-system EQM mechanisms are all being manufactured. Procurements for the ESA contributions to the Roscosmos Descent Module and for the ESA Carrier Module are progressing.

The 2016 Mission and Science Ground Segment is moving forward with the spacecraft developments. An ESA/Roscosmos Working Group continues to define the implementation of the interfaces to integrate a Russian 64-m antenna into the ESTRACK system to augment the science return of the 2016 TGO mission. The station will also become a baseline antenna to support the 2018 spacecraft cruise phase.

ExoMars Trace Gas Orbiter

→ SOLAR ORBITER

Solar Orbiter Deep Space Transponder Engineering Model (Thales Alenia Space)

The spacecraft is in the final design phase with the System CDR planned for March. Assembly of the spacecraft STM is nearing completion, and mechanical and thermal system testing will follow during the year. The heat shield STM has undergone thermal testing and has now been shipped to the mechanical test facility. Integration and testing of the spacecraft Engineering Test Bench is nearing completion for the spacecraft platform elements. Spacecraft FM units are being manufactured and several spacecraft platform elements have already been delivered.

The two major spacecraft schedule-critical elements are the solar generator and the reaction wheels. To improve the schedule of the solar generator, an additional supplier for the solar generator panel substrates has been added to the industrial team and is acquiring process validation and qualification. For the reaction wheels, it has been decided, in view of EMC problems encountered, to initiate an additional procurement as soon as possible. Even though the new wheels will significantly reduce the emitted EMC, additional magnetic shielding will be implemented. Improvements are also being defined for the payload radiator so its performance matches more closely the goals of the payload complement.

The STIX, SWA and RPW instrument CDRs are near completion. The METIS ICDR is planned for June. Following the announcement by several instrument teams of a significant slip of the expected instrument delivery dates, intensive efforts have been made by the instrument teams and the lead funding agencies to establish a full assessment and to identify schedule stabilisation and recovery actions. A change of launch date from 2017 to 2018 is being considered to ensure continued completeness of the payload complement.

Technological development of Solar Orbiter-specific high-temperature surface treatments is proceeding: a black version has been implemented on the heat shield and it is planned to use this on the antennas and smaller local elements exposed to the Sun. A white version, with even better performance, has passed validation. Specific surface treatment facilities have been established for both surfaces and are nearing completion, with full qualification to follow. Technological development for Solar Orbiter spacecraft elements has otherwise been completed, except for minor qualification of several items inherited from BepiColombo.

Mission Operations Centre and Science Operations Centre (SOC) development design have both passed their respective Design Reviews. The Atlas V-411 launch vehicle interface definition is proceeding. NASA has placed United Launch Alliance, supplier of the baseline Atlas V-411 launch vehicle, under contract.

→ JAMES WEBB SPACE TELESCOPE

Work continues towards the planned launch date in October 2018. The Integrated Science Instrument Module (ISIM) FM completed the gravity sag test after the second cryo-vacuum test. ISIM has been partly disassembled and the instruments are being upgraded to final flight configuration, with expected completion in early March. The next environmental tests are the ISIM vibration and acoustic tests, for which preparations are being completed. The acceptance reviews of the rebuilt NIRSpec detector and micro-shutter assembly were completed. The upgrade of NIRSpec to final flight configuration is proceeding as planned at Goddard Space Flight Center (GSFC), and the newly built detector and micro-shutter assembly have been installed.

New Micro-Shutter Assembly being installed on the NIRSpec instrument by Airbus Defence & Space engineers (NASA/C. Gunn)

The upgrade of the MIRI optical instrument assembly was completed without having to disintegrate from ISIM. The main activity was the exchange of the top Multi-Layer Insulation. The upgraded MIRI detector electronics have been completed and delivered to GSFC from the Jet Propulsion Laboratory. The MIRI FM cooler Cold Head Assembly was delivered to GSFC and already installed on the ISIM.

→ EUCLID

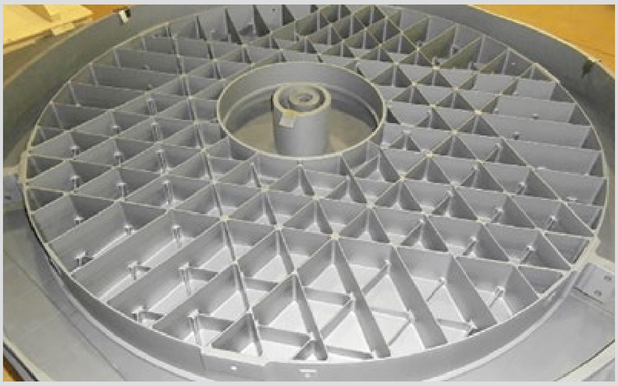
Prime contractor Thales Alenia Space Italy is finalising the activities of Phase-B2, while the Payload Module (PLM) contractor, Airbus Defence & Space, Toulouse, is already in Phase-C/D. Both companies have completed the definition of the subsystem requirements and are now advancing the system design and are proceeding with the subsystem and unit procurement. Some mechanical parts and Mechanical Ground Support Equipment are still to be procured. On the Service Module (SVM), the procurement is proceeding. The contractor for the main subsystems was selected at the end of 2014.

The Visible Imager (VIS) instrument subsystem PDRs are being finalised. The design of the subsystems is ongoing and subsystem CDRs are planned for early 2015. Several subsystem STM tests have been performed. The contract with e2v for the development, qualification and production of FM VIS CCD detectors is proceeding.

