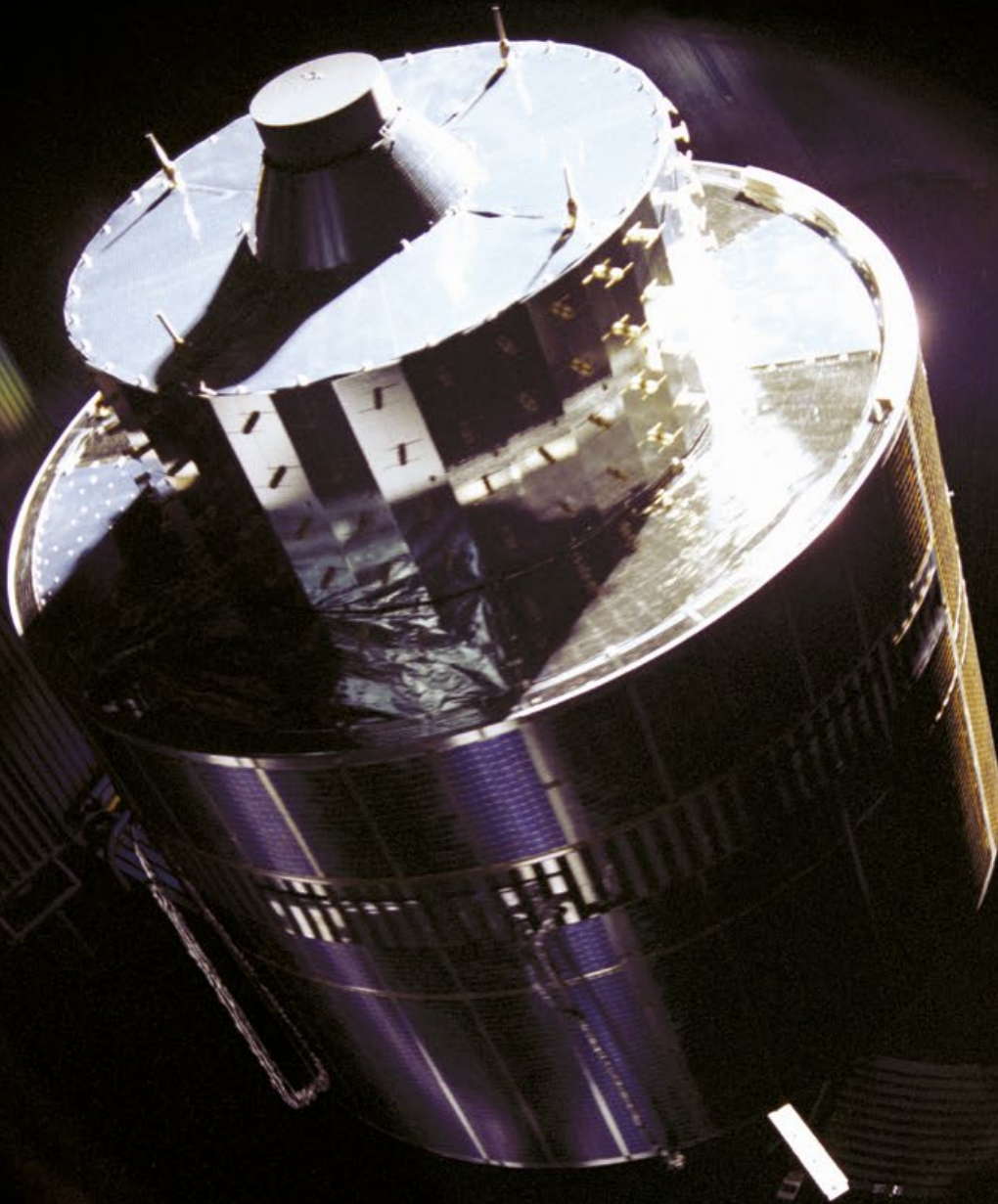


number 171 | 3rd quarter 2017



bulletin

→ **united space in 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. Slovenia is an Associate Member. Canada takes part in some projects under a cooperation agreement. Bulgaria, Cyprus, Malta, Latvia, Lithuania and Slovakia have cooperation agreements with ESA.

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.

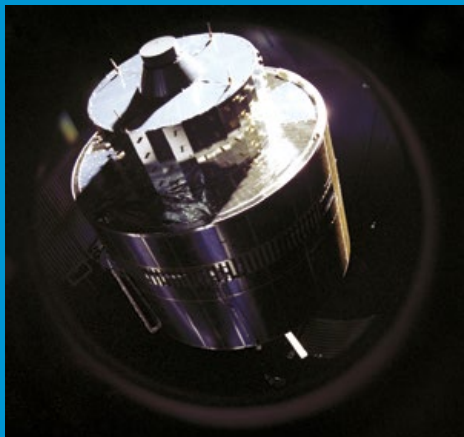
EAC, Cologne, Germany.

ECSAT, Harwell, United Kingdom.

ESEC, Redu, Belgium.

Chair of the Council:
Jean-Yves Le Gall

Director General:
Jan Woerner



On cover:
The Meteosat-1 Flight Model during a solar
simulation test at the Toulouse Space Centre in
May 1977 (ESA/P. Sjodin)

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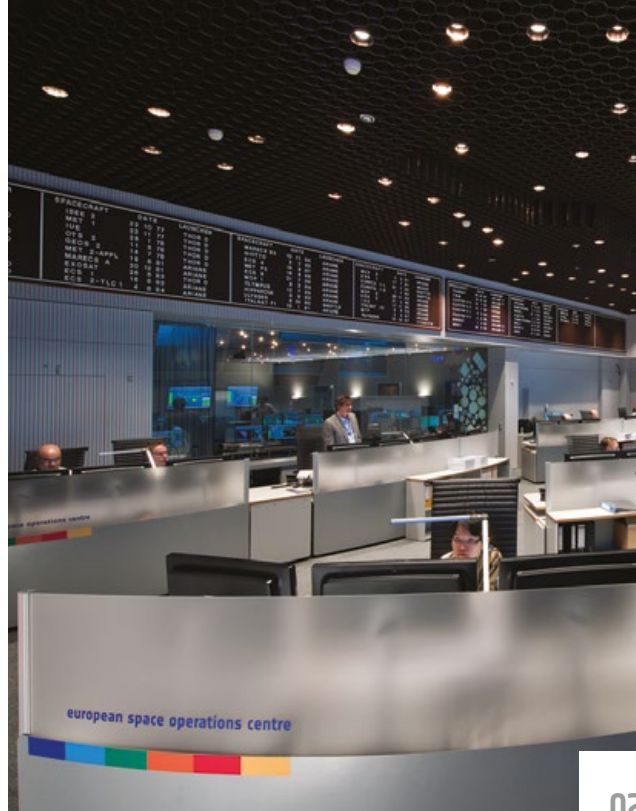
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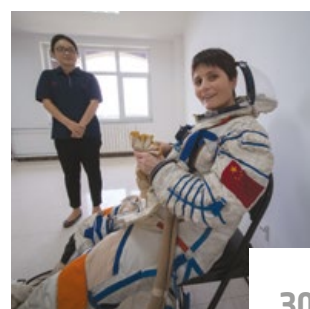
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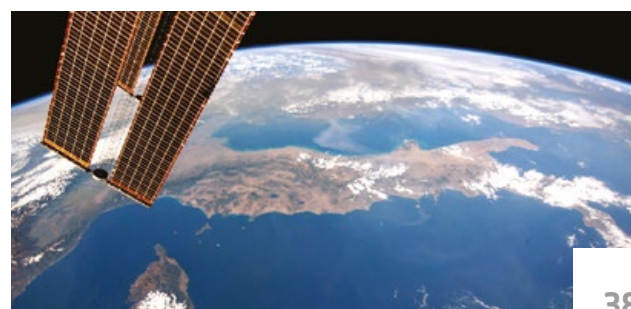
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european space operations centre

europaean space operations centre

→ THE SPACE CHOREOGRAPHERS

Europe's Space Operations Centre celebrates half a century

ESOC Communication Office with the Coordination Office
Directorate of Operations, ESOC, Darmstadt, Germany

DATE	MISSION	OPERATION	TIME	STATUS
1. 1. 1968	Apollo 8	Launch	17:00	Success
2. 1. 1968	Apollo 8	Orbit	17:00	Success
3. 1. 1968	Apollo 8	Orbit	17:00	Success
4. 1. 1968	Apollo 8	Orbit	17:00	Success
5. 1. 1968	Apollo 8	Orbit	17:00	Success
6. 1. 1968	Apollo 8	Orbit	17:00	Success
7. 1. 1968	Apollo 8	Orbit	17:00	Success
8. 1. 1968	Apollo 8	Orbit	17:00	Success
9. 1. 1968	Apollo 8	Orbit	17:00	Success
10. 1. 1968	Apollo 8	Orbit	17:00	Success



ESOC's Main Control Room



↑ The ESOC Main Control Room during a VIP visit in 1972

September marks 50 years since the official inauguration of ESA's European Space Operations Centre (ESOC), in Darmstadt, Germany.

As Europe's centre of excellence for satellite operations, ESOC is home to the engineering teams that control spacecraft in orbit and build the systems on the ground that support missions in space. Imagining the ground systems needed for innovative missions requires the teams to work together from the start to put in place the hardware and systems on Earth that enable engineers to control satellites in space and receive and distribute precious data to scientists. They also plan and select the best possible orbits, launch trajectories and launch windows.

By the time a mission is ready to launch, ESOC has all its systems in place, and liaises with Europe's spaceport in Kourou, French Guiana to prepare for liftoff. From minutes after launch and insertion into orbit, ESOC takes control. It maintains real-time contact with missions near Earth, orbiting the Sun or voyaging deep in our Solar System and determines the real-time position, speed and attitude of satellites in space as they perform their celestial dances.

Other vital activities at ESOC include managing ESA's worldwide Estrack ground station network, cooperating with other agencies and international bodies to define technical standards, and operating as a centre of excellence for space debris studies and services, ground system engineering, the design and development of tracking stations, and satellite navigation.

The early days

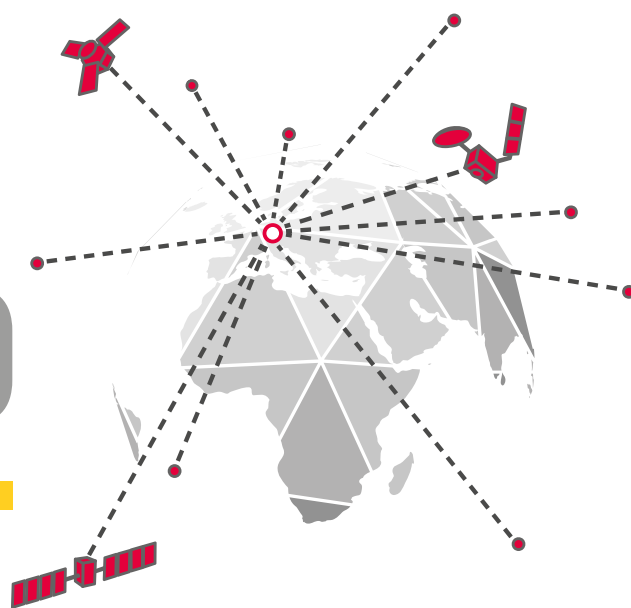
Fifty years ago, of course, ESOC was not technically ESA's, nor was it totally new. While the US-Soviet space race unfolded in the 1950s and early 1960s, other countries and organisations developed their abilities to place satellites into orbit for scientific research and applications such as weather forecasting, telecommunications, television and resource management. In Europe in 1962, the European Space Research Organisation (ESRO), one of the two precursors of today's ESA, was founded (the other was the European Launcher Development Organisation, ELDO). ESRO had already been operating a facility in Darmstadt for four years before what we now recognise as ESOC came into being.

“

ESOC maintains real-time contact with missions and determines the position, speed and attitude of satellites in space as they perform their celestial dances.

”

esoc50



As ESRO was being formed, its committees discussed where to locate the main constituent sites. In addition to headquarters, the organisation would have one establishment devoted to engineering and testing satellites and payloads, as well as a science laboratory and a data centre. France, the Netherlands, Switzerland, the United Kingdom, the Federal Republic of Germany,

Belgium and Italy all proposed sites for use by October 1961. Darmstadt was the sole selection for the European Space Data Analysis Centre (ESDAC), although it later fought off competition from sites in the UK and Switzerland. By the time voting was complete, in April 1962, Darmstadt's role in the future of space in Europe was settled.

↓ ESOC gatehouse, 1967





↑ Siemens 330 computer used to support LEOP activities from 1976

Settling in Darmstadt

The first office was staffed by just three people and was located on the Rheinstraße in Darmstadt. The facilities initially housed large mainframe computers for the analysis and study of recovered satellite data.

“Space travel came to Darmstadt because one of Germany’s few mainframe computers was in the German data centre in the Rheinstraße at the time,” recalled Kurt Debatin, head of ESOC’s Computer Division until 1997. He was among the first space generation in Darmstadt. In 1965, he joined ESDAC as a systems analyst.

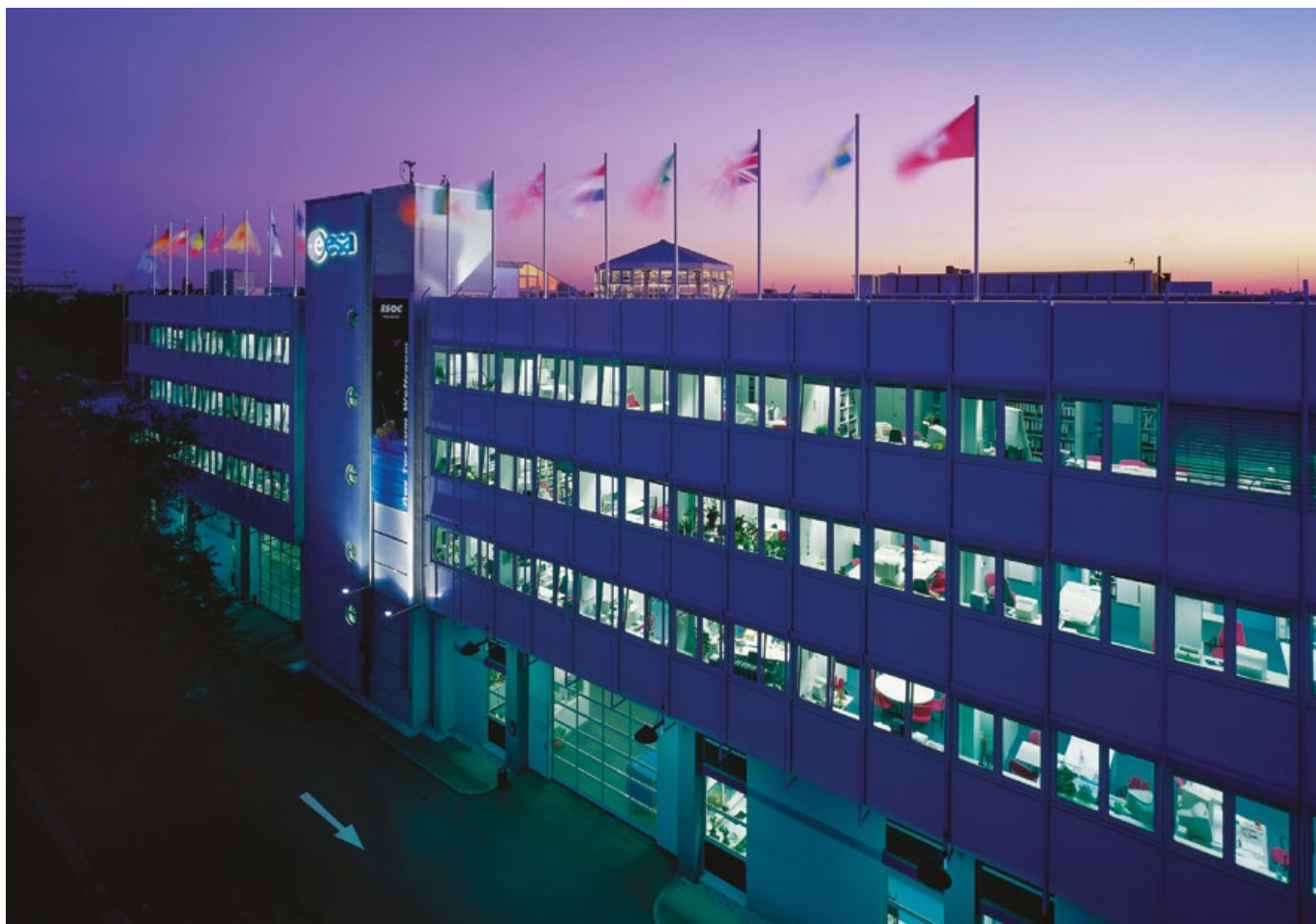
Although the computer filled entire rooms, today’s mobile telephones far exceed its capacities. Keyboards were non-existent and commands were inputted with punch cards. Computer displays were not yet known. Debatin says, “There were only line printers and they spewed out only octal numbers which we had to convert in our heads.” Engineers could only deduce from the computer’s flashing signals whether the satellite was working.

The initial years are vividly described in the book *How to Survive Space*, a memoir by Madeleine Schäfer, which was published for ESOC’s 30th anniversary and is now available online. She began work in ESDAC in June of 1964, when the

“

Young ESOC engineers of today cannot imagine that we had to train with and actually use these devices to calculate orbits.

”



↑ ESOC Main Building in 2002

office was based in Havelstraße, and recalls a warm summer and stimulating conversation. Over the following months, a larger staff and more computers were brought to Darmstadt, and Madeleine recounts stories of programmers working on hundreds of punch cards at a time and the gradual infiltration of the English word 'computer' into German.

ESOC's permanent home

In those early years, spacecraft operations had been assigned to ESTEC – which started out in Delft and then moved to its current site of Noordwijk, the Netherlands. In 1967, teams from ESLAB and ESTEC in Noordwijk, were

moved to Darmstadt, to form ESOC. With the renaming and repurposing for spacecraft operations, the centre and its staff – now numbering 90 – moved to a new facility on the western side of Darmstadt. ESOC was opened on 8 September 1967 by then Minister of Research of the Federal Republic of Germany, Gerhard Stoltenberg.

The move of Control Centre staff and hardware from Noordwijk to Darmstadt was decided in a resolution in April 1967, leaving a little over a year for the change to take place before the planned launch of the ESRO-2B scientific research satellite. Staff adapted quickly to new lives in a new country, while also working long hours in anticipation of the launch.

“

Sure, we knew one day we would be able to do a mission to Mars or Venus, and in fact we are doing so. But to fly to a comet did – like Rosetta – that was only a dream.

”



Aerial view of ESOC in 2008

The launch went ahead and by May 1968, ESOC was already conducting its first operations, controlling ESRO-2B, the first in a long series of successful missions operated from ESOC for ESRO, and later ESA.

As ESOC thrived, office space was beginning to get scarce. ESOC's 184 staff were housed in a building intended for 80, along with all the necessary supercomputers. Madeleine Schäfer recalls, "It had been built to house a new super computer (an IBM 360 – the crème de la crème of computers), its attendants (mathematicians, physicists and programmers), and a few administrative staff, in total about 80 people. It had not been designed for an entire Control Centre with sophisticated wiring and air-conditioning requirements, not to mention the Control Centre people from ESTEC plus a plethora of new staff."

The solution at the time was to use every bit of space available – not excluding lavatories – and start work on the first of many extensions to the centre.