The Near Infrared Spectro-Photometer (NISP) instrument PDR was completed and the lower-level PDRs are being carried out. However, some reviews still need to be completed. The instrument mass increase is of concern, but despite this the filter/grism wheel mechanism compensation unit has been transferred from the instrument to the spacecraft platform.

The NISP schedule is also a major concern and a consolidation exercise has been started with NISP's lead funding agency. Procurement of NISP detectors is ongoing. The qualification test at 'triplet' level has started. Additional tests have been performed to qualify the reliability of the data transmission from this unit to the NISP acquisition warm electronics. The flight production phase, under NASA/JPL responsibility, started with the manufacturing of the first detector elements and procurement of the proximity electronics long-lead items.

The Euclid Ground Segment development is progressing. The Science Ground Segment SRR is being held between January and March. Launch is planned for 2020 on a Soyuz-Fregat from Kourou.



Blank of a Flight Model Euclid SiC power mirror

→ JUICE

The Interim SRR was completed in November for both studies: Airbus Defence & Space and Thales Alenia Space. This gave the green light for mission adoption at the November Science Programme Committee. Immediately afterwards, during the November Industrial Policy Committee, the procurement proposal for the Phases-B2, C/D and E1 was approved. The ITT for those phases was released in December and the industrial proposals are expected in March. The contractor for the JUICE Coordinated Parts Procurement Agent was selected and the contract starts in February. The interactions of the newly appointed JUICE project team with the ten instrument teams have started.

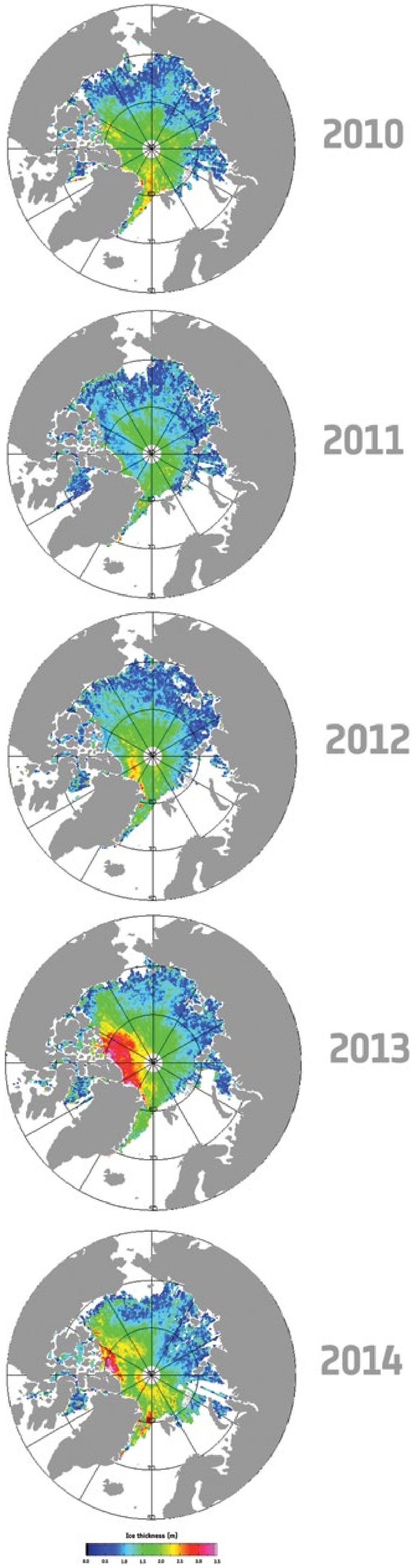
→ SMOS

The satellite has been in orbit for five years and continues to operate beyond its nominal lifetime. Mission operations have been extended to the end of 2017. A second reprocessing of the entire SMOS data set is ongoing and reprocessed data will be available in early 2015. The second SMOS science conference is planned for May at ESAC, near Madrid, **www.smos2015.info**

→ CRYOSAT

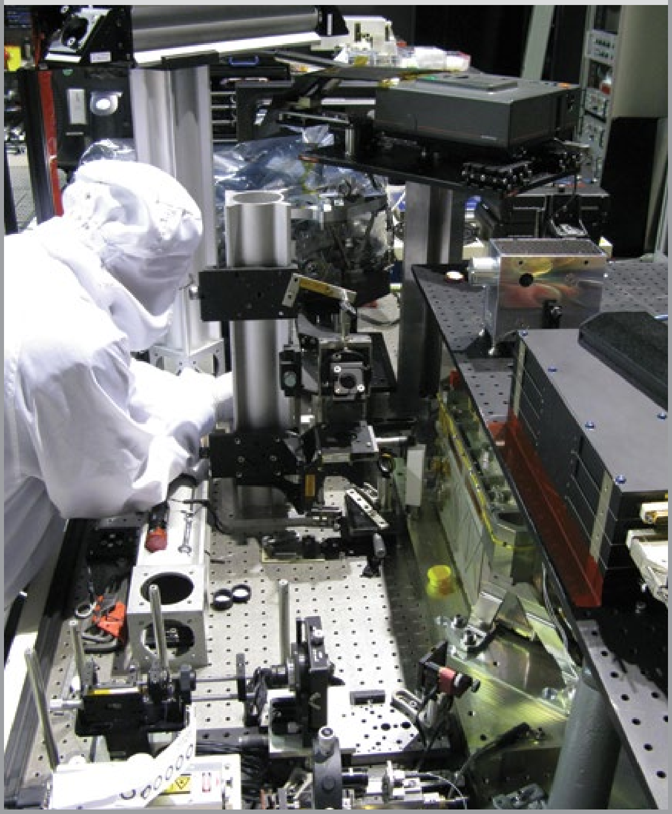
The mission continues to be operated flawlessly, acquiring and generating science data systematically to measure the variation of sea-ice mass floating in the Arctic and trend of land ice volume over Greenland and Antarctica.