A growing centre of excellence

Construction of the purpose-built operations Control Centre (OCC) at ESOC began in 1970 and was completed in March 1971. The project would provide a dedicated control facility capable of processing three simultaneous telemetry datastreams and displaying the data to several spacecraft control positions. The building has been extended and refurbished in the intervening years, including the development of facilities for individual missions and

technical and aesthetic makeovers of the main control room. An extension was added in 2003 to house the Rosetta Engineering Model, which had a vital role in the mission when new software was tested on the ground.

The combined building, or 'H' Building, was planned first 30 years ago, and was opened in phases in the late 1980s and early 1990s. The old stores building and barracks were demolished to make way for the new building and a multistorey car park. New conference facilities in the H Building were in place for the launch of ERS-1 in July 1991, and have since become familiar to millions of viewers around the world as they hosted televised events such as the Huygens probe landing on Titan, and the Rosetta comet landing.

New office space was added again under a plan unveiled in 2011, while ESOC has also been working to diminish its environmental impact. A new secure area was also required for the Galileo satellites. Technical upgrades have been less obvious, but vital.

During 2005, 100 km of new data cabling was needed, while the control centre got new voice-intercom and video-display systems. It seems almost unimaginable that communication between different ground stations was once by a dedicated Telex network.

Today, the computers and networks at ESOC have little in common with systems of the 1960s and 1970s. Back in the 1960s, the technology used at ESOC to operate missions is hardly imaginable to the cell-phone toting,



↑ Paolo Ferri and the ESA Rosetta flight control team prepare for the last command to the spacecraft in 2016

home-computer using, high-speed internet citizens of today. Computers filled rooms and were commanded, not by a keyboard, but by punch cards, with coded characters laborious punched into many stacks of them.

In 50 years, satellites controlled from ESOC have voyaged deep into our Solar System, exploring not only our home planet, but also the Moon, the Sun, Venus, Mars and Titan.

The establishment of ESOC and the subsequent evolution of ESRO and ELDO into ESA with the Ariane launcher programme proved that Europeans working together could not only build satellites and boosters, but could also operate sophisticated missions as well.

Computer-filled rooms

“Young ESOC engineers of today cannot imagine that we had to train with and actually use these devices to calculate orbits,” said Siegmund Pallaschke, a flight

dynamics analyst who joined ESDAC/ESOC in 1966, speaking on the occasion of ESOC’s fortieth anniversary. He recalled that, in the early days, everything was focused on low- and near-Earth orbits – or on flying to the Moon.

“Sure, we knew one day we would be able to do a mission to Mars or Venus, and in fact we are doing so. But to fly to a comet – like Rosetta – that was only a dream.” Jean-Francois Kaufeler, responsible for ground systems infrastructure at ESOC, remembers his initial years at ESOC – and the start of the ESA era, “I have always been impressed by the cooperation here between people of different nationalities, different cultures and individual work styles. Today, the level of mutual understanding has progressed much further and cooperation is easier.”

Kaufeler sees this as an advantage for the future of ESOC, “In the future, we will continue sharing the expertise of engineers and scientists from different nations and build ever closer cooperation.”

“

No one had come so close to a comet yet – not even NASA – let alone dared a landing. The risks were too great.

”



↓ ESOC Climbing Club members unfurl a banner on the new ESOC II buildings in 2013



By the mid-1980s, ESOC was already controlling the comet hunter, Giotto, ESA's first deep-space mission. Tracking spacecraft through complex trajectories millions of kilometres away and receiving huge amounts of valuable scientific data from onboard instruments have required new methods, hardware and software; ESOC has constantly upgraded as the mission demands have increased.

"The Russians led the way and NASA's budget was always ten times higher than ours. We Europeans were not really taken seriously," recalled Manfred Warhaut, Director of Mission Operations at ESOC until 2013. Europe's image changed with missions such as Giotto, and Huygens that landed on Titan in 2005.

"And we even overtook the Americans with Rosetta," said Manfred proudly. He managed the mission until 2006 and was one of the faces of the mission on ESA TV as its exploits unfolded. Another key figure during the Rosetta mission was Paolo Ferri, Head of ESA Mission Operations, who has been at ESOC for more than 30 years. Ferri's first mission was EURECA – the European Retrievable Carrier that NASA sent into space in 1992 on a Space Shuttle and retrieved a year later.

"That was a great mission and adventure," recalls Ferri, who was a 32-year-old operations engineer at the time. "When I first began working in ESOC, I immediately got the missions operations bug. That was what I wanted to do." Rosetta was to prove a huge challenge, and a European first. "We had no experience," said Ferri.

The approximately seven billion-kilometre journey to rendezvous with the comet, parts of which were nearly a billion kilometres from Earth and 800 million kilometres from the Sun, was uncharted territory even for the most experienced



ESOC Main Control Room

engineers as well as people in flight dynamics and operations. “No one had come so close to a comet yet – not even NASA – let alone dared a landing. The risks were too great.”

Ferri remembered the predictions from across the Atlantic, that ‘The Europeans will never manage that’, but he said, “The enthusiasm always outweighed the anxiety.”

ESOC is today ESA’s ground segment hub, with control rooms for each of the spacecraft now in operation, and separate control rooms for computer networks and for ESA’s Estrack ground tracking station system. The global network of eight stations includes three giant 35 m antennas in Australia, Spain and Argentina; all engineering and design work for these marvellous devices is also done at ESOC.

Rolf Densing, ESA Director of Mission Operations and Head of ESOC, believes joint efforts, pooling of skills and competences are key. He believes ESOC has a role at the heart of ESA, not merely as a centre of operations where engineers, mathematicians and astrophysicists are able to calculate one-off missions such as the ten-year journey to a comet.

“ESOC is important to ESA’s identity. This is where successes are celebrated and emotions come to the fore. Everyone comes together here and toasts successful missions, to be

captured by TV cameras, photographers and global media,” Densing added.

Flying into the future

The decades have further proven that many activities in space can only be achieved through international cooperation. ESOC is also a hub for software development, as the complexity and sophistication required for mission control systems grows from one mission to the next.

ESOC’s engineers, scientists and technicians have always been passionate about humankind’s voyages into the Universe. In the past, they combined boundless enthusiasm and superb expertise to achieve great aims. In the future, they will lead us further than we ever imagined. ESA’s operations experts have celebrated many historic firsts at ESOC over the decades, including Giotto’s flyby of Halley’s Comet in 1986 and Rosetta’s landing on Comet 67P/Churyumov-Gerasimenko in 2014.

The 50th anniversary of ESOC is a shared celebration, with all of those who have worked at or visited the site, and with the local community in Darmstadt. While we control spacecraft millions of kilometres away, our hearts will always be in Europe. ■

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While we control spacecraft millions of kilometres away, our hearts will always be in Europe.

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→ THE EVOLUTION OF ESEC

The European Space Security and Education Centre at Redu

Daniele Galardini

Directorate of Telecommunications and Integrated Applications, ESEC, Redu, Belgium

Cindy Leonard and Sabrina Guillaume

Redu Space Services, ESEC, Redu, Belgium



Member State flags at ESEC,
Redu, Belgium



↑ Signage at Redu, 1960s

Since 1968, the postcard village of Redu in the Belgian Ardennes has been connected with space. First hosting a tracking facility, the site has now been renamed as a fully fledged ESA centre.

Just short of its 50th anniversary, ESA's base in Belgium will now be known by a new name: the European Space Security and Education Centre, or ESEC. Letters posted to 'ESA REDU Belgium' over many years led to this becoming the recognised public name, but in fact it has been an ESA centre since 2007. Redu has been engaged in new activities for several years, and has been given its new name to reflect that.

Between 2014 and 2017, ESA began some promising new work in space cyber security and education. After a search for an appropriate acronym to describe Redu and its activities, ESA Director General Jan Woerner decided to rename it as ESEC, not as a way of limiting its mission to the innovative activities but to strengthen their future in the centre. This new chapter begins just before the centre's anniversary next year and exemplifies the growth and development over the past half a century.

Five decades after the site was chosen, ESEC has grown to cover more than 20 hectares in the municipality of Libin, with around 50 radio dishes pointing mostly at geostationary satellites. Some of its antennas are used to control the Proba microsattellites and conduct in-orbit testing of telecommunications and navigation satellites.

The site also houses the backup control centre for the major Luxembourg satellite operator, SES.

The roots of Redu

The story of Redu starts at the very beginning of the European space adventure. In the early 1960s, everything was starting from scratch: launchers, satellites and even the ground stations needed to pursue and control the space vehicles and to allow the computation of their orbital parameters.

Belgium was already one of the most active states in the European Space Research Organisation (ESRO) and the European Launchers Development Organisation (ELDO) and immediately offered to host technical facilities.

In 1963, ESRO decided to establish the European Space Tracking and Telemetry Network. It was necessary to have one of these facilities close to ESA's European Space Research and Technology Centre (ESTEC). ESTEC was located in Delft at that time but later moved to Noordwijk, in the Netherlands, so the tracking facility was earmarked for Belgium, with a final location to be confirmed.



The ECS satellite control room, Redu, in the 1980s

Surveys showed that the best site in terms of technical characteristics, and to minimise investments, was Redu. In February 1965, with the agreement of ESRO, the Belgian government chose Redu, located 380 m above sea level and situated in a natural basin amid pasture and woodland. The topography of the site, a natural amphitheatre, and its remoteness from towns, provide natural protection from radio interference.

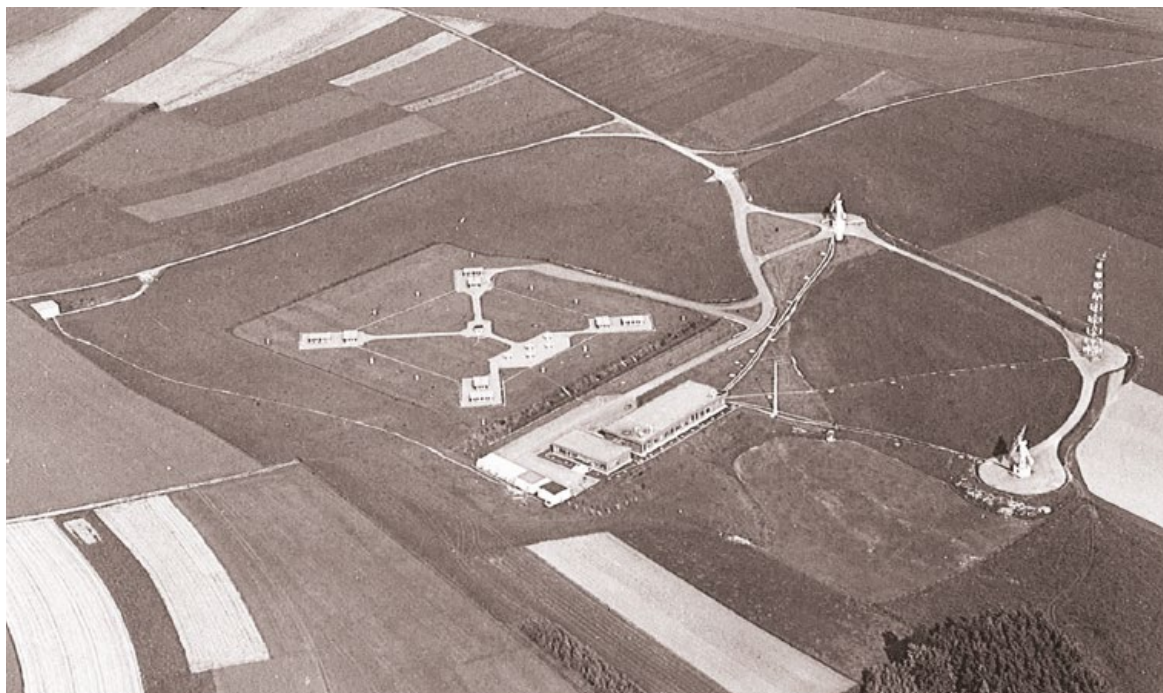
At that time, there was no security fence marking the station's boundary. Instead, at the entrance to the site, there were some unusual road traffic signs. Motorists were met with a stop sign, a red light and a sign saying: 'Stop when red light shows and turn off engine. Satellites passing overhead. Approximate duration: ten minutes'. Warned against causing interference with their tractor engines, Redu farmers became participants in Europe's great space adventure.

Since 1968, Redu has been part of Estrack, formerly ESRO's and now ESA's satellite tracking and control network. It participated in many European science missions, relaying

signals from ESRO's scientific satellites in orbit to the European Space Operations Centre (ESOC) in Darmstadt, Germany. These included: ESRO-2B (launched in May 1968), HEOS-A1 (December 1968), ESRO-1B (October 1969), HEOS-A2 (January 1972), TD-1A (March 1972), ESRO-4 (November 1972), ANS (the Netherlands' first satellite, August 1974) and COS-B (August 1975) – all European satellites launched by NASA.

The European Telecommunication Satellite Organisation (Eutelsat) was founded as an intergovernmental entity for satellite communications in 1977. It used ESA's first communication satellite programme, Orbital Test Satellite (OTS), along with ESA for more than 13 years. OTS led to the European Communications Satellites (ECS) for use by Eutelsat.

Under a 10-year agreement, ESA provided the first-generation space segment for Eutelsat, which became the owner of each satellite after the in-orbit testing performed from the ESA Redu station, where the control centre was installed. The last payload was handed over in 1988 and operated until



← →

Then and now: during construction of the interferometer site in the 1960s and a current aerial view

1 December 2002, when the final command to shut down ECS-4 was sent. Eutelsat began launching its own satellites and became a private company in 2001.

Expanding capabilities

During 2001–14, Redu hosted the Artemis Mission Control Facility to schedule user services, the Ka-band ground terminal with a 13.5 m-diameter dish, serving as a user ground station and all the facilities used to test the status of the different payloads.

Artemis clocked up a number of 'firsts' in the space field during its recovery process: first optical inter-orbit satellite link, first major reprogramming of a telecom satellite in orbit, first transfer to geostationary orbit using ion propulsion, and survival of the longest-ever operational drift orbit. It also provided the much-needed promotional opportunity and stimulus for Europe's future data-relay services, EDRS. Telecom antennas, used for ESA and third-party programmes, have changed the shape of this site over the years – and this will continue.

The expertise acquired through controlling ECS satellites positioned Redu as the site for routine operations of ESA's small and low-cost missions such as Proba, as part of the In-Orbit Demonstration Programme. The first, Proba-1, validated new spacecraft autonomy and three-axis control and data system technology. The Proba-1 main payload is the novel CHRIS imaging spectrometer. Launched on 22 October 2001, its mission was initially foreseen for two years but it is still serving the scientific community, becoming our longest serving Earth observation satellite.

In 2009, Proba-2, a solar mission, was launched, followed in 2013 by Proba-V (V for 'Vegetation') for monitoring Earth's vegetation every 10 days. Future Proba missions operations will also be handled in Redu.

Thanks to its several decades of experience in testing telecommunication payloads, it was naturally decided to install the in-orbit testing facilities for European navigation satellites in Redu. It started with GIOVE-A and -B testing, using a specific antenna. GIOVE satellites were precursors of the Galileo satellites, to validate the new signals and some state-of-the-art technologies from space.

Later, a custom-designed L-band 20 m dish was installed for testing Galileo payloads. Such a big antenna is necessary for the detailed analysis of the spread of signals that are used to allow accurate timing and positioning. In addition, a C-band antenna was installed to uplink test navigation signals to the satellites, as well as a Yagi UHF antenna to transmit test signals through the search and rescue transponder of the Galileo satellites.

As consequence of the in-orbit testing conducted from Redu, the Redu-1 antenna, a 15 m S-band dish, has been incorporated into the Galileo Telemetry Tracking and Commanding Facility network that allows the Galileo Control Centre near Munich in Germany to continuously monitor and control the Galileo constellation of satellites.

In-orbit testing of the navigation and search and rescue payload is a key milestone in satellite lifetime because it is the mandatory step before the satellite is declared ready to provide navigation services to citizens and customers.



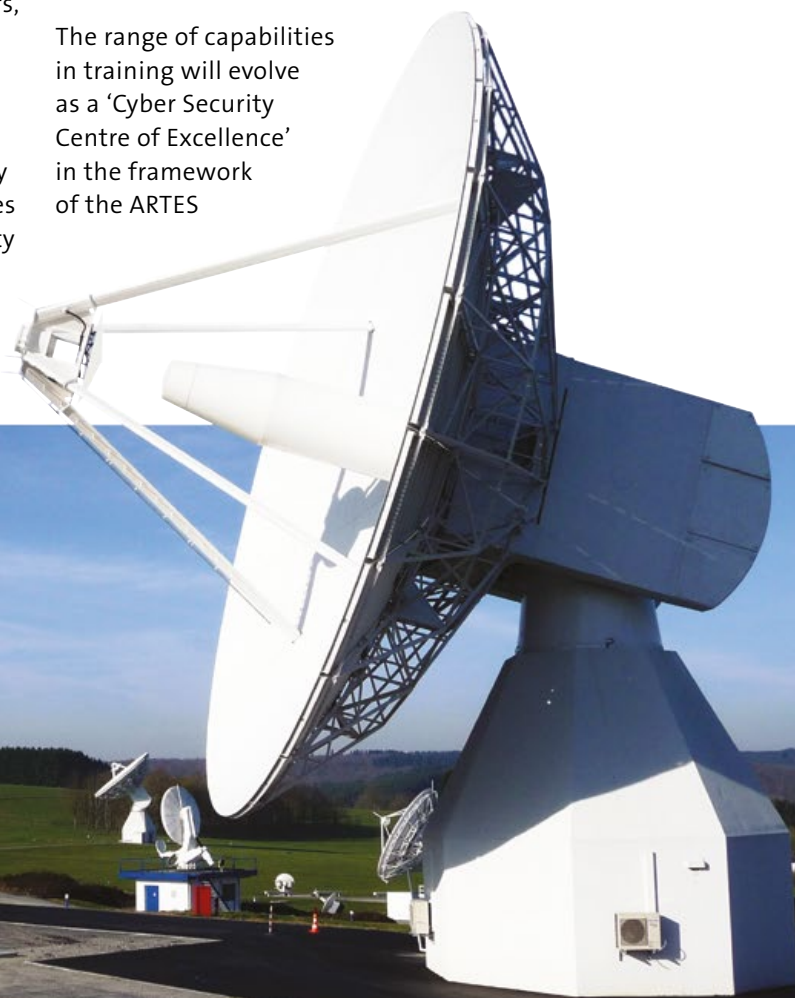
The emergence of ESEC

Redu's new title acknowledges its role as the European reference centre for cyber security services. ESA will be a catalyst through its interest in cyber security, with the objective of having a reference centre for cyber security matters operated by industry. ESA will be one of the users, and the owner of the part of it that relates to space.

Several companies interested in ESEC business have already expressed their views regarding their development about future plans related to cyber security on the site. A consolidated assessment of these strategies shows that all of the companies involved in cyber security connected with ESA programmes also operate in other domains, and that they can exploit overlaps between ESA and external activities.

Some steps have been already taken toward the implementation of this vision. Thanks to initial Belgian investment, and building on the recommendations of two ESA (classified) parallel studies about potential cyber threats to ESA, the first European 'space-assets training range specialised in cyber security' has been established in ESEC.

The range of capabilities in training will evolve as a 'Cyber Security Centre of Excellence' in the framework of the ARTES



The custom-designed L-band 20 m dish installed for testing Galileo





King Philippe
of Belgium
visited ESA's
centre at Redu
on 17 March
2015

Competitiveness and Growth programme co-funded by industry and the Belgian authorities.