The mission delivered the 2014 autumn map of sea-ice thickness in the Arctic, revealing a small decrease in ice volume. In a new phase for ESA's ice mission, its measurements can now also be used to help vessels navigate



Ice-thickness change in the Arctic basin for October/November over five years (ESA/CPOM) through the north coastal waters of Alaska, for example. Measurements made during October and November 2014 show that the volume of Arctic sea ice now stands at about 10 200 km³ – a small drop compared to last year's 10 900 km³. The volume is the second-highest since measurements began in 2010, and the five-year average is relatively stable.

ADM-Aeolus alignment for Optical Bench Assembly Fluence Test (Airbus Defence & Space)



→ SWARM

Swarm continues to acquire excellent science data. Satellite constellation maintenance operations are proceeding, this is particularly relevant and important to achieving the best-possible estimate of all contributors to the total magnetic field. Last year, early mission data were used to derive candidate solutions for the 2015 International Geomagnetic Reference Field (IGRF) model. The IGRF is a main field model that (by convention) is updated every five years, and which is used by practically all applications communities and services in need of geomagnetic data. IGRF-12, as the final 2015 model is called, is based on a combination of Swarm, historical satellite data and ground-based observatory data. In addition, a Swarm Initial Field Model, which includes also the computation of the crustal magnetic field at high spatial resolution, has been produced and made available to the community.

→ ADM-AEOLUS

The nominal laser transmitter and the optical bench with its transmit, receive and spectrometer optics are being integrated and aligned within the Aladin instrument by Airbus Defence & Space in Toulouse. The redundant laser transmitter has experienced performance degradation during the final acceptance test because of internal laser beam misalignment. The unit has been realigned at Selex-ES to reach full performance in ambient conditions. A qualification campaign to verify performance under vacuum conditions after exposure to representative launch vibrations is now under way. The work to complete the in situ cleaning system, responsible for providing in-orbit oxygen purging to the UV optics of the instrument, has restarted at Airbus Defence & Space (GB) following delivery of the latch valves.

A first compatibility test has been executed with the Level 2 processing facility at the European Centre for Medium-range Weather Forecasts in the frame of the Ground Segment Overall Verification.

→ EARTHCARE

The Base Platform Units electrical integration tests are ongoing at Airbus Defence & Space (DE). Delivery and integration took place of the Multi-Spectral Imager Instrument Control Unit for the satellite EFM, with an updated central software version. The ATLID CDR began in December 2014. Integration of the PFM laser transmitter head is progressing in Selex-IT. The Broadband Radiometer CDR took place. The Multi-Spectral Imager CDR was also completed following qualification of the Thermal Infrared Camera Filter and Dichroic Assembly. The Cloud Profiling Radar PFM subsystems delivery was completed in Japan and instrument integration testing is under way.

The EarthCARE International Science Workshop, co-organised by JAXA and ESA, took place in September 2014.

EarthCARE Broadband Radiometer Protoflight Model mechanism (ESTR-UK/Thales Alenia Space)

→ BIOMASS

Two parallel and competitive mission definition studies with consortia led by ADS and OHB/Thales, respectively, were concluded. This paved the way to seek the final approval from Member States to continue with the implementation of the mission and to release the call for proposals from industry to actually build the satellite. This process is expected to lead to the selection of the industrial prime contractor in the second half of the year.

→ METEOSAT

Meteosat-8/MSG-1

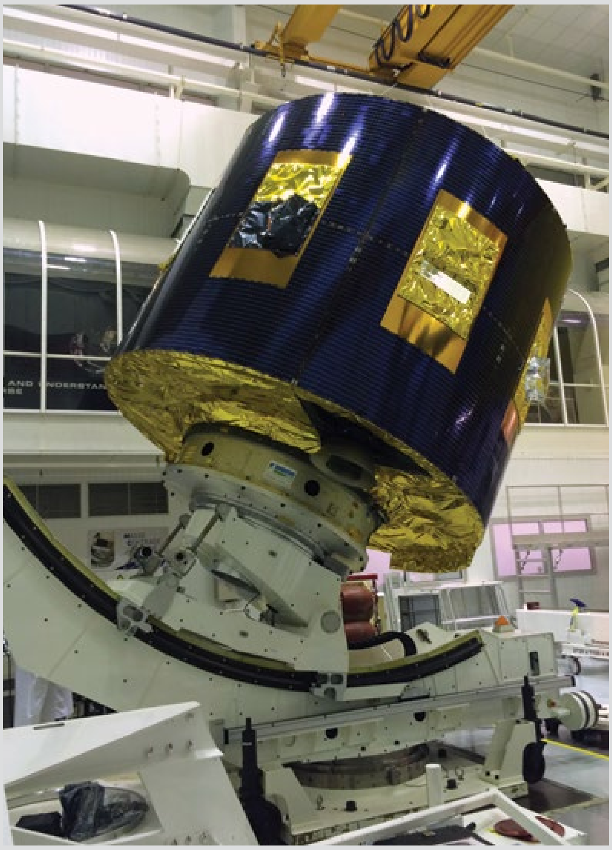
Located at 3.9°E longitude, operations normal. Now the operational back-up for Meteosat-9 and 10.

Meteosat-9/MSG-2

Located at 9.5°E longitude, providing the Rapid Scan Service, complementing the full-disc mission of Meteosat-10.

Meteosat-10/MSG-3

Located at 0° longitude, performing the full-disc mission, as well as the data collection, data distribution and search/rescue missions.