Thanks to this, in 2019, the ESEC Cyber Security Centre of Excellence will include education and training offering a wide range of professional development in cyber security: awareness, hosted hands-on tools and procedure training supported by operational use cases, for example. This will involve research, development, integration and testing of advanced cyber security technologies applicable to space-based assets and supporting ground systems, as well as security evaluation of space systems and solutions, including resilience to cyber threats.

The ESA Academy

Education is also vital. As a mandatory activity in the ESA Convention, it is another crucial component of the Agency's undertakings such as space sciences, engineering or technology. It is an unquestionable investment in our competitiveness and in the development of the future workforce, which is needed by Europe to implement its space strategy.

In close partnership with Member States, and continuously seeking to offer improvement and new opportunities to the Member States' education communities, the ESA Education Office programme offers:

- classroom resources tailored to the curricula taught by primary and secondary education teachers with training opportunities using space in a training and learning context;

- complementary academic training in areas of ESA's expertise for university students across Europe.

These are unique hands-on opportunities to gain, within a working space environment, significant practical experience during the full life cycle of real space projects.

Since 2014, the Education Office has offered an e-robotics lab to primary and secondary teachers that focuses on robotics and related sciences such as engineering, physics, mathematics and informatics. This infrastructure is fully operational and has already welcomed hundreds of European teachers.

- ↓ Courses in a range of specialised engineering subjects are now held at the ESA Academy, based at ESEC





The Galaxia space business park, where the ESA Business Incubator Centre Wallonie Redu, the Galileo Logistic Centre and the Euro Space Visitor Centre are already based



Education is vital. As a mandatory activity in the ESA Convention, it is another crucial component of the Agency's undertakings.



In March 2016, the site introduced participants to the ESA Academy Training and Learning Centre which, in collaboration with universities and academic institutions, aspires to transfer the expertise, knowhow and best practices of ESA to European university students.

Equipped with a Concurrent Engineering Centre (or Concurrent Design Facility), the ESA Academy complements technical and scientific training courses on subjects such as technology transfer, mission operations, project and risk management, gravity-related research and space medicine. This set-up is fully operational and has already welcomed more than 200 European students.

Educational CubeSats have become a vital component of learning for young engineers and scientists. In perfect symbiosis with the ESA Academy Training and Learning Centre, an assembly, integration and verification infrastructure, equipped to ESA standards, will begin this year providing university students involved in the development of CubeSats with unique end-to-end support, from the design phase to operations in orbit.

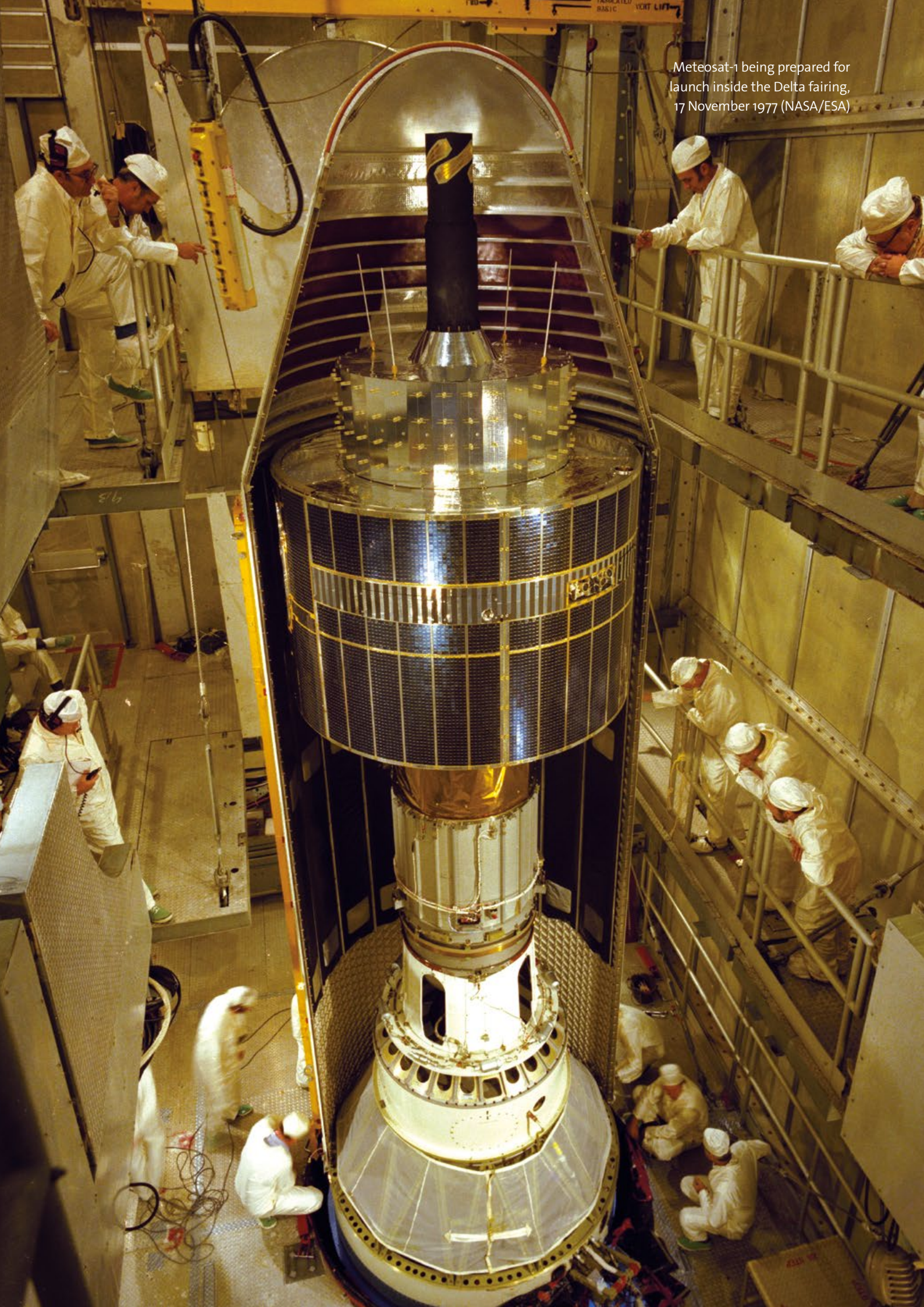
One centre, two sites

ESA has accepted the offer from IDELUX, a public company devoted to the development of the Belgian Luxembourg Province, to host the ESA Academy in its Galaxia space business park, where the ESA Business Incubator Centre Wallonie Redu and the Galileo Logistic Centre are already based. This means that ESEC can concentrate its operational and cyber security activities in Redu and that the educational activities can take place at Galaxia.

Since 2007, Redu Space Services SA (RSS) has provided maintenance and operation services in ESEC, as well as facilities management services. RSS is a Belgian company founded by SES TechCom and Qinetiq Space. Other companies in ESEC include Rhea, Vitrociset, EPB and Creaction. They all have a long association with the centre, and are diversifying and expanding their work. Rhea and Vitrociset constitute the consortium that has provided the first cyber security demonstration facility in ESEC.

As Redu transforms into ESEC, it brings invaluable history and experience to a new series of challenges. ■

Meteosat-1 being prepared for launch inside the Delta fairing, 17 November 1977 (NASA/ESA)



→ FORTY YEARS OF METEOSAT

Europe's geostationary weather satellites reach milestone

Ruth McAvinia

Communications Department, ESTEC, Noordwijk, the Netherlands

Meteosat-1 was launched on 23 November 1977 and became ESA's first Earth observation satellite. It marked the start of true European cooperation in meteorological satellites, and completed coverage of the whole globe from geostationary orbit.

Many aspects of our lives are dominated by the weather – our well-being and prosperity rely on it. The economic and social benefits of accurate weather forecasts are immense and include improved efficiencies in agriculture, better planning of transport and energy networks, and better preparation for hazardous conditions. Weather satellites can be used to gather data for immediate use, and for long-term climate characterisation.

The addition of weather information from space has improved forecasting and saved many lives, as well as building a better picture of global atmospheric patterns.

The first photograph of cloud cover from space was taken by Vanguard-2 in 1959, while atmospheric monitoring from space began in earnest in 1960 with Tiros-1, the first weather satellite. From low orbit, Tiros-1 sent back television pictures with the aim of informing weather forecasters and emergency managers on the ground about immediate threats from the weather. The first geostationary weather satellites were launched in the mid-1960s by the United States, but it was not until the 1970s that a coordinated global effort of weather prediction was begun.

In Europe, Earth observation satellites had begun with monitoring of the ionosphere by individual countries. The United Kingdom worked with NASA to launch Ariel-1 in 1962, while Italy had conducted measurements in the ionosphere with the San Marco-1, also launched from the United States in cooperation with NASA.

France used its own rocket and launch site in French Guiana to launch Astérix, which briefly conducted ionospheric research, followed by FR-1. The need for a European weather satellite came under discussion by the European Space Conference in the mid-1960s – a body combining members of the Conférence Européenne des Télécommunications par Satellites and of ESA's predecessors, the European Space Research Organisation (ESRO) and the European Launcher Development Organisation. On a global scale, the World Meteorological Organization had also called on Europe to take the opportunity to be involved in world efforts in satellite meteorology.

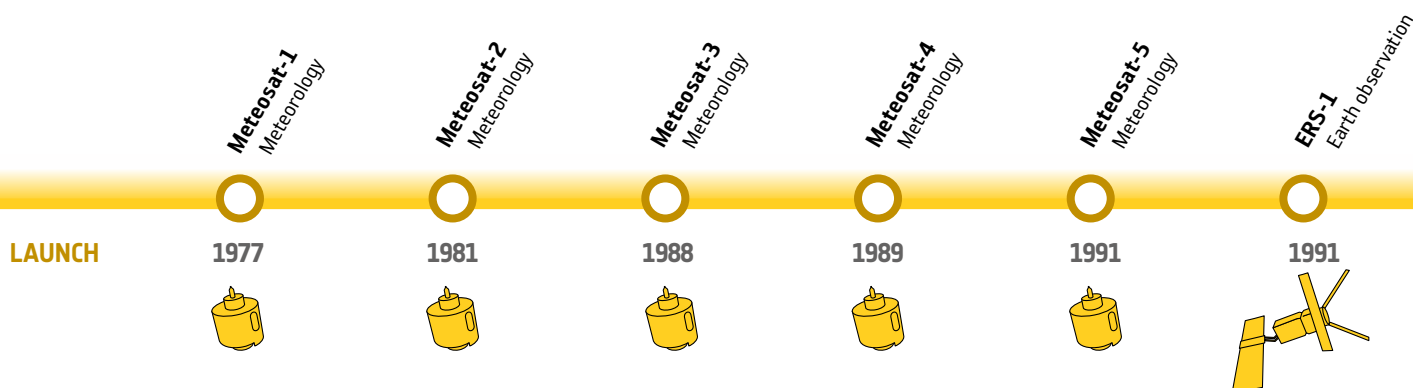
A global aim

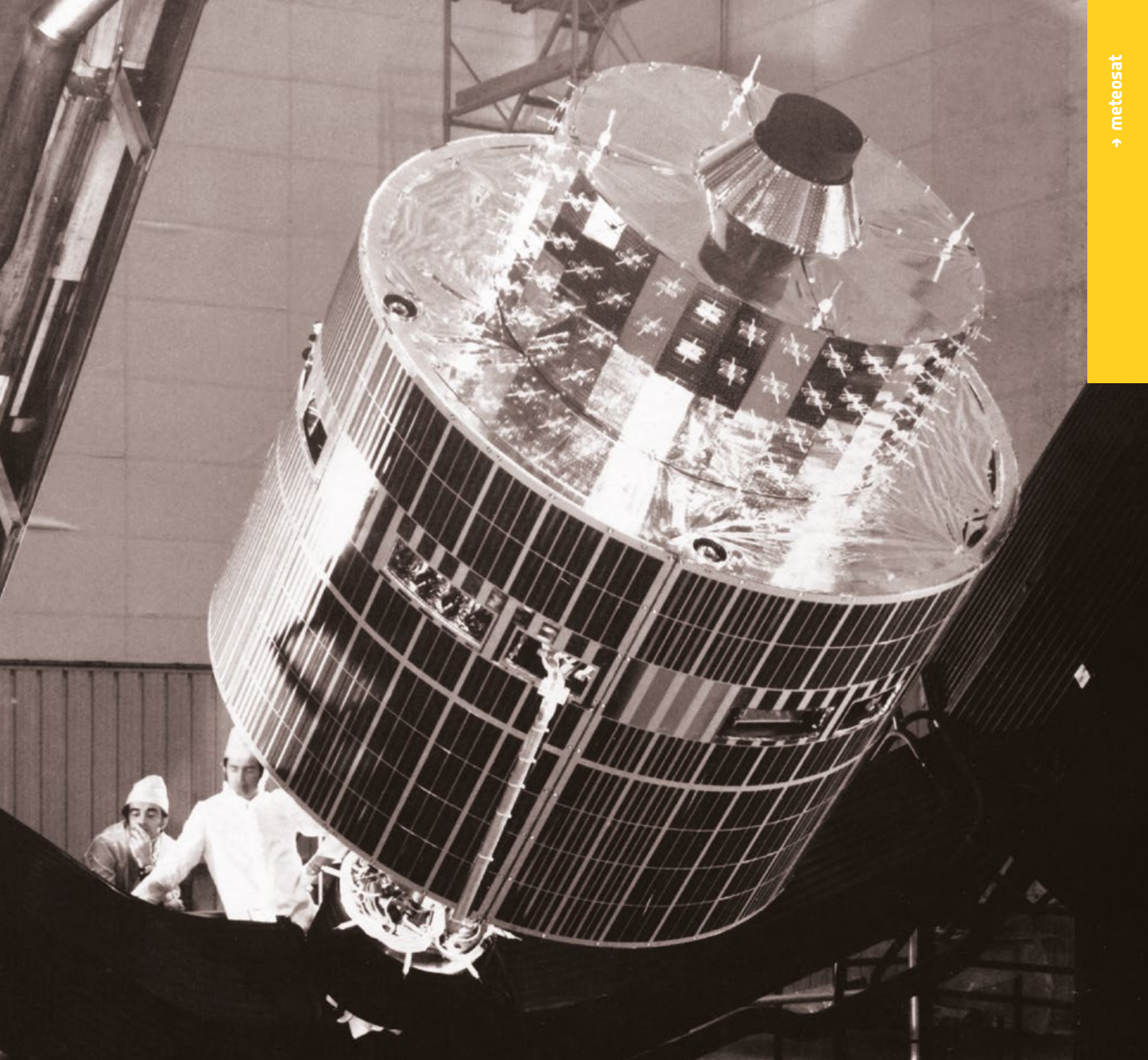
Before the satellite era, weather prediction had relied on surface observations from weather stations on land or on ships and buoys, combined with some measurements from kites, balloons and aircraft. The development of satellites, along with new computing power, offered the possibility of modelling the atmosphere in detail never seen before, and predicting weather events before they were visible – the era of numerical weather prediction had begun.

Data from polar-orbiting satellites combined with information from geostationary orbits would be vital in composing this picture of the atmosphere. The European Centre for Medium-Range Weather Forecasts (ECMWF) had been founded in 1975 to pool meteorological resources between its member states and to produce climate and weather forecast data. Global cooperation in sharing raw data as well as computer model outputs improved forecasts worldwide.



→ EUROPEAN EARTH OBSERVATION MISSIONS





↑ Testing the Meteosat-1 Thermal Model at the Centre Spatial de Toulouse in France in 1975

Meteosat-6
Meteorology



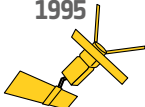
1993



ERS-2
Earth observation



1995



Meteosat-7
Meteorology



1997



Proba-1
Technology demonstrator
Earth observation



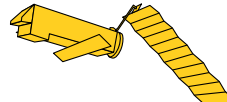
2001



Envisat
Environmental monitoring



2002



MSG-1
Meteorology



2002



MSG-2
Meteorology

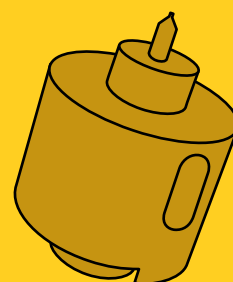


2005



→ Meteosat vital statistics

Launch date	23 November 1977
Launch vehicle	Delta 2914
Launch site	Cape Canaveral, Florida
Mass	697 kg including 345 kg for the ejectable apogee boost motor (ABM) and 60 kg for the ABM and third-stage attach fittings
Prime contractor	Aérospatiale (Cannes)
Reached geostationary orbit	7 December 1977
Main instruments	Imaging radiometer Data collection platform
Data collection platform	2.1 m diameter, 3.195 m high
Dimensions	Spin-stabilised 100 rpm



The Europeanisation of Meteosat

Meteosat began life as a French project, with involvement both from CNES and from the meteorological service in France. The project had performed initial feasibility studies and worked on the original design for the radiometer. Meanwhile, ESRO was considering possibilities for polar-orbiting and geostationary satellites. Once settled on a geostationary satellite for Europe, it was obvious that this would be a duplication of the French effort. Over a long period of fact-finding and negotiation, the foundations were laid for the Meteosat project to evolve into a European one. By this time, ESRO had become part of the new European Space Agency.

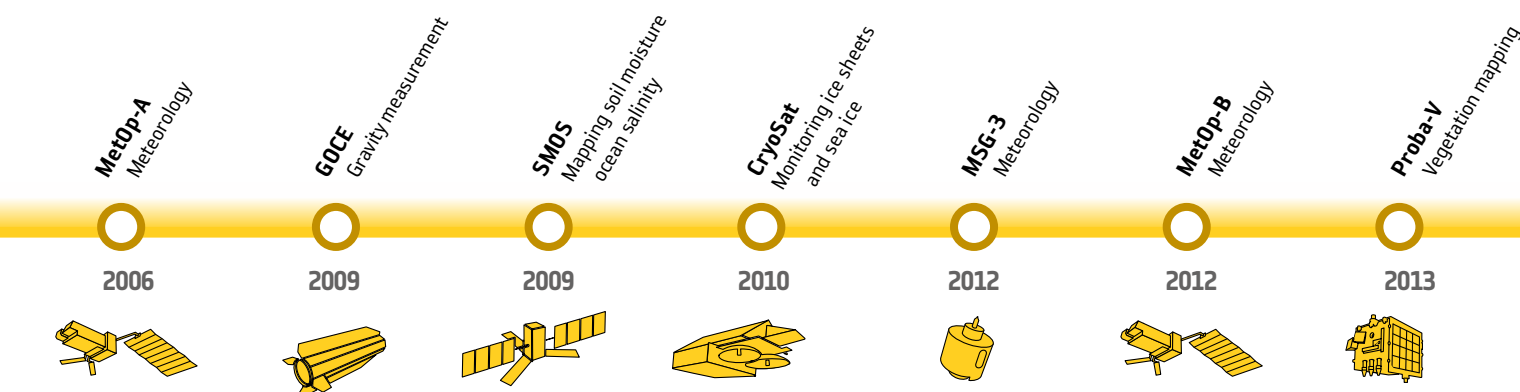
Rather than uproot the whole operation from France, it was decided to establish an ESA office in Toulouse, from where Meteosat could be developed and guided under the direction of Dieter Lennertz. The solution was only temporary as the team from Toulouse eventually disbanded, but it served to smooth the transition. Before Meteosat-1 was launched, it

had already been decided that Meteosat-2 would be launched by Ariane in 1980, signalling that ESA's involvement in meteorological satellites would not be a one-off.