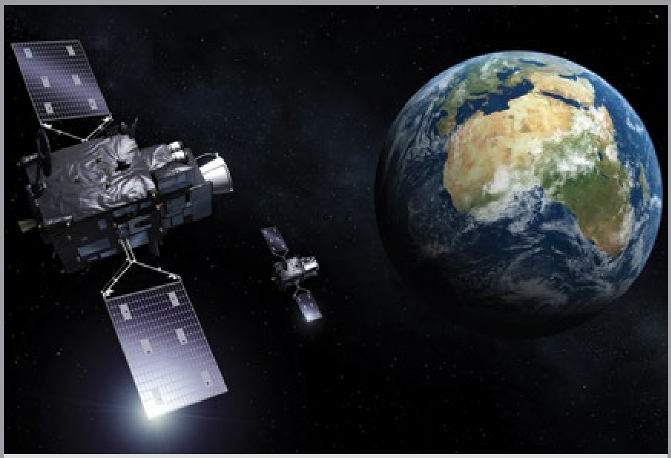


MSG-4 mass and centre of inertia measurement

MSG-4

The testing activities in preparation for the launch campaign are almost complete. The Readiness for Shipment Review will start in January. MSG-4 should be ready for launch at the beginning of July. A precise launch date is yet to be agreed between Eumetsat and Arianespace.

→ MTG



The MTG-I and MTG-S satellites (ESA/P. Carril)

The agreements reached in the frame of price conversion, including the optimised development baseline, have been implemented in a rider to the main MTG contract signed by ESA and Thales Alenia Space France in November 2014. The predicted satellite performance commitments are also clearly documented.

For the Flexible Combined Imager and the Infrared Sounder (IRS), significant effort has been targeted on the critical equipment activities. The modifications required to the instrument structure and thermal control and Scan Assembly, as a result of findings from the PDR, have been consolidated.

Design modifications required for the Lightning Imager (LI), to improve robustness to microvibrations, are now being implemented and will be reviewed in the LI PDR.

An evolution in the MTG-I PFM FAR date was declared by the prime contractor. This delay has been largely driven by predicted delays to the FCI and LI instruments, however delays to the Platform are also apparent. Significant effort is being made to recover the committed date of October 2018.

While a delay has also been identified for IRS, no delays are expected for the MTG-S PFM FAR, largely because of margins that exist in the satellite integration activities. The date for MTG-S PFM FAR as defined during price conversion is August 2020.

→ METOP

MetOp-A

The satellite will operate in parallel with MetOp-B until the successful commissioning of MetOp-C.

MetOp-B

Eumetsat's primary operational polar-orbiting satellite.

MetOp-C

Now in storage, with annual reactivation to confirm the good health of its hardware. Launch on Soyuz from French Guiana in October 2018.

MetOp Second Generation

The SRR was completed in October 2014 with no major actions. Airbus Defence & Space (DE) was selected as the contractor for the Scatterometer instrument. The remainder of the industrial consortium is being built up, with ITTs being released for satellite and instrument equipment.

→ COPERNICUS

Sentinel-1

Sentinel-1A is providing free, full and open data to users at **http://scihub.esa.int.** The satellite is in very good health and running a preprogrammed operation mode to produce consistent long-term data series. In November, Sentinel-1A and Alphasat linked up via a laser communication beam, stretching almost 36 000 km across space, and delivered, for the first time in space, a Synthetic Aperture Radar (SAR) image of Earth.

The AIT campaign of identical sister spacecraft, Sentinel-1B, is in progress. Preparation for launch on a Soyuz rocket from Kourou continues, planned for early 2016.

Sentinel-2

The Sentinel-2A qualification test campaign was completed at IABG in Germany, including mechanical, acoustic, launcher interface and thermal vacuum tests. The last satellite EMC test was scheduled for completion in February. A third Satellite Validation Test was made by the Sentinel-2 Flight Control Team at ESOC in December to prepare for in-orbit operations. The Optical Communication Payload has been integrated on the satellite and is under test. Given the Sentinel-2A launch was planned for May, the Ground System Acceptance and Qualification Acceptance Reviews were organised to authorise the satellite shipment to Europe's Spaceport in French Guiana.

The functional test campaign of the second satellite FM is ongoing at Airbus Defence & Space (DE). Delivery of the second payload instrument FM by Airbus Defence & Space (FR) is expected in September. This is consistent for launch readiness of Sentinel-2B in Spring 2016.

Sentinel-3

Sentinel-3A AIT campaign is continuing. Mechanical testing at satellite level was completed in 2014. Testing of the Sea and Land Surface Temperature Radiometer (SLSTR) FM2 was also completed and calibration begins soon, lasting about three months. It will then be swapped onto the Sentinel-3A satellite to replace the SLSTR 'un-calibrated' model currently installed. System Validation Tests with the Ground Segment are being carried out with Eumetsat.

Sentinel-2A in the thermal vacuum chamber (Airbus Defence & Space/IABG)

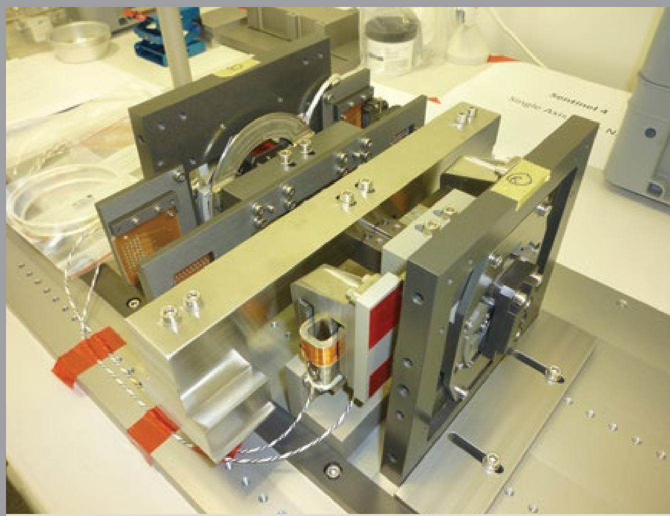
Sentinel-3A in the acoustic chamber at Thales Alenia Space France in Cannes (Thales)

Sentinel-3A on the shaker at Thales Alenia Space France in Cannes ready for Sine Vibration test (Thales)

Sentinel-3B satellite mechanical AIT has also begun, with integration of elements of the Topographic Payload. Activities on this model will interleave with Sentinel-3A activities, optimising use of the AIT teams.

Sentinel-4

Functional and performance tests on a breadboard, fully representative of the scanner mechanism FM, have been completed. Lens manufacturing readiness reviews for the telescope and the ultraviolet and visible light spectrograph FMs were completed; approval for lens manufacturing was granted. The subsystems PDR should be completed in June. Phase-C/D price conversion negotiation is ongoing.



Breadboard of the Scanner Mechanism Assembly (RUAG)

The fully integrated TROPOMI flight payload (Airbus Defence & Space NL)

Sentinel-5

The baseline designs for all spectrometers have been completed. The focus is on finalising the procurement documentation to allow issue of ITT for the remaining sub-system procurements. The Short-Wave Infrared (SWIR) and CCD detectors requirements reviews were completed. Heavy ion tests performed on the SWIR detector breadboards did not reveal any showstoppers. Development of critical optical component breadboards is progressing.

Sentinel-5 Precursor

The anomaly discovered on the Remote Interface Unit (RIU) during System Validation Testing (SVT-1) has been resolved and both the RIU and the Power Conditioning and Distribution Unit (PCDU) have been reintegrated on the platform. SVT-1 was concluded in December. The TROPOMI payload passed all environmental qualification testing. An intensive four-month calibration programme began in December at CSL Liege. A Final Mission Analysis Review for the Rockot launcher is scheduled for March.

Sentinel-6/Jason-CS

The satellite PDR was completed in December. Preparation for the full Phase-C/D continued following the final subscriptions to the programme during the Ministerial Council. The ESA component of the programme is now fully funded and the Phase-C/D contract between ESA and the prime contractor, Airbus Defence & Space (DE), has been negotiated. There will be a bridging Phase-C0, planned for early 2015, while the full Phase-C/D for the two satellites, expected in mid-2015, requires the commitment of funding for the second satellite from two other European partners: Eumetsat and the European Commission.

Apart from the programmatic activities, some radar altimeter and satellite equipment procurements are well under way, to be followed by the majority of satellite-level equipment procurement. Radar altimeter breadboarding activities are progressing to plan.

→ ALPHASAT

The end of 2014 marked the first full year in orbit for the four ESA Technology Demonstration Payloads, flying on board Alphasat as hosted payloads. The Laser Communications Terminal (supplied by DLR) was used extensively to demonstrate laser communication links with Sentinel-1A in low Earth orbit. After an initial demonstration in November, the campaign continued with an impressive series of links in December.

→ SMALLGEO

Spacecraft integration was completed in October and integrated system tests have been running since December. The payload full performance tests, including the Redsat elements, were completed in January. The pre-shipment review, giving consent

Representatives of the European Commission, DLR, TESAT, Airbus Defence & Space and ESA celebrate the in-orbit demonstration of the laser link between Sentinel-1A and Alphasat (ESA/J. Mai) to transfer the spacecraft to IABG for environmental testing, was planned for January. For LEOP and Ground Segments, development and validation work is progressing. RF compatibility tests with Hispasat were completed.

→ EDRS

As part of the EDRS programme, the ASI Opportunity Payload (ASI OP) – providing broadcasting services in Ku-band over Italy – will also be embarked on Eutelsat's EB9B commercial satellite. Following all on-ground AIT activities, ESA's EDRS-A FAR, as well as Eutelsat's EB9B Flight Model Competition Review (FMCR), were held in December. The EB9B satellite is now in storage, awaiting its shipment to the launch site, for a launch on Proton in 2015.

The EDRS-C satellite CDR should be complete in early 2015, and will be followed by the EDRS-C Mission CDR in the second half of 2015. Procurement of satellite equipment is progressing and first flight hardware elements have been delivered to EDRS-C prime contractor OHB in Bremen. Satellite-level AIT activities has begun.

All elements of the EDRS Ground Segment required for EDRS-A have been reviewed as part of the EDRS-A Mission CDR. Development of the Ground Segment hardware is in progress, and the first Ground Segment Validation Test is being conducted in early 2015. A number of System Validation Tests of increasing complexity were carried out as part of the EB9B Satellite AIT campaign in order to ensure operability of the EDRS-A mission through the Ground Segment.

All Ground Segment hardware is being manufactured, and the stations in Weilheim, Redu and Harwell are deployed and undergoing final tests. The Mission Operations Centre (MOC) is the heart of the EDRS, were the overall data relay link and data flow planning will take place. It provides the link between the EDRS Space and Ground Segments on one side and the EDRS users on the other. The utilisation of the system capacity and the type of services provided will be planned from here based on the requests received from users.