Launch and operation

The launch of Meteosat-1 was a cause for celebration, but there were a few tense moments. The first attempt on 20 November 1977 had to be scrubbed just two hours before liftoff after the discovery of stray radio signals. John Krige recalls the story in his history *The European Meteorological Satellite Programme*. The signals involved matched those used as a safety measure to destroy rockets in flight should they go off track. The source of the signals was identified and confirmed by NASA: an accidental transmission from a tracking ship.

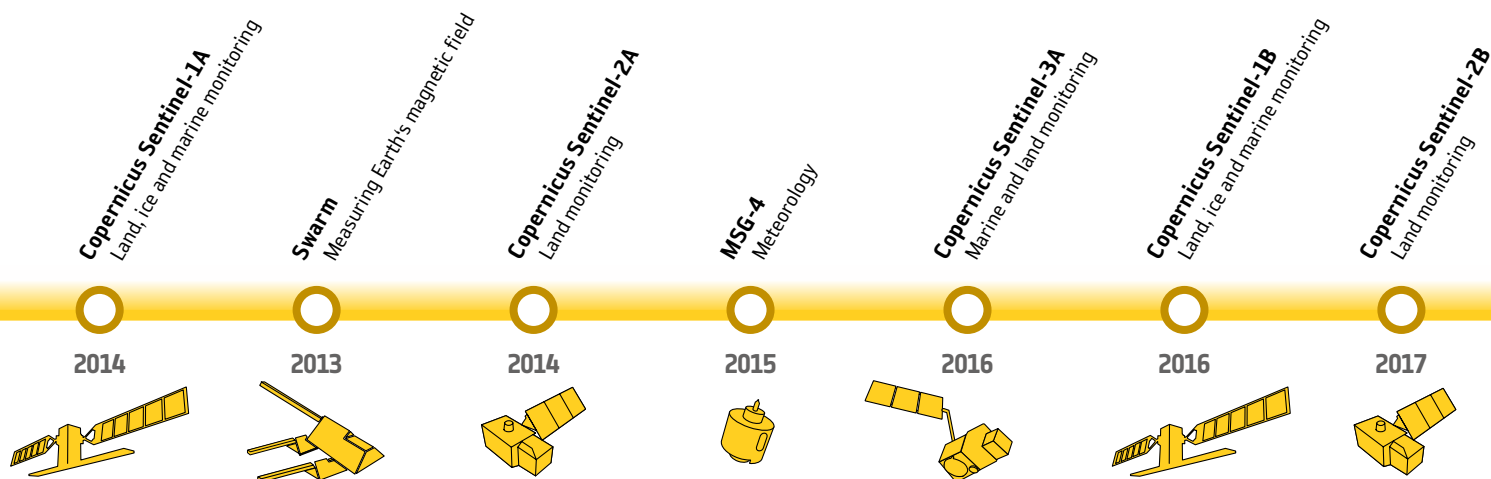
With no further concerns about the range, Meteosat-1 left the ground at 13:35 GMT on 23 November 1977. Meteosat-1 reached its orbit on 7 December 1977, and its first image was sent back on 9 December.





METEOSAT-1

FIRST IMAGE: 9 DEC 1977
COPYRIGHT ESA



The new geostationary ESA missions needed a new and much more powerful computing system. At the European Space Operations Centre (ESOC), this system, later to be termed the multisatellite support system was designed to process telemetry data from up to six separate satellite sources, to generate telecommand in real time and to drive up to 13 alphanumeric displays in the Operations Control Centre control room. In addition to this new computer system, a second and even larger system would be needed to support the Meteosat image data processing as Meteosat would transmit raw-image data at 166 kbit/s every half hour, 24 hours a day. To cope with this task and to provide all the other functions needed to support the Meteosat mission, the Meteosat ground computer system was installed.

Meteosat joined the Global Atmospheric Research Programme (GARP) and was quickly called into service to be part of the First GARP Global Experiment (FGGE). Although Meteosat failed just before the end of the experiment period, FGGE was one of the biggest cooperative scientific ventures of the era, and provided a truly global dataset for atmospheric science for the first time. The experiment was important in proving that imagery from space was worth the investment, both in the space segment and the extensive ground segment needed.

From its position over the Greenwich meridian, Meteosat-1 could scan Earth's full disc every 30 minutes, with the data being provided in near-real time to users. Meteosat could detect clouds in the atmosphere and by tracking their movements, also give information about wind speed and direction (see *ESA Bulletin* No.3, October 1975). It was the first satellite in geostationary orbit to have a water vapour channel to track the motion of moisture in the air. From the early days of the discussion, the volume of data generated was also important: how would it all be processed in time to be of use? This is still a problem in numerical weather prediction today even though computer power continues to increase.

→ A policy puzzle

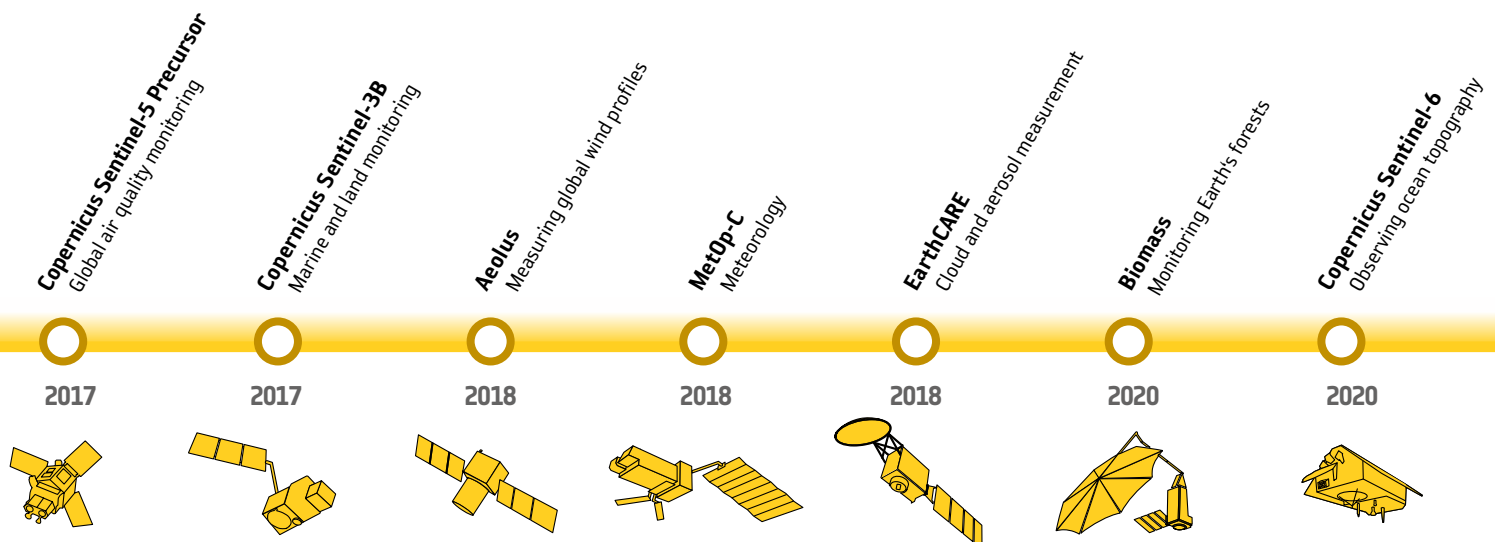
The need for Meteosat was clear, but the means for bringing it about as a European project was significantly less so. ESRO had a science remit, but meteorology nudged it into the realm of space applications. While the telecommunications community had taken over responsibility for satellite communications through Eutelsat, the meteorological community across Europe was not yet prepared to take over responsibility for a satellite system.

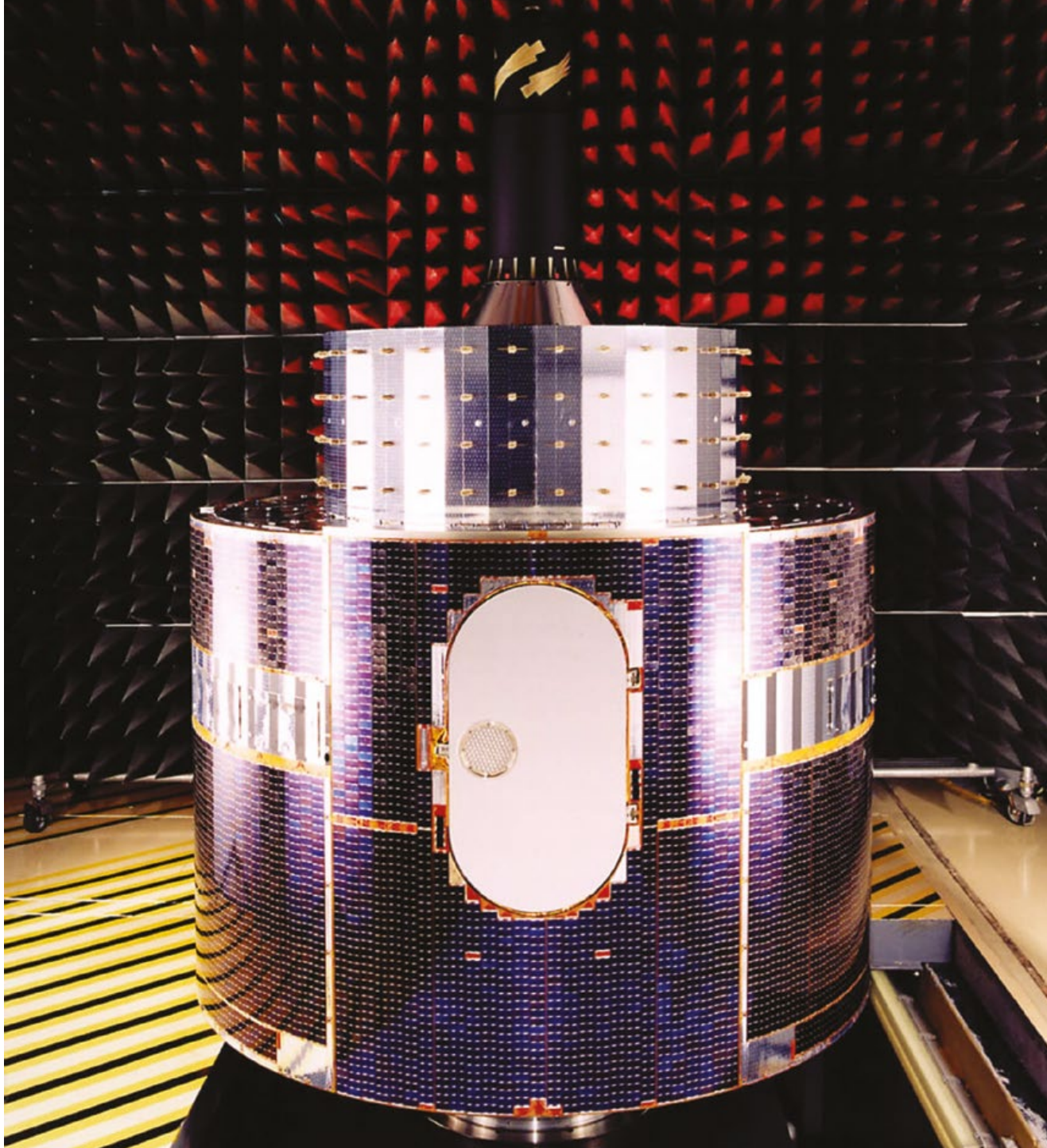
Unlike Eutelsat, the meteorological satellites would not yield a profit, and so funding had to be put in place for the continuing operation and management of the satellites and programmes. The structure for Meteosat was put in place following a legal arrangement made in 1972 between ESA and eight of its Member States (Belgium, Denmark, France, Germany, Italy, Sweden, Switzerland and UK).

There was a gap of almost a decade between the launch of Meteosat-1 and the official founding of Eumetsat, with clear operational responsibilities and funding. Even then it transpired that its conventions needed to be rewritten once it was ready to develop its own satellite programmes. Eumetsat has since grown to 30 member states, and continues to develop new satellites in cooperation with ESA.

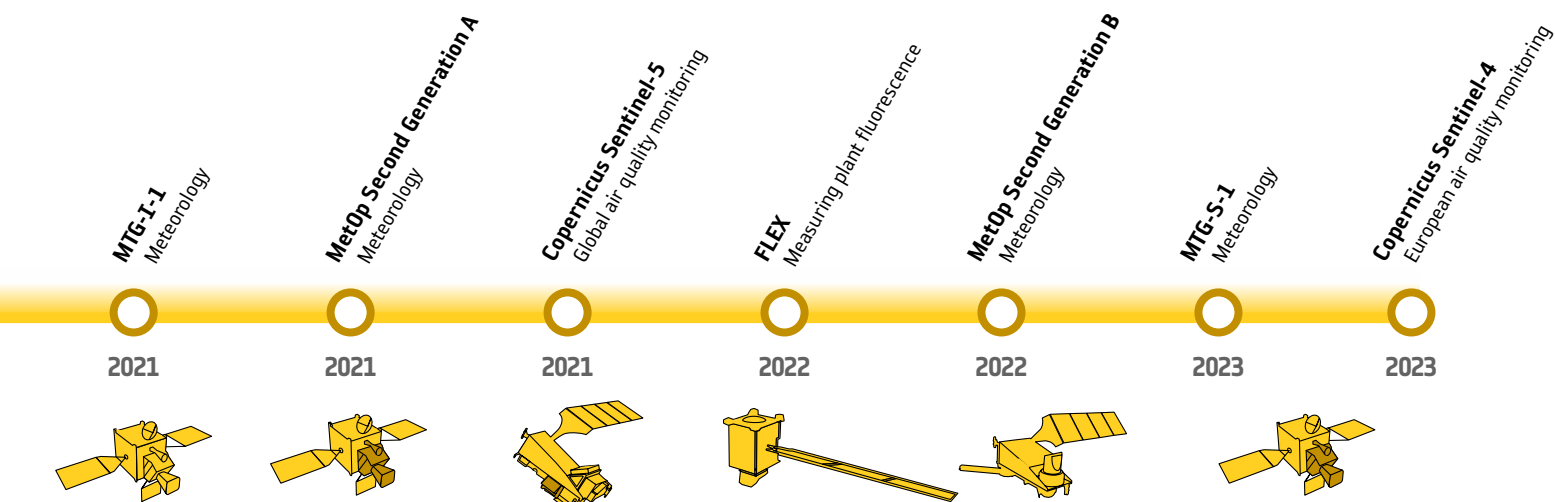
A proud record

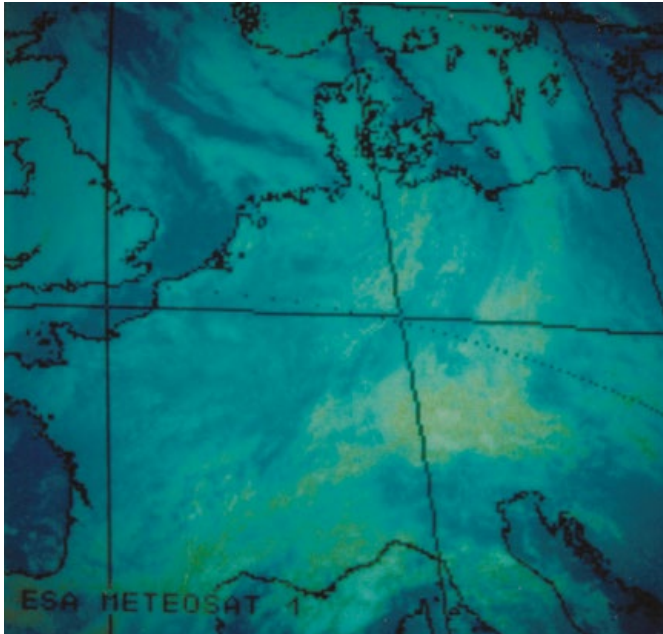
Since the launch of the first Meteosat, 40 years of imagery and derived meteorological data have helped to significantly improve weather forecasting, with direct





↑ Meteosat-1, launched in 1977, was Europe's first meteorological satellite





↑ One of the polaroids saved by ZDF showing original Meteosat-1 imagery (Eumetsat)

→ MSG-1 is installed on the launcher, at the final assembly building August 2002 (ESA/CNES-Service Optique CSG)

→ → Meteosat Third Generation prototype antenna undergoing testing



benefits to users such as air and marine transportation, as well as, for example, the construction, energy, retail, agriculture and leisure industries. Lives have also been saved through the warning and earlier evacuation of populations threatened by hurricanes and other severe weather events.

One of Meteosat's most notable achievements was the contribution it made to the forecast of Hurricane Andrew in 1992, allowing air traffic to be rerouted and precautions taken on the ground to limit damage. Meteosat-3 was occupying an unusual position, at 75°W over the US east coast, at the time. The satellite had been moved into this position after the failure of the US GOES-East satellite, which normally occupied it.

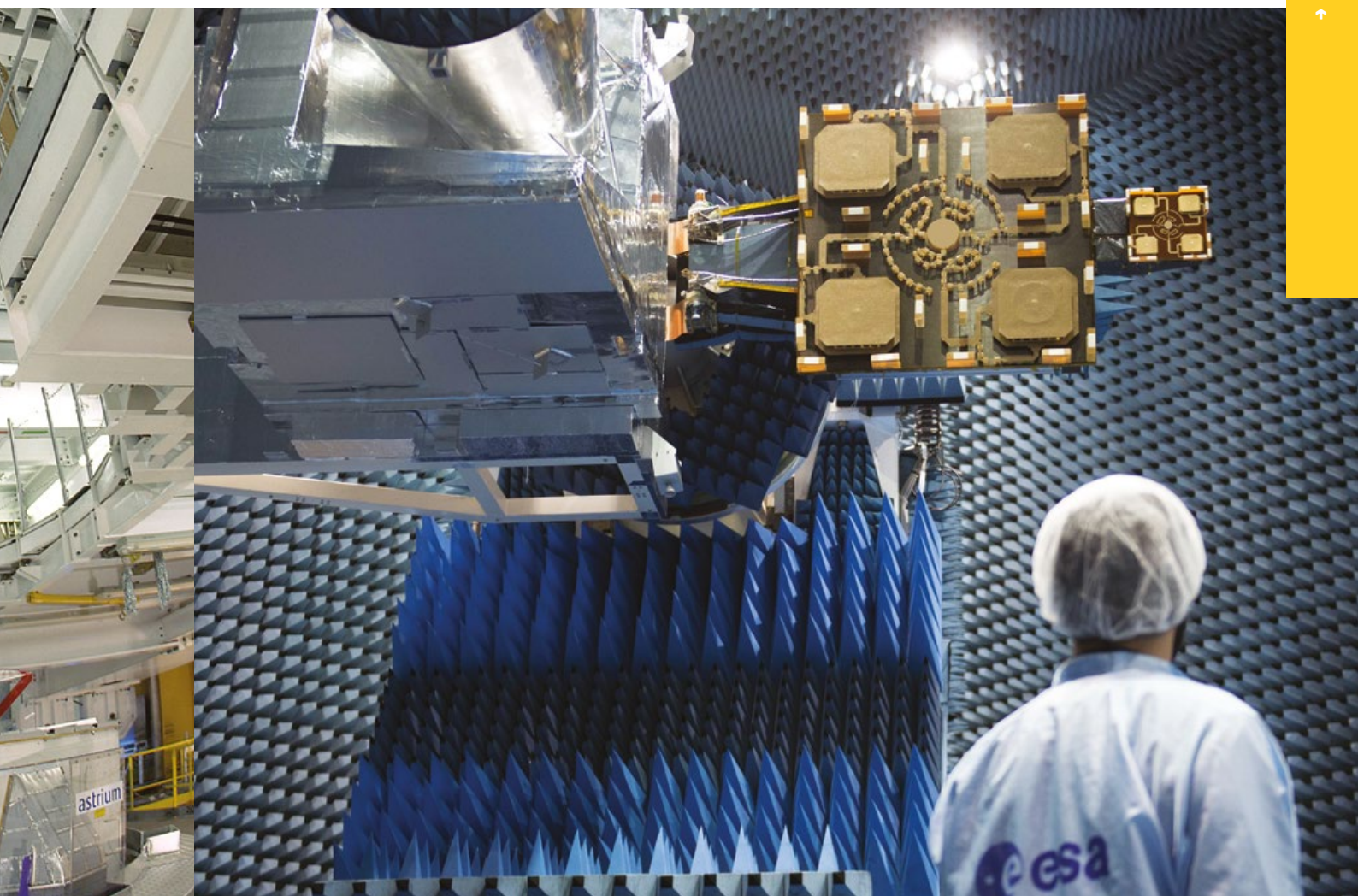
Meteosat began a record of imaging from space that constitutes an important body of evidence in climate science. Although the space era is short relative to climate change over time, imagery and data from space are a useful component. Climate scientists use reanalysis to ensure they compare similar records and do not introduce

errors across the satellite record, bridging multiple different instruments, operators and eras.