→ ADAPTED ARIANE 5 ME AND ARIANE 6 ACTIVITIES

After the declaration on the programme for Ariane and Vega development (containing four elements) was approved during the Ministerial Council in December, the Memorandum of Understanding (ESA/CNES/Airbus & Safran Joint Venture) was signed on 18 December.

Adapted Ariane 5 ME and Common Upper Stage activities
With the Ministerial Council decision to develop Ariane 6 and to stop Ariane 5 ME and Common Upper Stage (CUS) activities, specific Ariane 5ME/CUS activities are being stopped and those activities to be continued for Ariane 6 PHH development are being identified. All contracts are under review and necessary CCNs placed to stop and/or transfer the Ariane 5 ME/CUS activities to Ariane 6 are under preparation.

Ariane 6

A first Authorisation To Proceed (ATP) for the Ariane 6 PHH launcher Phase-A initial activities was signed in December. Two ATPs covering the activities until mid-2015 are in preparation, one covering the Launcher System development and the Ground Segment development. The PPH activities including the Consolidated Launcher Elements are now finished. The Design Analysis Cycle-1 began for the new PHH configuration. The baseline remains unchanged with respect to Vinci, cryo-stage architecture (separated tanks), but the trade-off on the stages diameter is to be performed. Discussions on the commonalities between Ariane 6 and Vega- C are ongoing.

A Steering Committee took place in December to conclude on the Solid Rocket Motor Technical Requirement Specification. Ariane 6 Ground Segment Phase-A/B1 activities are being reoriented with no cost impact. The meetings of the Working Group for interfaces between Launch Vehicle and Ground Segment are ongoing (mandate to be formalised as an extension of the mandate of the PPH configuration).

→ VEGA

The VECEP Work Order 2 was signed, covering Phases-0/A and part of Phase-B activities for the evolution of the launcher, namely co-engineering and urgent activities not dependent on the change of Ariane 6 configuration (and consequent commonalities with Vega).

→ IXV

Mission preparation activities progressed according to plan, revised following the launch postponement, with all Flight and Ground Segment hardware and mission team deployed worldwide, ready for the launch on 11 February.

→ PRIDE

The PRIDE programme objectives were refocused at the Ministerial Council in 2014. They are now:

- to implement applications-driven mission requirements (to start from space application needs and priorities in terms of technology in-orbit experimentation and demonstration shared with European end-users);

- to build on wider past and present European achievements, not only ESA but also national, with the objective to limit risks and minimise financial efforts;
- to harmonise European resources, including ESA and national, with the objective to optimise the use of the financial resources available in Europe.

The funding available is sufficient to complete the first objective, addressing the mission and system definition phases including supporting technology developments, and to prepare the development for the second objective (to be submitted for approval at next Ministerial Council).

→ FUTURE LAUNCHERS PREPARATORY PROGRAMME

Period-3 continuation gained additional subscription at the Ministerial Council, confirming the FLPP stakeholders interest and support for future launcher evolution preparation.

Propulsion

For storable propulsion, the Demonstrator hot-firing test campaign at Lampoldshausen was completed with 53 successful firing tests. This engine is the precursor of the Europeanised AVUM for Vega-C launcher. In line with the German subscription to VECEP at the Ministerial Council, FLPP is now anticipating and preparing for the storable demonstrator to go into development. The Hybrid Propulsion Demonstrator campaign began in September and two successful full thrust tests have been performed up to now, showing very promising performance data.

Technologies and integrated demonstrators

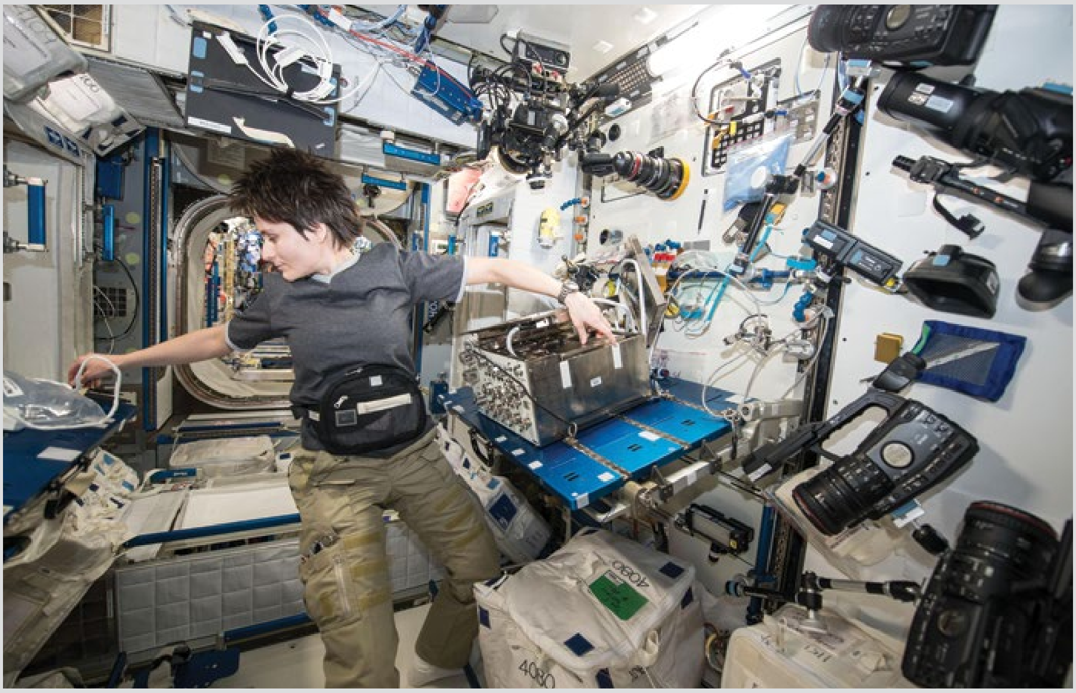
Implementation of integrated demonstrators is progressing with the aluminium/lithium cryogenic tank demonstrator burst test, with results very close to predictions. The ISS technology maturation Request for Quotation is ready. The SRR for TTEthernet Demonstration has also been performed. The contract for the European Launcher Localisation Kit (ELK) was placed for a PDR-to-CDR phase, with a view of first implementation on Vega.

→ HUMAN SPACEFLIGHT

Alexander Gerst (DE) undocked from the ISS in Soyuz TMA-13M with two fellow Expedition 40/41 crewmembers on 10 November, landing in Kazakhstan after six months in space. Two weeks later Samantha Cristoforetti (IT) and fellow Expedition 42/43 crewmembers were launched to the ISS with docking occurring less than six hours later. She is scheduled to remain on the ISS for just under six months.

During this time she will be involved in a full programme of research, education and public relations, and will play a leading role in the undocking of ESA's fifth and final Automated Transfer Vehicle (ATV *Georges LeMaître*).

SpaceX CRS-5 docked with the ISS on 12 January with 2300 kg of resupplies (including new ESA experiments Airway Monitoring and TripleLux-B). ESA lost two experiments in the Orbital Sciences Cygnus CRS Orb-3 launch failure on 28 October, GRIP and SODI DCMIX3. These experiments will be replaced.



Samantha Cristoforetti working on the Airway Monitoring experiment, delivered to the ISS in January (NASA/ESA)

Samantha Cristoforetti preparing the Biolab experiment rack for starting the TripleLux-B experiment (NASA/ESA)

→ ISS

Astronauts Andreas Mogensen (DK), serving as Flight Engineer for Soyuz TMA-18M, and Thomas Pesquet (FR), TMA-18M back-up crew, undertook Columbus User and Operator Payload Training at EAC. Andreas also participated in the launch campaign of Samantha Cristoforetti in November, while Thomas Pesquet had scuba proficiency training.

Tim Peake (GB) is in his final year of training for his mission as a member of the Expedition 46/47 crew starting in November. He had Payload and Columbus Emergency Training, as well as medical activities, at EAC in November and also trained in Japan and USA.

ESA astronaut Tim Peake during medical activities at EAC, Cologne, in November and December

ATV *Georges LeMaître*

The mission ran with no anomalies reported in the period. Undocking was targeted for 14 February with reentry on 27 February. Most of the cargo was transferred, with around 40% of the water and 30% of air still remaining to be transferred. Two urgent ISS debris avoidance manoeuvres were performed by ATV-5 on 31 October and 12 November.

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

The industrial Phase-C/D contract between ESA and Airbus was signed in November. Most sub-system PDRs took place, with the last one to be concluded in April. NASA's Orion Exploration Test Flight 5 December 2014 was successful. The next major milestone is the ESM system CDR in December.

ESA astronaut Samantha Cristoforetti and cosmonaut Yelena Serova inside ATV *Georges LeMaître*

→ RESEARCH

European research on the ISS

The European ISS utilisation programme has been continuing successfully with the assistance of the Expedition 41/42 crew on orbit. Highlights of the three months until 31 December are as follows:

The second part of the joint ESA/NASA Seedling Growth experiment was carried out with four six-day experiment runs in the European Microgravity Cultivation System, with each run having different light/gravity parameters. The experiment builds on previous space experiments and studies the effects of various gravity levels on the growth responses of plant seedlings. The research will provide insight into the cultivation of plants during spaceflight on long-term missions.

Research with ESA's Expose-R2 facility on the external surface of the Russian Service Module of the ISS began with the removal of the facility's Sun shield (and exposure of samples to solar irradiation) during a Russian spacewalk on 22 October. The following day all the external payload sensors were switched on and data acquisition was started. Expose-R2 hosts three ESA experiments (BIOMEX, BOSS and PSS) and one from IBMP in Moscow. These experiments could help to understand how life originated on Earth and survivability of samples to conditions on, for example, Mars and the Moon.

The Plasma Kristall-4 (PK-4) experiment was installed inside the European Physiology Modules rack on 27/28 November, and checkout activities carried out in December. PK-4 is investigating complex plasmas or dusty plasmas, which are plasmas (ionised gases produced by high temperatures) that contain micro-particles, e.g. dust grains as well as electrons, ions and neutral gases. Most experiments on complex plasmas are strongly distorted, or even impossible, on Earth and therefore require weightless conditions.

The first four science runs for ESA's new MagVector experiment were completed inside the European Drawer Rack in Columbus. The MagVector experiment from DLR qualitatively investigates the interaction between a moving magnetic field (of Earth origin) and an electrical conductor. Using extremely sensitive magnetic sensors placed around and above the conductor, researchers will gain insight into how the magnetic field influences how conductors work.

The MagVector instrument is also acting as a dedicated wireless hub to receive signals from the Wireless-Sensor NETwork (WiSe-NET) deployed in Columbus by Samantha Cristoforetti on 31 December. WiSe-NET is a wireless mesh networking system consisting of easy-to-use and low-power consumption sensors (for monitoring of physical or environmental conditions such as temperature, pressure, humidity and accelerations) and micro-controllers.