There are 35 years' worth of Meteosat imagery available online, but the original Meteosat-1 images are a rarer commodity. In 1978, Zweites Deutsches Fernsehen (ZDF) worked with ESOC to broadcast satellite imagery as part of the weather forecast. The images were produced by taking a polaroid photograph of a computer screen in ESOC. The photograph would then be couriered to Mainz to be broadcast on television. ZDF kept the polaroids and they have since been digitised and can be accessed on the Eumetsat website. Since ZDF is a German broadcaster, the images were zoomed in on to show Germany.

Serendipitous discovery

Eumetsat recently reported that some 'lost' imagery from Meteosat-1 had been recovered. During celebrations last year to mark 30 years of Eumetsat, scientists long involved with the organisation were given a memory stick with the satellite data record for climate science



from 1 January 1984 onwards. The stick was missing two days' worth of the images, prompting Paul Menzel of the Cooperative Institute for Meteorological Satellite Studies, part of the University of Wisconsin-Madison's Space Science and Engineering Center (SECC) to investigate. Dr Menzel didn't find his quarry of the two missing days, but instead uncovered Meteosat-1 data from the FGGE – the global experiment that incorporated some of the very earliest European data from geostationary orbit.

The data, comprising 20 790 images originally collected in 1978–79, had been transferred to a different storage format, but otherwise ignored for decades. SSEC's engineers manager to piece the files together and decode them to find the data. Then David Santek, who had worked on the original code, provided modules for navigating and calibrating the data. Against the odds, and through hard work and collaboration, the data can now be restored to the satellite record.

This type of detective work has been conducted in various research institutes to preserve the satellite data record

and to conduct reanalysis for climate science. Although the early meteorological satellites were not envisaged as tools for measuring climate change, imagery showing changes in land cover or polar ice and data on sea-surface temperature have become very useful for climate research and modelling.

A succession of Meteosats

The Meteosat programme always has one satellite in the operational position at 0° longitude. Additional satellites are currently over Africa and the Indian Ocean, while the last of the Meteosat Second Generation satellites is being stored in orbit. Meteosat Second Generation kept the drum-shaped design of the original but is two and a half times larger and offers improved resolution, 12 spectral channels as opposed to three on the original system, and faster scanning. Meanwhile, on the ground, Meteosat Third Generation is in development, with new capabilities such as lightning detection, and will guarantee continued European monitoring of the atmosphere from space into the 2030s. ■



→ THE CHINESE WAY

ESA astronaut training in China

Laylan Saadaldin
Communications Department, ESTEC, Noordwijk, the Netherlands

ESA astronaut Samantha Cristoforetti is assisted by a pressure suit technician during the joint training in August



ESA astronauts Samantha Cristoforetti and Matthias Maurer joined 16 Chinese astronauts in August this year for nine days of sea survival training off China's coastal city of Yantai. The ultimate goal is for ESA to establish a long-term cooperation with China, and for ESA astronauts to fly on China's space station.

Returning from space, astronauts need to be prepared for any eventuality – including landing in water. Sea survival is a staple of all training but this is the first time that other astronauts had joined their Chinese counterparts. (Chinese astronauts are sometimes referred to as 'taikonauts').

Working in groups of three, the astronauts put on pressure suits and entered a mock Shenzhou capsule that was then released into the sea. The astronauts had to swap their flightsuits for insulation and buoyancy suits before jumping into inflatable boats. They then practised rescue procedures with both a ship and a helicopter.

Samantha said, "The training was superbly planned and conducted. It was a great opportunity to refresh my skills and a first time practising capsule egress in the ocean with decent waves.

"Most importantly, we were welcomed as colleagues and friends by the 'taikonauts' and the instructors. Language and cultural differences are obviously a challenge, but also adds value, as we are all focused on the common goal of space exploration."

Matthias agreed, "The reception was warm. We truly felt the spirit of belonging to one universal astronaut family,

sharing the same values, goals and vision. Language was, as expected, the single most challenging obstacle, which we overcame with great enthusiasm and team spirit, speaking a mixture of Chinese and English."

Accompanying Samantha and Matthias were an ESA flight surgeon and training specialist to gain insights into the different cultural nuances and approaches. ESA's Head of Astronaut Training Rüdiger Seine added, "I see this as another milestone towards establishing good cooperation with China as a space partner."

While this is the first time ESA astronauts have trained in China, it is not the first collaboration. Last year, Chinese astronaut Ye Guangfu joined ESA's caving course in Sardinia to experience an extreme environment as part of a multicultural crew.

Both activities stem from the 2015 agreement to boost collaboration between ESA and the China Manned Space Agency, with the goal of flying European astronauts on the Chinese space station from 2022. In the meantime, other training opportunities and joint activities are in the pipeline for the agencies to get to know each other better. This sea survival course was organised by the Astronaut Center of China in cooperation with the Ministry of Transport's Beihai Rescue Bureau.

Matthias concluded: "I am very much looking forward to expanding our cooperation with our Chinese friends into space." ■

Laylan Saadaldin is an EJR-Quartz writer for ESA



In 2016, Chinese astronaut Ye Guangfu joined an international astronaut team of Ricky Arnold (NASA), Sergei Korsakov (Roscosmos), Pedro Duque (ESA), Jessica Meir (NASA) and Aki Hoshide (JAXA) (ESA-V. Croubu)



Matthias is picked
up from the sea by
helicopter





Samantha and Matthias join Chinese colleagues for a briefing on their survival equipment



“

We were welcomed as colleagues and friends by the ‘taikonauts’ and the instructors. Language and cultural differences are obviously a challenge, but also add value.

”

- The astronauts had to swap their pressure suits for insulation and buoyancy suits before egressing the Shenzhou into inflatable boats. Here Matthias jumps from the capsule
- ↘ Matthias and colleagues successfully recovered



Lowering Matthias onto the recovery ship after being airlifted



I am very much looking forward to expanding our cooperation with our Chinese friends into space.

A happy Matthias gives the thumbs-up signal after rescue by the recovery ship





Samantha gets into
Shenzhou capsule



The crews practised rescue
procedures with both a ship
and a helicopter



- ↑ Samantha practises water entry wearing special insulation/buoyancy suit
- ← The Shenzhou capsule is lowered into the sea
- ↓ Samantha helps her taikonaut crewmates to board liferafts



A photograph of a satellite's solar panel arrays in space. The panels are large, rectangular, and covered in a grid of solar cells. They are positioned diagonally across the frame, with the Earth's horizon and clouds visible in the background. The Earth's surface shows a mix of blue oceans and brown landmasses.

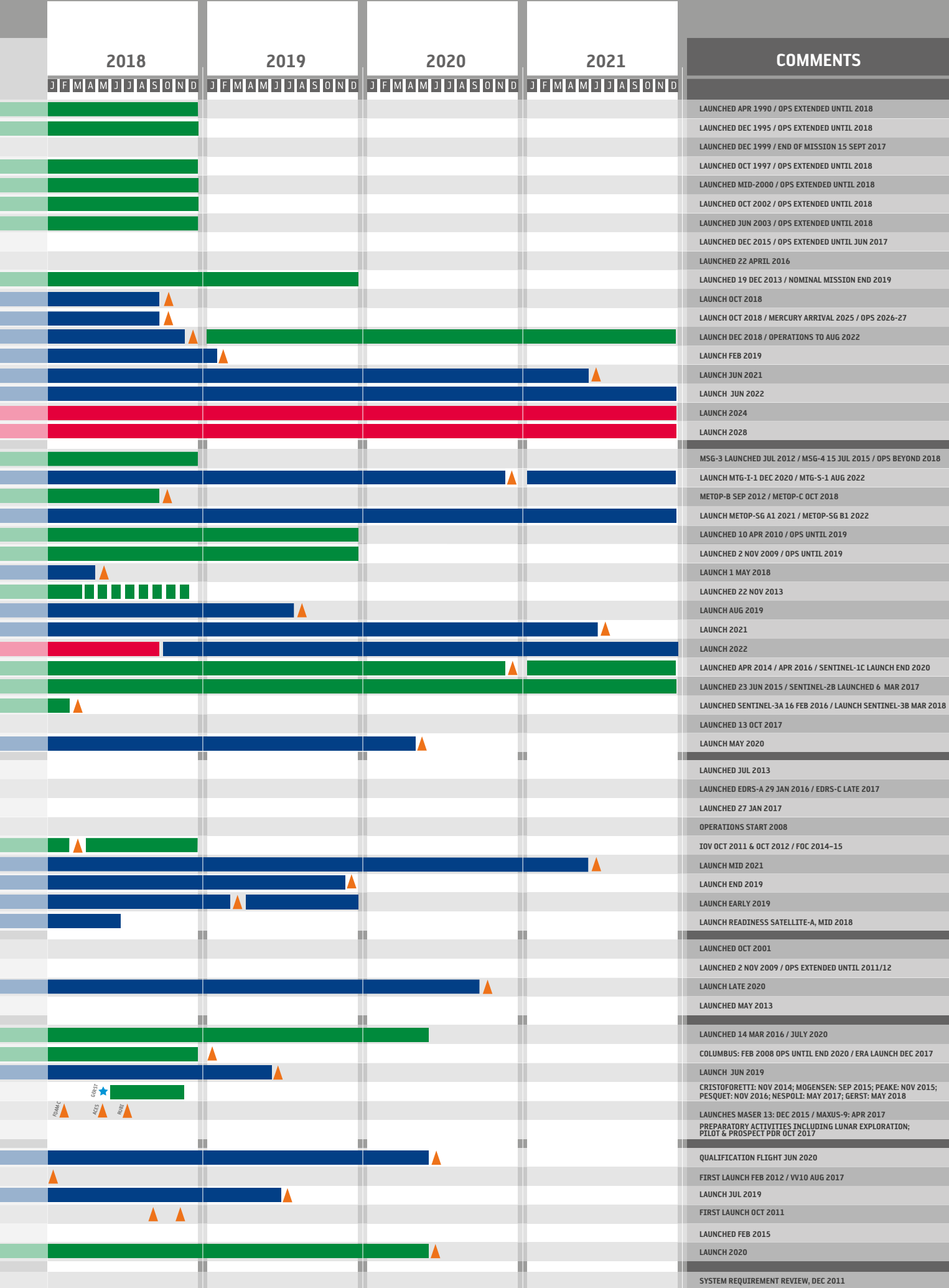
→ PROGRAMMES IN PROGRESS

Status at August 2017

Southern Europe,
Italy, Greece and the
Mediterranean, as seen
by ESA astronaut Paolo
Nespoli in August 2017
(NASA/ESA)







KEY TO ACRONYMS

AM - Avionics Model	LEO - Low Earth orbit
AO - Announcement of Opportunity	LEOP - Launch and Early Orbit Phase
AIT - Assembly, integration and test	MoU - Memorandum of Understanding
AU - Astronomical Unit	NEO - Near Earth object
CDR - Critical Design Review	PDR - Preliminary Design Review
CSG - Centre Spatial Guyanais	PFM - Proto-flight Model
EFM - Engineering Functional Model	PLM - Payload Module
ELM - Electrical Model	PPP - Public-private partnership
EM - Engineering Model	PRR - Preliminary Requirement Review
EMC - Electromagnetic Compatibility	QM - Qualification Model
EQM - Electrical Qualification Model	SM - Structural Model
EQSR - Equipment Qualification Status Review	SRR - System Requirement Review
FAR - Flight Acceptance Review	STM - Structural/Thermal Model
FM - Flight Model	SVM - Service Module
FQR - Flight Qualification Review	SVT - System Validation Testing
GEO - Geostationary Earth orbit	SWE - Space Weather
IPC - Industrial Policy Committee	TM - Thermal Model
ITT - Invitation to Tender	

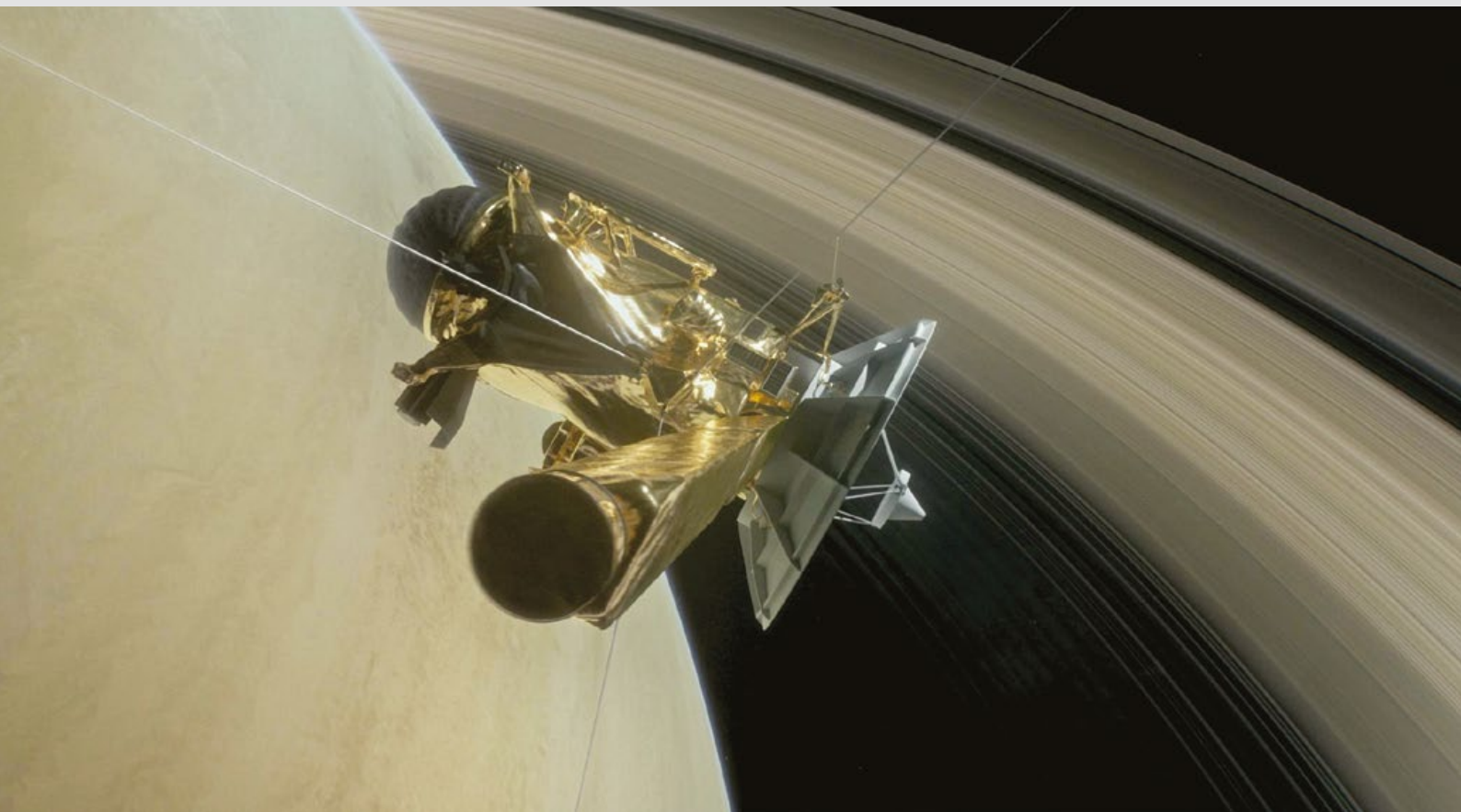
→ CASSINI-HUYGENS

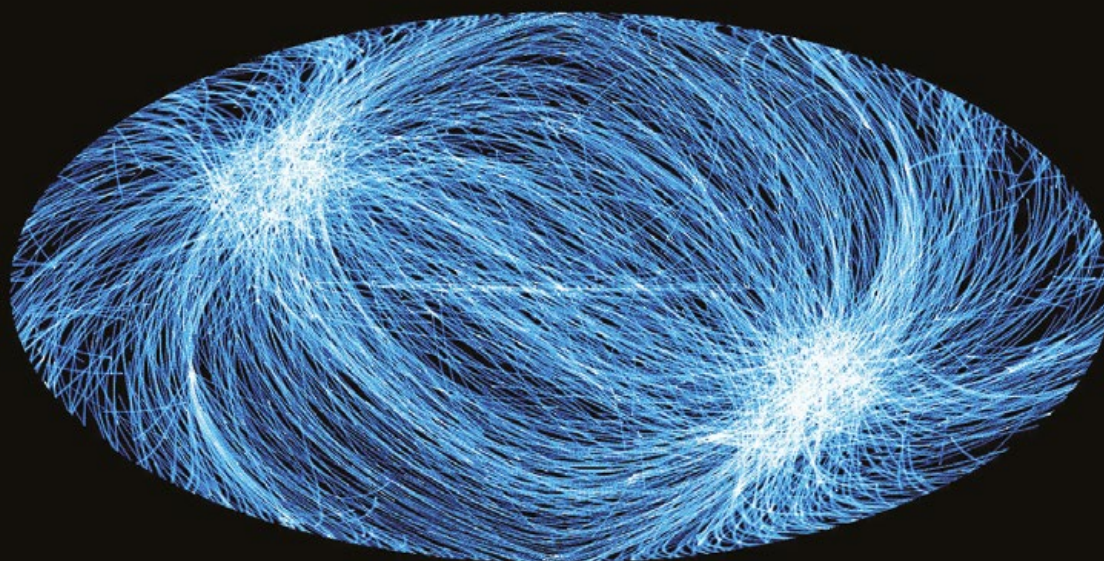
The Cassini spacecraft is performing its final orbits around Saturn. The last 22 orbits of the mission, initiated on 23 April

and called the 'Grand Finale', are an opportunity to make manoeuvres and trajectories that are riskier than usual, but allow a potential harvest of unprecedented scientific results in regions of the system not explored so far. A final close flyby of Titan (nicknamed the 'farewell kiss') was performed on 22 April to modify Cassini's trajectory, providing the gravitational pull necessary to reduce the periapsis (nearest point) altitude from 2.467 Saturn radii to just 1.063 Saturn radii, and reducing the orbital period to about a week. On this new trajectory, Cassini repeatedly crosses Saturn's ring plane through a 2000 km wide gap between the upper atmospheric layers of Saturn and the innermost D-ring.

The main science objectives of the Grand Finale include: direct *in situ* sampling of the ring particle composition and of Saturn's exosphere and innermost radiation belts; probing the magnetic and gravity field in unprecedented detail to gain a better understanding of the magnetic dynamo and interior structure of Saturn; measuring the relative abundance of various chemical compounds of Saturn's ionosphere; observing the upper atmosphere for molecules that escape the atmosphere itself and for water-based molecules originating from the rings; constraining the total ring mass and observing its fine-scaled structures with the highest resolution possible.

Cassini skimming the top of Saturn's atmosphere during the its 'Grand Finale' (NASA/JPL-Caltech)





XMM-Newton collects scientific data even when moving, shifting its view from one X-ray object to another, revealing more X-ray sources across the entire sky. This image of a blue 'ball of string' illustrates the paths of 2114 telescope manoeuvres made between August 2001 and December 2014. The plot is in galactic coordinates

so the centre of the plot corresponds to the centre of the Milky Way. The slew paths pass predominantly through the ecliptic poles, indicated by the density of overlapping slew paths to the top left and bottom right. The image was created as part of the updated XMM-Newton Slew Survey Catalogue released in March.

The radio signal transmitted by the high-gain antenna is used to perform ring occultations and gravity experiments around the closest approach to Saturn. The ESA deep-space antennas at New Norcia and Malargüe are joining the NASA Deep Space Network to provide the best signal-to-noise ratio for those measurements.

At the time of writing, Cassini's 18th dive between the rings and Saturn has worked as planned. After a distant nudge from Titan, Cassini dropped closer to Saturn for its first of the final five orbits, skimming the top of Saturn's atmosphere. As expected, the spacecraft had to use its thrusters to offset the torque imparted by atmospheric drag.

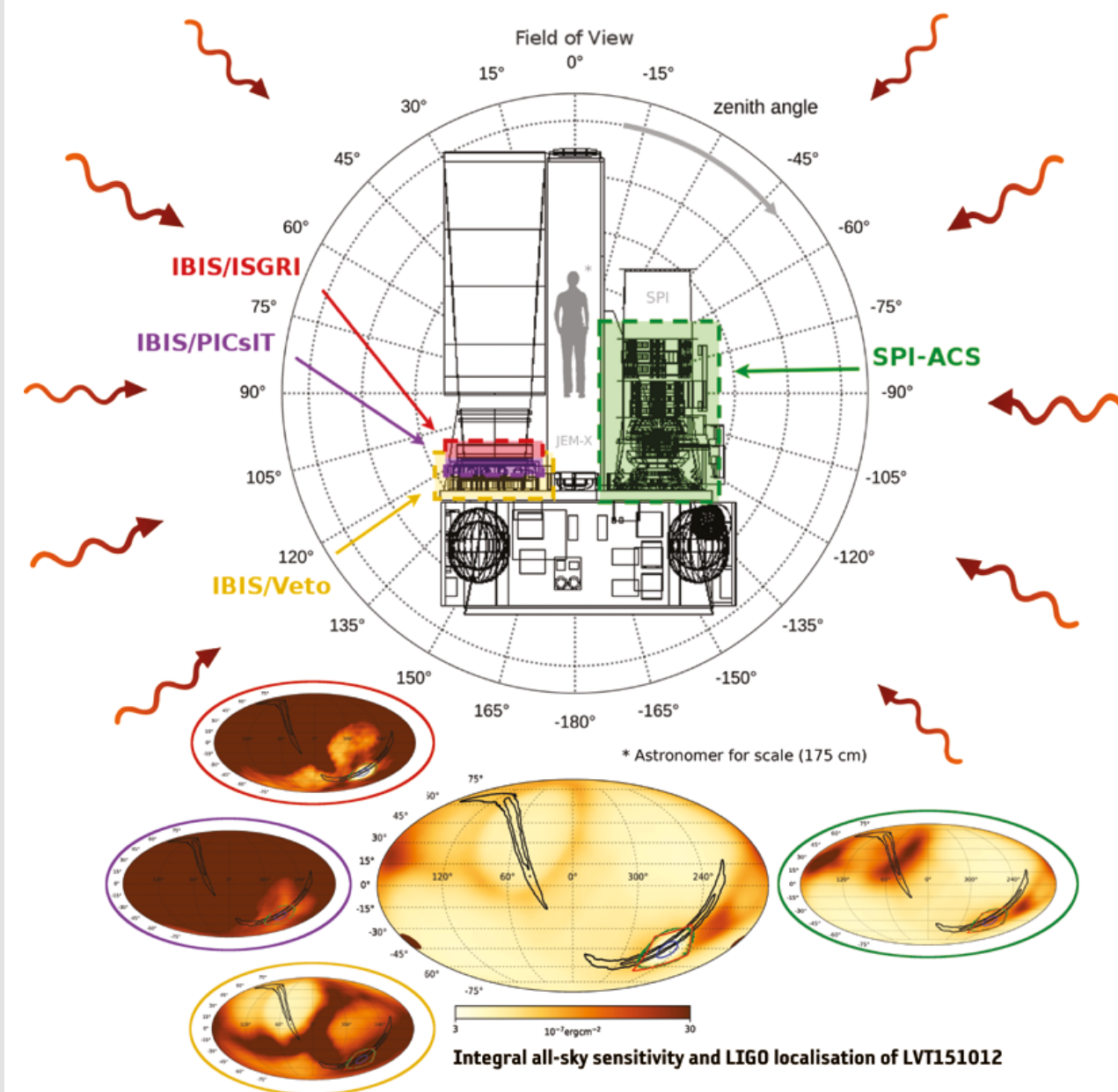
→ INTEGRAL

Integral's unique payload, comprising a set of large and heavy detectors, allows it to detect the elusive weakly interacting low-energy gamma-ray photons from any direction of the sky at a given moment. Coupled with an exceptionally stable background owing to the elongated orbit mostly far from Earth's violent magnetosphere, this makes it an ideal instrument to search for electromagnetic counterparts to sources of various impulsive transients,

such as gravitational wave events. It can use the large field of view of its sensitive X-ray and gamma-ray detectors to pinpoint and accurately characterise properties of any possible counterparts, if detected.

The LIGO/Virgo trigger LVT151012 is one of the three binary black-hole merger events observed by LIGO in the first breakthrough scientific run in 2015/16. Unlike the other two events (GW150914 and GW151226), LVT151012 had a slightly lower LIGO detection certainty and had just over a 90% chance of being of astrophysical origin. If astrophysical, it corresponded to a merger of two black holes of 13 and 23 solar masses, releasing gravitational wave radiation equivalent to a rest energy of 1.5 solar masses in a fraction of a second.

The positions of gravitational wave events detected by LIGO have large uncertainties and the location of LVT151012 could only be constrained to two very elongated arcs, each spanning more than 60 degrees in the sky. Fortunately, a large fraction of the LIGO localisation of LVT151012 was in the fields of view of the most sensitive Integral instruments at the time that the gravitational event occurred. Observation of the complete, extended, localisation of LVT151012 could only be obtained by combining data from both Integral high-energy detectors



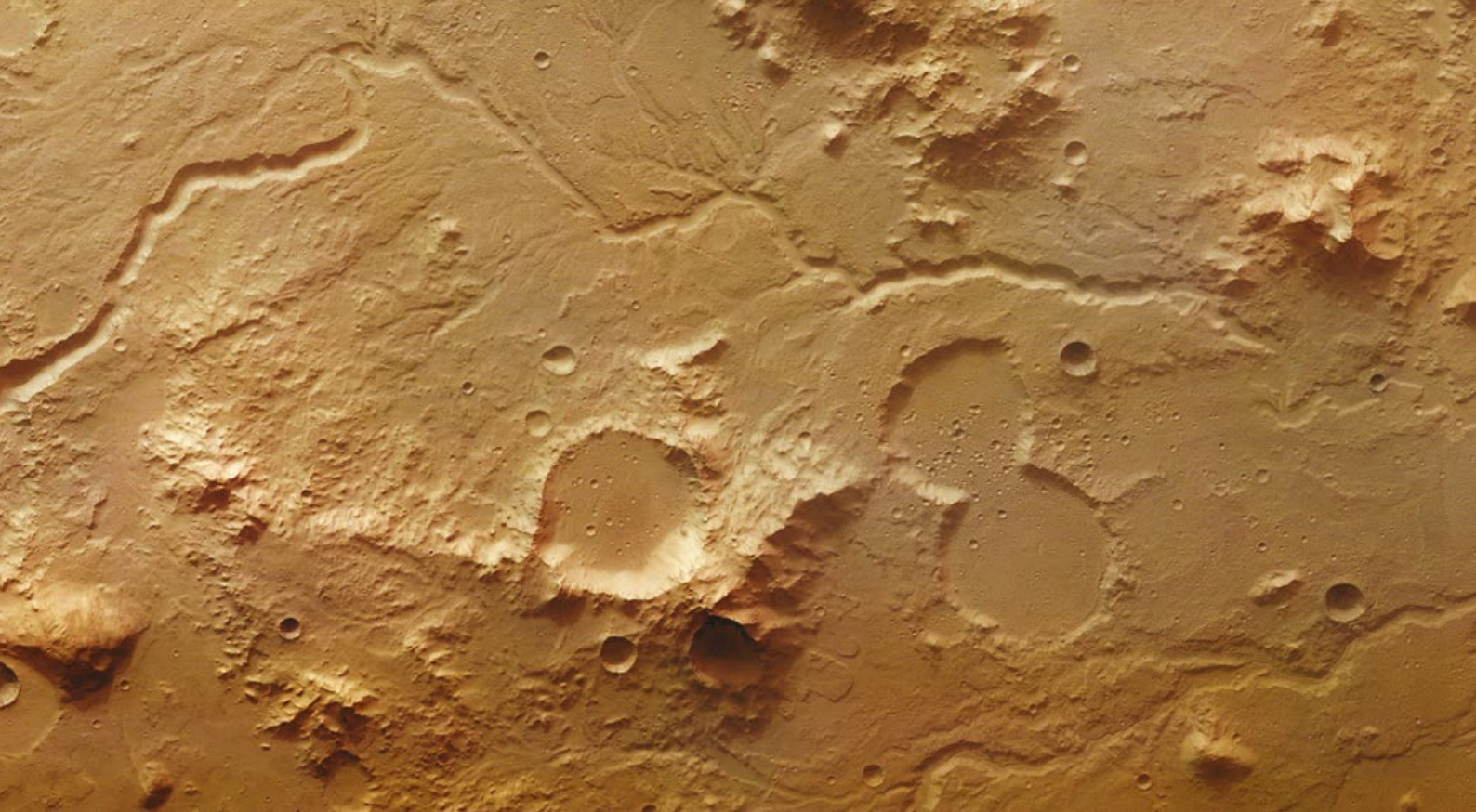
Integral can search for electromagnetic counterparts to gravitational wave detections, although the sources of the gravitational waves are difficult to locate (V. Savchenko/ISDC Data Centre for Astrophysics, CH)

and their active shields, i.e., of SPI (including SPI-ACS), IBIS (ISGRI, PICsIT and IBIS/Veto).

Although no electromagnetic counterpart was detected, it allowed the most stringent upper limit to be determined for a truly all-sky observation, constraining the ratio of energy released in gamma rays to the gravitational wave energy to less than 4.4×10^{-5} . Stop press: Integral was among the observatories to see electromagnetic signals related to the gravitational wave event GW170817 announced in October.

→ ROSETTA

One of the major science targets was to examine the comet and its connection with the formation and early evolution of Earth and the Solar System. A number of studies have already been published examining the constituents of the comet, and the implications of those detections for those early days of the Solar System. Most recently, a scientific publication was published reporting the discovery of several isotopes of the noble gas xenon at Comet 67P/Churyumov-



A dried out river valley with tributaries can be seen in this view of the Red Planet captured by ESA's Mars Express High-Resolution Stereo Camera on 21 February. The Libya Montes mountain area, located on the martian equator at the boundary of the southern highlands and northern lowlands, is one of the oldest regions on Mars. It was uplifted during the formation of the 1200 km wide Isidis impact basin some 3.9 billion years ago. The features here are indicative both of flowing rivers and standing bodies of water, such as lakes or even seas that were present on early Mars.

The prominent river channel that runs from south to north (left to right) apparently originates from the impact crater in the south, breaching its wall and flowing towards the north, navigating the local mountains. The valley is fed by numerous tributaries, pointing to extensive rainfall and surface runoff from higher to lower regions. A similar channel runs across the bottom right of the scene. The mineralogy in the Libya Montes region is very diverse,

as revealed by spectrometers on orbiting spacecraft. Aqueously formed and chemically altered minerals testify to past hydrothermal activity that may be linked to the formation of the Isidis impact basin. For example, the impact could have mobilised liquid water by melting subsurface ice that subsequently interacted with the ancient, volcanic mountain rocks.

There are numerous craters in various states of degradation, testament to the region's long history. Perhaps the most noticeable craters are the two situated side by side close to the centre suggesting a double impact. Another interesting crater on the left has subsequently experienced a collapse of its rim onto the valley floor. The rich diversity of geological features in this region demonstrates the dynamic environment the planet has witnessed, evolving from a warmer wetter climate that enabled liquid water to flow freely across the surface, to the arid world that we see today.

Gerasimenko. Xenon is the heaviest noble gas and its many isotopes originate in different stellar processes, so it can provide information about our cosmic origins.

This special fingerprint has been used by scientists to investigate the composition of the early Solar System and these Rosetta results show that the specific blend of xenon found at the comet closely resembles U-xenon, the primordial mixture that scientists believe was brought to Earth during the early stages of Solar System formation.

Searching for xenon at the comet was one of the most crucial and challenging measurements we performed with Rosetta, as it was very diffuse in the comet's thin atmosphere, so the navigation team had to fly Rosetta very close – 5 km to 8 km from the surface of the nucleus – for a period of three weeks, so that ROSINA could obtain a significant detection of all the relevant isotopes. Flying so close to the comet was extremely challenging because of the large amount of dust that was lifting off the surface at the time, which could confuse the star



Comet 67P/Churyumov-Gerasimenko seen on 15 May 2016 during the period that dedicated ROSINA instrument measurements were made to search for xenon, an important tracer of the early Solar System's composition (ESA/Rosetta/NavCam)

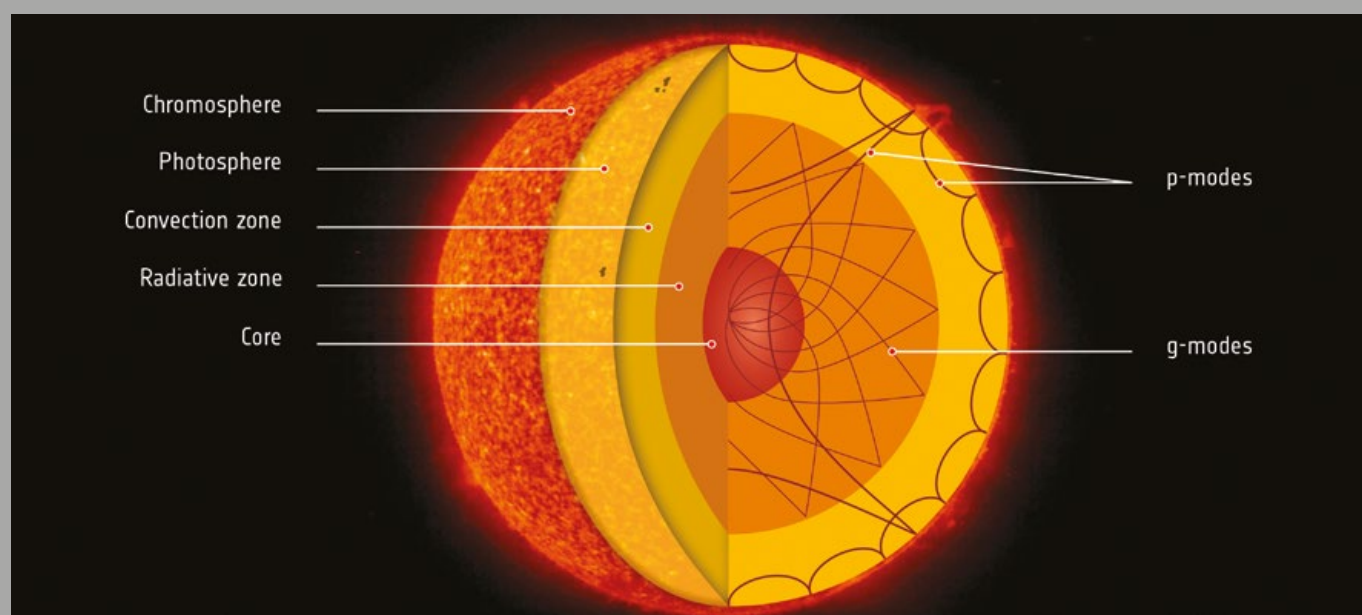
trackers that were used to orient the spacecraft. A dedicated three-week period was implemented in the second half of May 2016 as part of the mission extension operations, when dust activity was less intense. This eagerly awaited detection suggests that comets contributed about one fifth of the xenon in Earth's ancient atmosphere and has established the first quantitative link between comets and the atmosphere of Earth.

→ SOHO

After decades of searching, solar scientists examining 16.5 years of data obtained by the Global Oscillations at Low

Frequency instrument on SOHO have at last found evidence of a particular type of seismic wave in our Sun. These low-frequency waves, called gravity modes (or g-modes) reveal that the Sun's core is rotating four times faster than its surface. Gravity waves are fluid waves where buoyancy acts as the restoring force, and are distinct from astronomical gravitational waves.

Gravity waves are hard to find, because they have no clear signatures on the solar surface. Sound waves, also called pressure waves, or p-modes, on the other hand, are easy to detect on the solar surface and have been extensively used in helioseismic studies, but they don't give us any information about the Sun's core. Scientists looked at a



Propagation pattern of g- and p-modes in the solar interior

particular p-mode parameter that measures how long it takes for an acoustic wave to travel through the Sun and back to the surface again, which is known to be 4 hours 7 minutes. By applying analytical and statistical techniques to the data, they were able to detect a series of modulations in this p-mode parameter, which they interpreted as being due to the g-modes shaking the structure of the core.

The signature of the imprinted g-waves suggests the core is rotating once every week, nearly four times faster than the observed surface and intermediate layers, which vary from 25 days at the equator to 35 days at the poles. Detecting the signature of a fast core rotation opens up a new set of questions for solar physicists — such as how do differently rotating layers of the Sun interact, what can we learn about the composition of the core, and what are the implications for stellar evolution and thermonuclear processes in the core?

→ GAIA

The second Gaia Data Release (Gaia DR2) is in production. The processing is progressing toward the April 2018 release date. After scientific assessment and recommendation by the Gaia Science Team, a Gaia DR2 pre-release was made for three stars. These are stars being occulted by Chariklo (twice) and Triton. Chariklo is an asteroid with rings and Triton is a moon of Neptune. The need to have the best possible stellar position stems from the requirement to predict very precisely where the shadow of the event on Earth can be observed. This way, mobile ground-based telescopes can be positioned along the occultation path. So far, two Chariklo events have taken place with promising preliminary results for the asteroid and its rings. For Gaia, these observations are also a confirmation of the quality of the astrometric data gathered by the satellite and processed by the Data Processing and Analysis Consortium.