Non-ISS Research in ELIPS

Three Drop Tower campaigns were carried out in November and December at the Centre of Applied Space Technology and Microgravity (ZARM) at the University of Bremen. The Flexible Electromagnetic Leash Docking system (FELDs) from students of the University of Padua was the selected experiment for the Drop Your Thesis 2014 campaign, completing five drops. FELDs demonstrated an innovative docking system for spacecraft using electromagnetic coupling. The other two campaigns were the Slug Boiling (Injection of nucleate-boiling slug flows into a heat exchange chamber) and Microswimmers in Convection-free Environment (MiCE) experiments, which completed nine drops and 16 catapult shots respectively.

The latest Concordia winter-over season including ten ESA experiments and 13 crewmembers was completed in November.

→ EXPLORATION

ESA's Space Exploration Strategy

The ESA Strategy for Space Exploration has been consolidated. Key elements of the strategy have been presented at various ESA internal and external events. A comprehensive assessment of private sector initiatives in the field of space exploration was performed. Opportunities and approaches for strategic partnerships with the private sector for advancing ESA's strategic goals for space exploration are being investigated.

International Docking Standard System (IDSS) and International Docking Standard System (IDSS)

The PDR of the new version of the IBDM compatible with the updated IDSS was completed. Testing at SIRRIS (BE) continued for various initial conditions of the docking vehicles. An Avionic Engineering Model design was completed and is being manufactured.

The Expose-R2 facility being installed on the ISS during a Russian spacewalk (Roscosmos)

A joint ESA/NASA activity to demonstrate full compatibility of the IBDM with the new US docking ports and the NASA docking system is in preparation, including testing of the IBDM on the 'six-degrees of freedom' docking facility at the NASA Johnson Space Center (JSC).

Operation Avionics Subsystem (OAS)

Cooperation with the NASA JSC Crew Office is being set up for the participation by European industry in the development of the Orion cockpit prototype

Meteron

The HAPTICS-1 investigation continued on board the ISS through December and January. HAPTICS-1 is the first part of a suite of Exoskeleton experiments to demonstrate a full bilateral control interaction between ground and space. The objective is to optimise the design for the mechatronic drive systems of the later Exoskeleton as well as identifying changes in human perception/performance in such tasks when exposed to weightlessness for long periods.

Expert

The Expert vehicle remains in storage conditions at Thales Alenia Space in Turin.

Lunar Exploration

ESA Member States decided at the Ministerial Council in 2014 to fund Lunar Exploration activities in the frame of the ISS Exploitation programme. This confirms the Moon as the next destination beyond low Earth orbit for extending human activities, as initiated already with the ESM development for the NASA Orion vehicle.

→ SPACE SITUATIONAL AWARENESS (SSA)

System Engineering

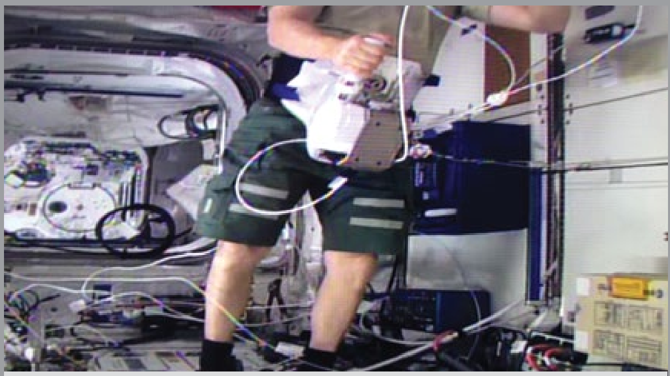
Architectural design studies for the SWE, NEO and NEO segments of the SSA system were completed and presented to the Programme Board. These architectures will constitute an essential basis for further development activities of the SSA system components.

Space Surveillance & Tracking (SST)

Requirement analyses for an Expert Centre for federated Satellite Laser Ranging (SLR) and optical observations are progressing. Studies on data correlation prototypes and on fragmentation event modelling and assessment have been started. Testing the reentry prediction applications with complementary test cases supported by the Space Debris Office is progressing.

Space Weather (SWE)

The SWE Segment continues helpdesk support to the users through the SSA SWE Coordination Centre (SSCC) in Space Pole, Brussels. SSCC operations were transferred in the autumn 2014 to a new contract led by the Belgian Institute for Space Aeronomie (BIRA). SSCC has continued providing tailored space weather bulletins to ESA mission operation teams.



NASA astronaut Butch Wilmore completed the first full HAPTICS-1 data collection on ISS in January

Development of new space weather capabilities utilising European assets continued. Three new services from the SN-VI Space Weather Additional Service activity are expected to be available in early 2015. These services focus on providing radiation dose estimates to aircraft passengers and crews, geomagnetic information to resource exploitation users and a Space Weather Toolkit (SWTK) to support the work of space weather forecasters.

Implementation of two hosted payload missions for space weather instruments is in progress. The Next Generation Radiation Monitor FM for the EDRS-C mission will be delivered in June for the integration on the platform. ESA participation in the Korean Space Environment Monitor (KSEM) instrument package with the SOSMAG (Service Oriented Spacecraft Magnetometer Set) is being prepared with the KSEM prime contractor Kyung Hee University.

Near Earth Objects (NEO)

A collaboration with the Large Binocular Telescope in Arizona was started and used to follow faint NEOs. A workshop with emergency response agencies from Germany and Switzerland took place at ESOC in November 2014. In its capacity as chair of the UN-sanctioned Space Missions Planning Advisory Group (SMPAG), ESA has worked on bringing all international space agencies together to jointly discuss how to best deflect a possible threatening asteroid.

Radars and telescopes

The test and validation campaigns using the monostatic breadboard radar, deployed in Spain, are continuing. About 380 different objects have been detected to date, with a total of more than 1100 observations carried out. The bistatic breadboard radar, located in France, has passed the Factory Acceptance Tests.

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