→ LISA PATHFINDER

The demonstrated differential freefall performance of the test masses greatly exceeded the mission requirements. Being a demonstration mission, the performance was relaxed compared with the requirement for the full LISA mission. However, the demonstrated performance exceeded the LISA requirements over the full LISA measurement bandwidth goal. The mission has demonstrated that the detection of low-frequency gravitational waves from space is achievable, paving the way for LISA.

In addition to the European payload demonstration, the US-provided Disturbance Reduction System (DRS) was also operated on the satellite. DRS operations were primarily related to a novel thruster architecture (colloidal electrospray thrusters) as well as drag-free control of the

satellite. All primary performance requirements of the DRS have been met with margin.

During the post-operations phase, the science community is focused on consolidating the data analysis, with the goal of issuing the first batch of instrument papers by the end of the year. In addition, the operations teams are finalising the lessons learnt from the mission, both in development and operation; this is timely given that the LISA mission was selected for study as the third 'Large' class mission in the Cosmic Vision programme in June.

The LISA Pathfinder science archive is now available. The archive can be accessed via <http://lpf.esac.esa.int/lpfsa/>

→ CHEOPS

Spacecraft development is on course for launch readiness in late 2018. The platform and system AIT activities are progressing. At Airbus Defence & Space (ES), the platform multi-layer insulation fit-check was completed and the refurbished Remote Interface Unit reintegrated and tested. The first Integrated System Test (AOCS closed loop) has been executed, followed by the first part of the SVT 1 (focused on platform functionality), when the flight platform was controlled from the Mission Operations Centre.

Instrument development is also progressing, although the schedule remains critical. The FM telescope passed its final



CHEOPS flight platform at Spain during the insulation fit-check (Airbus D&S)

performance verification campaign and was delivered by Leonardo to the University of Bern and integrated with the Focal Plane Module (FPM) EM. The FPM FM is the last missing element for the instrument and is expected in October. A first set of functional and performance tests was run at instrument level with satisfactory results. Arianespace is targeting a launch at the end of 2018 as passenger on a Soyuz.

→ BEPICOLOMBO

System-level AIT activities continued as planned. All FMs, the Mercury Transfer Module (MTM), the Mercury Planetary Orbiter (MPO) and the JAXA-provided Mercury Magnetospheric Orbiter (MMO) were mounted on top of each other to achieve the stacked launch configuration. As a major project milestone, the mechanical testing (consisting of acoustic noise, three-axis sine vibration and launch vehicle adaptor separation test) was completed,

BepiColombo environmental testing: the full spacecraft on vibration table at ESTEC



followed by system electrical testing that confirmed the stack integrity. The next activities will be the commanded modules separation and activation on all mechanisms on module level, i.e. solar array, HGAMA, MGAMA and Magnetometer Boom for the MPO; solar array- and thruster steering- mechanisms for the MTM. The MTM thermal vacuum/thermal balance test will complete the major system functional tests for this year. The schedule remains stable and ground segment development and validation plans were updated for a launch opportunity in October 2018.

→ JAMES WEBB SPACE TELESCOPE (JWST)

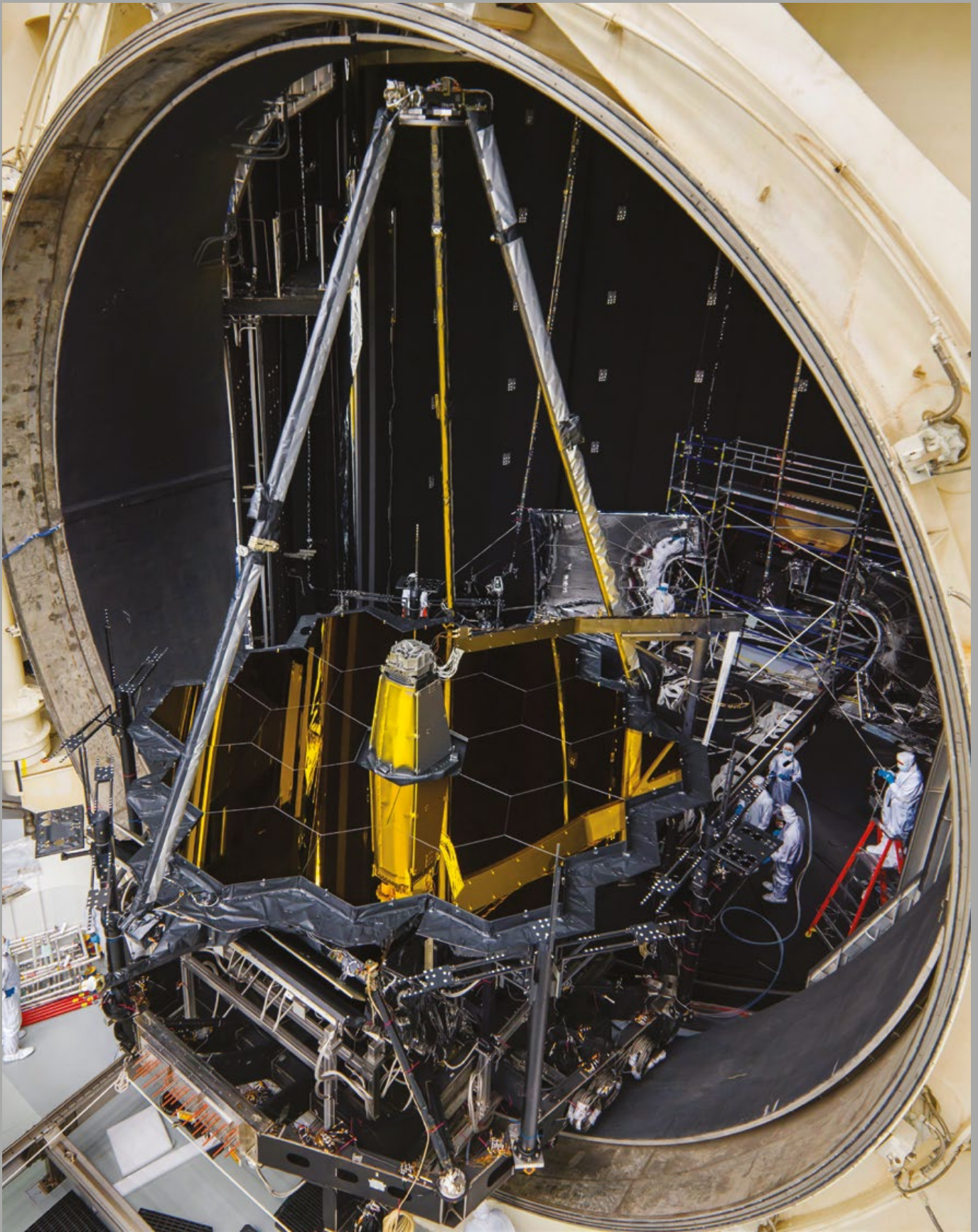
The overall programme continues towards the planned launch date in October 2018. The Optical Telescope with the Integrated Science Instrument Module (OTIS) is now at NASA's Johnson Space Center where cryogenic functional and optical end-to-end tests are continuing. Operational temperatures have been reached and testing has no major issues. Integration of the spacecraft and the sunshield were completed. The initial full deployment test of the shield is planned in September. JWST will be launched on an Ariane 5 ECA, and the contracts for the launch service agreement and the launcher delta-qualification study specific to JWST are progressing.

→ SOLAR ORBITER

The payload FM development is complete, all 10 instruments have been delivered to the prime contractor. The scientific instruments will simultaneously perform *in situ* measurements and remote observations of the Sun at 0.3 AU.

Spacecraft FM integration is continuing. In particular, the instruments are being integrated and tested with active participation of the scientists in the instrument teams. Functional testing continues on the two spacecraft Engineering Test Benches and on the FM avionics already installed on the spacecraft.

Progress has been made on the remaining spacecraft units in production. After acoustic and sine testing, the heat shield underwent thermal testing. The panels of the payload radiator assembly are being integrated and tested, and high-performance thermally conductive straps are already integrated with their corresponding instruments. The solar generator FM wings were completed, with one wing fully tested and the second in final stages of acceptance testing. Solutions for straylight protection, for surface conductivity and for cleanliness and contamination control are being manufactured.



The JWST OTIS module at Johnson Space Center's cryo facility. The telescope is pointing upwards with the wings fully deployed (NASA)



Solar Orbiter instrument panel showing PHI, METIS and SPICE optical units, and a number of instrument electronics units including those for EUI and MAG (Airbus D&S)

The development of the Mission Operations Centre and Science Operations Centre development are preparing for Ground Segment Implementation Review. Interface work with NASA/GSFC, NASA/KSC and United Launch Alliance for the Atlas V-411 launcher service is progressing towards PDR.

→ EUCLID

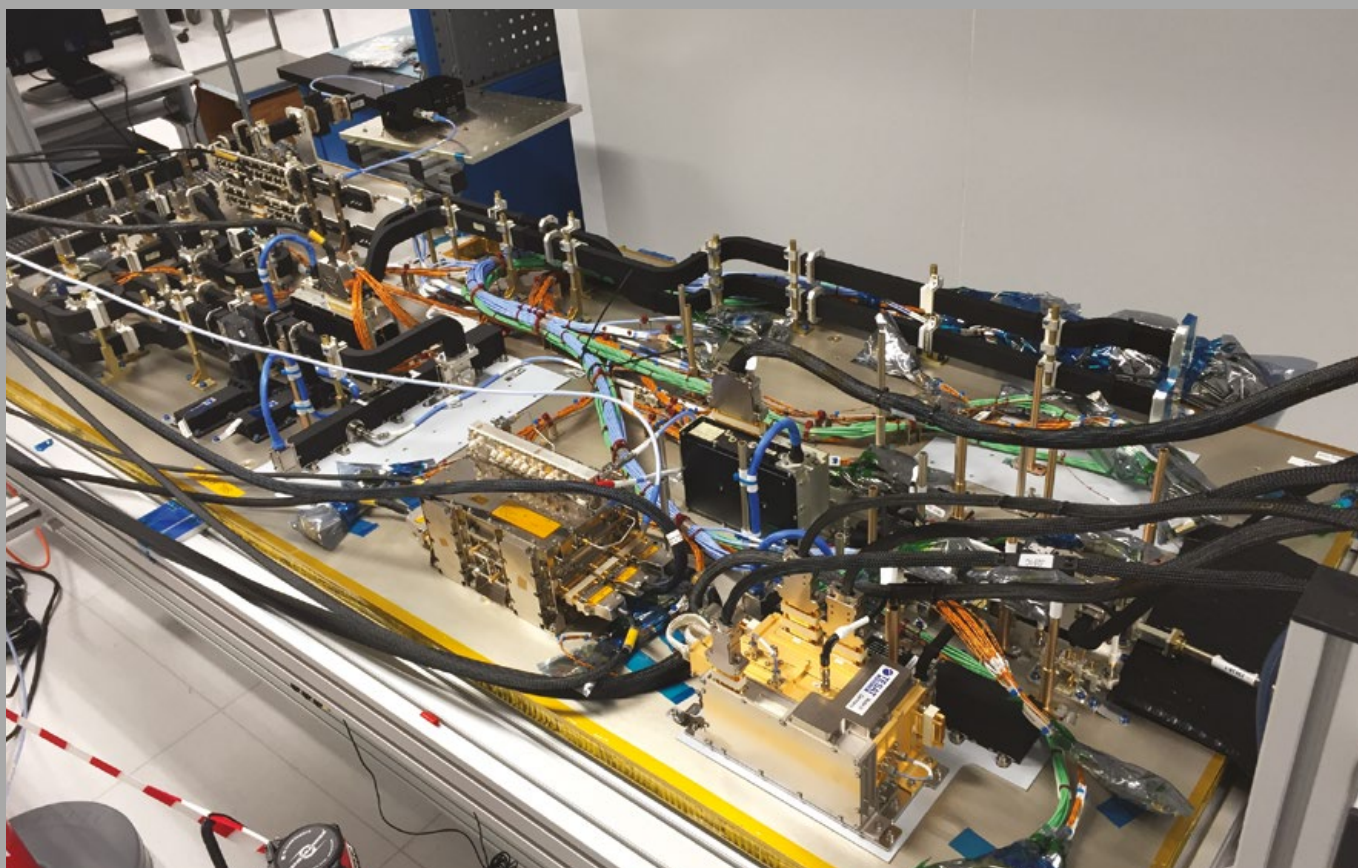
Development is proceeding in the detailed design phase. The prime contractor is finalising the system design in preparation for the System CDR. The PLM CDR was also held in June and showed that the design of the PLM is sound and meets its challenging requirements. In the meantime, many flight components are being manufactured. All the SiC reflectors optics have been manufactured and mechanically polished and proceed under ion-beam figuring, an operation that will continue for many months. All SiC baseplate eight pieces (four each for STM and FM) have been manufactured, with one part needing remanufacturing (leading to a significant delay of the PLM).

The Visible Imager (VIS) instrument suffered considerable delay in the last year. The subsystem EMs and STMs were manufactured and the STM tests at instrument level were

performed. The instrument EM tests were delayed and have not been completed. Instrument-level CDRs were held in January. No major technical issues were discovered, but the new FM development schedule showed a large delay. A delta-CDR is under way together with an independent review of the schedule. Reviews are not complete, but it is confirmed that the VIS FM delivery will be significantly delayed.

The instrument CDR for the Near Infrared Spectro-Photometer (NISP) was completed, with flight hardware manufacturing and integration now going ahead. The NISP STM, used for instrument vibration and thermal vacuum tests was delivered to industry for the PLM STM campaign. The procurement of the FM NISP HgCdTe detectors production phase, under NASA responsibility, is ongoing.

All detector FM elements have been manufactured and tested, showing excellent performance. However, the front-end electronics have shown serious anomalies, which led NASA to discard all the units produced as unworthy for flight. A Tiger Team was set up to investigate the cause of the failure and propose modifications. Progress has been made in the last two months, but a large delay is expected in the delivery of the new units. Fortunately a novel and technically challenging characterisation test at instrument



Avionics Model of the Tracking Telemetry and Control panel (Thales Alenia Space)

focal-plane level in the LAM laboratory in Marseille has been devised that will limit the delay of the NISP FM delivery. Ground Segment development is progressing. Because of the delays on the PLM (mostly on the instruments side), the launch can no longer take place in December 2020. A new launch date has not been announced, because it is driven by the instrument delivery (VIS FM and the NISP detector front-end-electronics delivery). For planning purposes, a launch date of mid-June 2021 is used.

→ JUICE

The overall schedule of the spacecraft is stable. The planned launch date is 1 June 2022 on an Ariane 5 ECA (in the middle of a launch window that starts on 20 May and closes on 10 June).

→ SMOS

Operations have been extended to 2019 and beyond, pending a review in 2018. CNES has also extended its support to the mission operations to 2019 and potentially beyond. New products, such as sea-ice thickness and soil-

moisture data in near-real time based on a neural network approach, have been included in the SMOS data catalogue.

→ SWARM

A resolution unanimously adopted by the participants at the Fourth Swarm Science Meeting in March indicates that the mission has, or by the end of its life will have, met all of its requirements. Given the very strong impact of the Swarm multipoint constellation in geospace research and geophysics, combined with the fact that no similar mission is on the drawing board anywhere in the world, the same resolution also recommends that ESA and its Member States provide the mission with a clear long-term perspective, ideally covering at least one full solar cycle (i.e. until 2024) and if possible longer. The user community asks for continued support to enable its groundbreaking research through funding of novel analysis techniques and also supporting orbital adjustments of the lower pair of satellites aiming to maximise the science return.

ESA is responding to these challenges in a variety of ways. A plan is under development to operate the satellite constellation under its current funding envelope until



Aeolus with its complex optical ground support equipment prior to entry into the thermal/vacuum chamber at Centre Spatial de Liège

the end of 2021, and at the same time address additional science objectives. Secondly, ESA is in active consultation to implement support activities that would be best described as 'Swarm for science' rather than more limited endeavours targeting 'science with Swarm'. This is an important step to address key challenges in Earth system science, and it also clearly signals that Swarm-like measurements should be continuously available.

Swarm-based science has therefore entered a 'golden age' in terms of new discoveries and applications. With all platforms performing essentially free of any anomalies, suffering no life-limiting issues and the space segment constellation geometry evolving in line with expectations, the mission is on track to serve the Earth sciences from the core to the magnetosphere for many years to come, programmatic concerns aside.

→ AEOLUS

The mechanical qualification and verification of the satellite and its compatibility for a launch on Vega were confirmed.

Preparations for the complex satellite thermal/vacuum test campaign are continuing at the Centre Spatial de Liège. The Ground Segment Acceptance Review was completed with a remaining action for the project to produce a close-out report upon validation of the planning and calibration facilities. The Satellite Qualification and Acceptance Review began with the delivery of the first batch of the data package. The second batch will be delivered on completion of the results analysis from the thermal/vacuum test.

→ EARTH CARE

The Base Platform Integrated System Tests are continuing at Airbus Defence & Space (DE) in Friedrichshafen. The ATLID PFM optical receiver integration with the Stable Structure was completed and mechanical testing concluded. Optical characterisation of the full receiver chain and PFM Transmitter coupling with the instrument EM are continuing.

The JAXA Cloud Profiling Radar PFM instrument, in its non-redundant configuration, was shipped at the end of March

and handed over to Airbus Defence & Space (DE) in mid-June. The instrument electrical and mechanical integration with the platform was then performed and preliminary testing initiated. The instrument will be shipped back to Japan for refurbishment, starting in April 2018 when the repaired transmitter (HPT-A) will be made available.

The Ground Segment CDR was concluded in June. The first SVT between the Flight Operation Segment and the satellite test bench took place at Airbus Defence & Space (DE).

→ BIOMASS

After just over a year of the development contract, the PDR began. The build-up of the industrial consortium is progressing. Providers for all instrument units and most of the critical platform items have been selected and negotiations are taking place to start work.

→ METEOSAT THIRD GENERATION

The CDR continued as planned with the closure of lower level reviews before the platform CDR later in the year. Development models are progressing, in particular the Platform STM and SM test campaigns were completed.

For the Flexible Combined Imager and Infrared Sounder instruments, the STM and EM development model manufacturing is progressing and the highly complex and technically challenging Scan Mechanism has completed mechanical and thermal qualification. For the Lightning Imager, the instrument SM will now be mechanically tested in August.

The schedule for the MTG-I and MTG-S PFM maintains FAR dates in December 2020 and August 2022 respectively.

→ METOP

MetOp-C

The environmental testing of the PLM in ESTEC and the SVM in Toulouse has been completed and the two modules have been integrated in preparation for the satellite-level test campaign. The GOME-2 and Microwave Humidity Sounder instruments have been removed from the PLM for recalibration/repair. Both instruments should be ready in January 2018 for reintegration on MetOp-C in time for the SVT. Launch on a Soyuz is planned for October 2018.

MetOp Second Generation

The satellite and instrument development activities have progressed on schedule. Technically, the focus remains on the technologically challenging Receiver Front-End and Back-

End equipment for the microwave radiometers (Microwave Sounder, Microwave Imager and Ice Cloud Imager). The schedule is being driven by the availability of the instruments and, in particular, the complex Customer Furnished Item instruments (METImage, IASI-NG and Sentinel-5). The current launch dates are September 2021 for the first Satellite A and December 2022 for the first Satellite B.

→ COPERNICUS

Sentinel-1

Sentinel-1A and -1B remain stable. The data downlink is routinely performed over Matera, Svalbard and Maspalomas stations and circulated within the Payload Data Ground Segment to systematically process to Level-0 and Level-1 products and archive. The use of the EDRS-A service by Sentinel-1A and -1B is now part of routine operations, increasing the overall mission capacity substantially.

Development of the Sentinel-1C and -1D models is ongoing with the Spacecraft Production Review Board in September. Carrying a new Automatic Identification System payload to augment maritime applications and a new GNSS receiver, also compatible with the Galileo navigation system, Sentinel-1C and -1D will eventually replace the operational Sentinel-1A and -1B at the end of their lives.

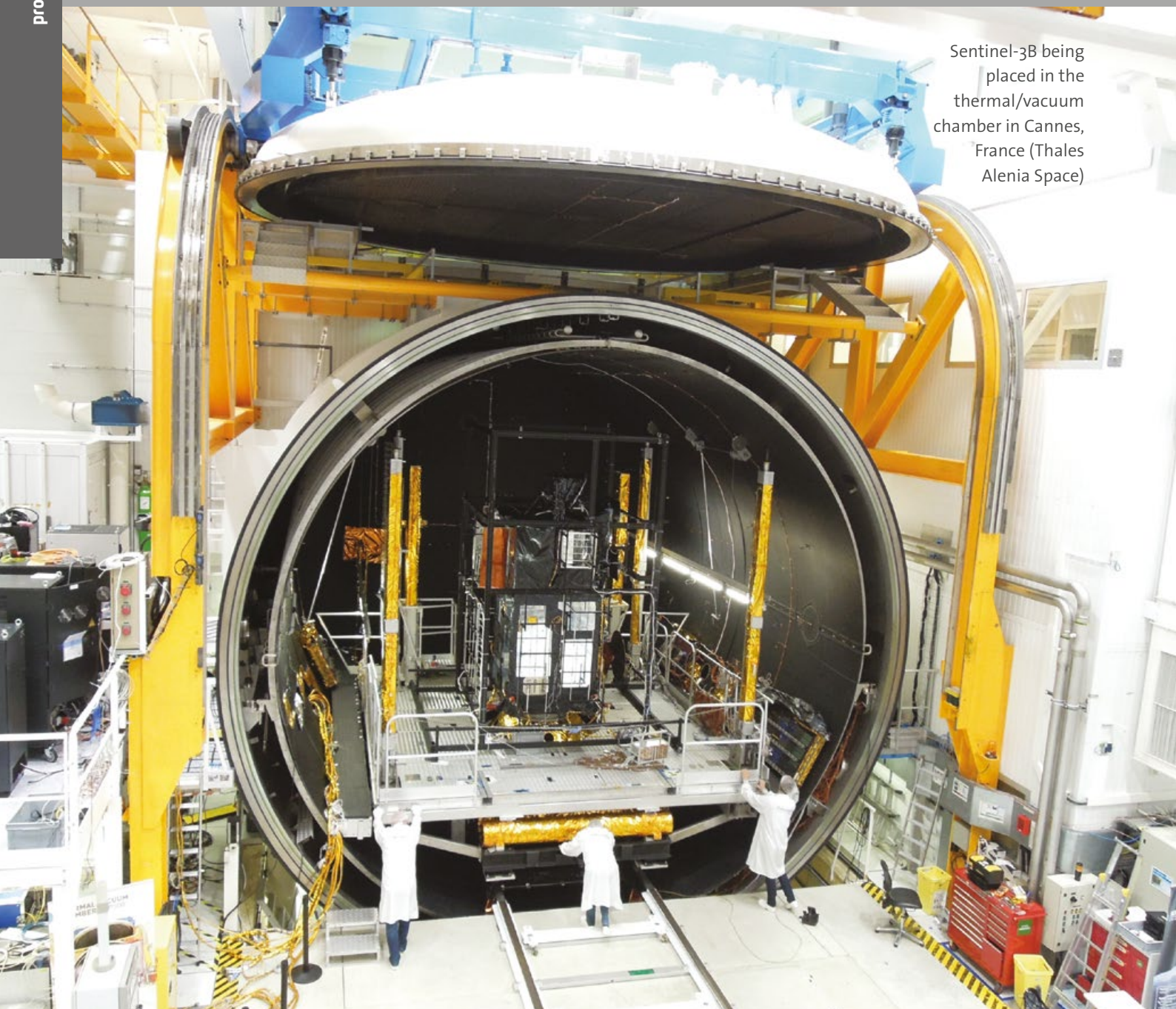
Sentinel-2

Sentinel-2B Commissioning Phase activities were executed according to plans and concluded with the In Orbit Commissioning Review on 15 June. All performance requirements have been met or exceeded. Sentinel-2C and -2D development reached the Satellite Production Review milestone (the equivalent of a CDR for a quasi-recurrent satellite).

Sentinel-3

For Sentinel-3B, the Ocean and Land Colour Instrument FM was assembled, tested and calibrated, with a final delivery to the prime contractor in June. In the meantime, the satellite underwent the first part of its environmental acceptance test campaign, including conducted emissions and thermal/vacuum testing. Sentinel-3B AIT activities should be complete in November, ready to start the launch campaign at the end of the year. The launch date is still under discussion with the launch service provider(s), but likely March 2018.

Most actions from the Sentinel-3C and -3D Satellite Production Review have been closed and manufacturing of the various units has started. While hardware-related activities are mainly proceeding at subcontractor level, prime contractor activities are concentrating on the update of the central software that will undergo a major review in the autumn.



Sentinel-3B being placed in the thermal/vacuum chamber in Cannes, France (Thales Alenia Space)

Sentinel-4

All pending actions from the CDR have been closed. The instrument EM integration has started. The qualification testing of the three Sentinel-4 mechanisms (Calibration Assembly mechanism, Aperture Cover mechanism and Scanner mechanism) is continuing.

Sentinel-5

All subsystem Equipment Requirement Reviews have been closed. All but one subsystem PDR has taken place. The first subsystem CDRs started. An ultraviolet/visible/near-infrared focal plane EM assembly has been manufactured and is undergoing environmental testing.

Sentinel-5 Precursor

The satellite is being prepared for de-storage at Airbus Defence & Space, Stevenage, UK, in readiness for launch on 13 October. The overall Ground Segment is ready. LEOP rehearsals at ESOC are about to start.

Sentinel-6/Jason-CS

The satellite CDR took place, enabling the project to move into the production Phase-D. Most flight hardware is being manufactured and satellite integration will start in September. Joint activities with the NASA, NOAA and Eumetsat partners are proceeding. Working groups have been formed to address the system engineering and mission

Artist impression of
Sentinel-6/Jason-CS
(ESA/ATG medialab)



performance aspects. The independent Mission Advisory Group advising the project partners on scientific issues specific to the Sentinel-6/Jason-CS mission had its first meeting in June.

→ EDRS

Provision of the commercial EDRS service via EDRS-A started on 23 November 2016 with Sentinel-1A. Since April, EDRS services have also been provided to Sentinel-1B, while both the Sentinel-2A and Sentinel-2B satellites are undergoing their user commissioning into the EDRS service in the second half of this year.

The second EDRS node based on a dedicated satellite built by OHB – using a SmallGEO type platform – carries the EDRS-C Payload, which includes a second laser communication terminal. It will also carry Avanti's HYLAS-3 communication payload as well as the Next Generation Radiation Monitor developed by RUAG in Switzerland as 'hosted payloads', and will be launched on an Ariane 5 launcher into geostationary orbit in late 2017.

The EDRS-C mission CDR will take place at the end of the year and will ensure the consistency of the EDRS-C satellite with the ground segment, thereby verifying the overall performance of the EDRS-C mission. Mating of the Platform

Module with the Repeater Module to constitute the EDRS-C spacecraft was completed in December 2016. The Initial Functional Test – a series of functional and performance tests at satellite level – is being conducted at the satellite integration facilities at OHB in Bremen.

The full suite of ground stations in Weilheim, Redu and Harwell has been fully deployed to support the provision of the commercial EDRS service through EDRS-A. Up to 14 regular link sessions per day for each of the Sentinel-1A and -1B satellites are prepared and conducted from the EDRS Mission Operations Centre in Ottobrunn. Development of an additional data reception station in Matera began in July.

The GlobeNet programme will extend the coverage area of EDRS by adding a third node – EDRS-D – in the Asia/Pacific region to complement EDRS-A and EDRS-C. Phase-B activities started with the User Requirements Review over the summer and are planned to conclude with the PDR towards the end of 2018.

→ ARIANE 6

Following Maturity Gate 6.1, a complementary board took place on 25 July, concluding on the remaining issues related to requirements and management of differences between the QM and generic configuration.

Launch of Ariane 5 flight VA238 in 28 June delivering two telecom satellites, Hellas Sat 3–Inmarsat S and GSAT-17, into their planned orbits. A new four-panel fairing was also validated on this flight (ESA/CNES/Arianespace)



A first step of the Test Readiness Review for the Vulcain 2.1 tests on P5 test bench took place in July. A major anomaly on the P5 test bench is under investigation. The first test of the Vulcain 2.1 engine is planned for October/November.

For the Launch Base, contracts for the development of the Ariane 6 mechanical transfer systems and for communication, optic and video systems have been signed.

Several industrial reviews have taken place: Industrial PDR for Utilities Control Bench, Mechanical Systems (Cryogenic arms, MANG LLPM box and cryogenic flexible hoses), Mechanical Transfer Systems for the Upper Composite Trailer, and Industrial CDRs for the Mechanical Systems (Table, mast, and deflector), Conventional and Cryogenic Fluidic Systems and Ground Operational Process Interface on ELA 4 and Ariane 6 Low Current and Safety Systems (e.g. fire and gas detection, sonorisation, video, automatism, access control). On the ELA 4 site in Kourou, the mounting of the BAL metallic structure, the concrete pouring of the mobile gantry rolling ways and the ZL4 pit flame activities are in progress.

In Launch System Architect (LSA) activities, progress has been made on critical interface functions, in particular the Cryogenic Connection System. A design key point enabled the system-level specifications to be set. The Ariane 6 operational concept was further re-analysed and the availability of a service road connecting CDL3 and ELA4 to enable movement of staff, even during safety critical transfers of materials on the National Road 1, was identified as critical. A solution was proposed and endorsed by ESA, ASL and CNES programme directors.

The Manufacturing Readiness Review definition of the P120C Inert Loaded Motor took place in May. Activities are on track on the Thrust Vector Control side. Concerning Step1.b, the industrial proposal from the launcher prime contractors was received in July. The evaluation of the proposal is ongoing, the Tender Evaluation Board report is expected by mid-September. Assessment of the impacts of the strike in French Guiana showed no margins for some of the activities on the BEAP (solid booster test stand) adaptations.

→ VEGA-C

Work Orders for the Launcher System and Ground Proximity Means (activities up to completion) and for Small Spacecraft Mission Service (activities up to Vega Proof-of-Concept and Vega-C CDR) have been signed. A review of the Integrated Master Schedule is incorporating slots for the modifications of the Ground Proximity Means and Ground Support Means in Kourou. In parallel, several activities took place, such as the Intermediate Project Key point, in between Launch System SDR and CDR.

→ FUTURE LAUNCHERS PREPARATORY PROGRAMME

Following the Microlaunchers workshop on 9 May and Work Plan approval, an open ITT was released in July and industry proposals are expected in September.

An authorisation to proceed initiating the Ultra-Low Cost Engine Demonstrator (Prometheus) activity was signed at the Paris Air Show on 21 June. In parallel, the Tender Evaluation Board was finalised and negotiations are ongoing with the contract proposal to be submitted to the IPC.

Consultations on Cryogenic Metallic and Composite tank demonstration projects are ongoing in view of the Request for Quotation issue.

On the FORC SRM Casing Demonstrator, the 6 m long and 3.5 m diameter booster was manufactured and transported to the test site at MPA-Stuttgart. The test campaign ended with the ultimate burst test where the burst pressure reached was 212 bar, corresponding to a uniform flux of 1120N/mm applied on the circumference of the skirt. The failure initiation was located on the nozzle dome.

→ SPACE RIDER

Activities are on schedule, including the following milestones:

- Phase-B1 activities, redirected to account for integration of Vega-C/AVUM as Orbital Service Module with the SRR planned in November;
- Phase-B2/C activities industrial proposal evaluation, with Tender Evaluation Board planned on 22 September, up to successful completion of system CDR.

→ HUMAN SPACEFLIGHT

On 2 June, ESA astronaut Thomas Pesquet (FR) and Russian commander Oleg Novitsky landed in Kazakhstan in Soyuz MS-03 after six months in space. Thomas was flown directly to Cologne, for debriefing and tests in EAC and DLR's Envihab facility.

Thomas took part in more than 60 experiments during his Proxima mission and set a new record for the number of hours spent on science in a week as part of an Expedition crew. On 28 July, Paolo Nespoli (IT) was launched on Soyuz MS-04 with crewmates Russian cosmonaut Sergei Ryazansky and US astronaut Randy Bresnik. His mission, called VITA (Vitality, Innovation, Technology, Ability) is part of a barter agreement between NASA and ASI involving ESA astronauts. New sessions of the Skinsuit experiment were performed on ISS, testing a new countermeasure



Thomas Pesquet landed in Kazakhstan with Russian commander Oleg Novitsky in Soyuz MS-03 on 2 June after six months in space

garment to counter the adverse effects of weightlessness on physiology.

Astronauts

Luca Parmitano (IT) participated in a two-day scientific caving and geological expedition in May in Sicily. One objective was to collect ideas for a possible evolution of ESA's CAVES analogue. Pedro Duque (ES) participated

in the 10-day NASA NEEMO 22 underwater mission at the Aquarius Reef Base in Florida in June. Pedro was involved in the testing of the ESA Lunar Evacuation System Assembly, which would allow the rescue of incapacitated EVA astronauts on the surface of the Moon. Alexander Gerst (DE) was in training for his Horizons mission in 2018. Matthias Maurer and Samantha Cristoforetti underwent intensive Chinese language training.



Luca Parmitano and geologist Marco Vattano sampling in the Cucchiara Cave, Sicily (ESA/N. Russo)



Liftoff of Paolo Nespoli's Vita mission on 28 July from Baikonur, in Kazakhstan



ESA's Pedro Duque joined NEEMO 22, the 22nd NASA Extreme Environment Mission Operations mission, in June. Here 'splashing down' with NASA astronaut Kjell Lindgren, planetary scientist Trevor Gradd and research scientist Dom D'Agostino (NASA)



NEEMO 22 aquanaut Pedro Duque on board the Aquarius underwater habitat off the coast of Florida (NASA)



Paolo Nespoli arrives at the International Space Station for his Vita mission (NASA/ESA)



ESA astronaut Thomas Pesquet, wearing the Skinsuit, with Space Station commander Peggy Whitson (NASA/ESA)



Thomas Pesquet operating the Grasp experiment with a VR headset to test how the brain interprets visual cues without gravity (NASA/ESA)



Thomas Pesquet working on the Fluid Shifts Experiment to see how eye and brain-pressure changes in weightlessness (NASA/ESA)



Thomas Pesquet's EveryWear biometric patch that for recording his temperature and monitor activity levels (NASA/ESA)



Paolo Nespoli preparing to photograph the total solar eclipse that crossed the US on 21 August (NASA/ESA)



This 1.25-m diameter 'Supersonic Parachute Experiment Ride on Maxus', or Supermax, flew piggyback on ESA's Maxus-9 sounding rocket on 7 April



ESA astronaut Alexander Gerst's mission to the International Space Station next year will be called Horizons (ESA/Steinbeis Beratungszentrum/Hochschule Darmstadt)

→ ACES/ASIM

MicroWave Link hardware and software finalisation is not proceeding as planned. Additional delays because of both technical issues and industrial resources caused the shift of deliveries to 2018, with major impacts on the ACES system testing. The Space Hydrogen Maser FM is under testing, and planned to be delivered in November. Contractual and financial issues are being discussed with Airbus Defence & Space to establish a way forward. Because of a failure of the Columbus External Payload Adapter (CEPA), ASIM had to go through a complete de-integration from the failed CEPA and has started integration onto the new one sent by NASA. The ASIM schedule is still compatible with a handover to NASA at the end of November, in time for launch on SpaceX CRS-14 (scheduled for early 2018).

→ ISS UTILISATION

Human research

Different test subjects completed inflight activities for ESA's Sarcolab-3 and Space Headaches experiments and two ESA experiments (EDOS-2 and Immuno-2) with Russian cooperation. These are respectively studying the effect of



ExoMars Trace Gas Orbiter aerobraking at Mars (ESA/ATG medialab)

weightlessness on: loss of muscle mass, function and motor control; headache incidence/characteristics; post re-entry bone loss and recovery; and integrative immune system mechanisms. Hardware was also commissioned on orbit for the Grip/Grasp neuromuscular control experiments.

Biology research

The third and final part of the ESA/NASA Seedling Growth experiment was performed in the European Microgravity Cultivation System. The experiment builds on previous research, studying the effects of different light/gravity parameters on the growth responses of plant seedlings. The Extremophiles experiment was also performed with sampling sessions to provide more detail on microbial communities inhabiting the ISS, and compared with spacecraft clean room microbial communities.

Materials research

Processing of the second batch of experiments in the Electromagnetic Levitator has started on different alloy samples. All of the experiments are studying different aspects of the solidification process in metal alloys, which will help to optimise industrial casting processes.

Radiation research

Seven-month personal astronaut monitoring campaign concluded in June within the ESA Active Dosimeter

project. Monitoring of the radiation environment in Columbus also continued within the DOSIS-3D and ESA Active Dosimeter projects.

Non-ISS platforms

The Maxus-9 sounding rocket was launched on 7 April. The rocket included four scientific experiments and one reentry technology demonstrator with a supersonic parachute. All experiments performed flawlessly. A very high scientific and technical return is expected. The 66th ESA Parabolic Flight Campaign was performed in May with 11 ESA experiments (seven physical sciences and four life sciences). A 60-day 'Cocktail' bed rest study concluded at MEDES in Toulouse in April. Fifteen science proposals were implemented. The 60-day bed rest period began on 1 February.

→ EXPLORATION

ExoMars 2016

The Trace Gas Orbiter (TGO) aerobraking operations progressed on schedule and were interrupted as planned on 25 June to prepare for the 'superior solar conjunction phase'. Aerobraking operations restart in August. TGO's two-hour data relay orbit will be achieved in April/June 2018. The Schiaparelli Inquiry Board report delivered 16 recommendations applicable to the ExoMars 2020 Mission.



ESA astronaut Matthias Maurer at the signing event formalising the ESA/Airbus Defence & Space contract to build a second European Service Module for NASA's Orion spacecraft in Bremen, Germany, in February (ESA—P. Sebirot)

These recommendations were integrated in an exhaustive Early Descent and Landing Statement of Work.

ExoMars 2020

Delays of 2–10 months have accumulated on the Rover Pasteur payloads since Ministerial Council 2016 with respect to Lead Funding Agencies' commitment. This was addressed with the relevant Member States on different occasions. The System Rocket Complex PDR was held in June allowing the consolidation of the spacecraft and combined operations activities plan at Baikonur.

Following the consolidation by Lavochkin and Thales Alenia Space Italy of the Descent Module and the Spacecraft Composite AIT activities and because of a longer launch campaign than initially assumed, Thales and Lavochkin were requested to propose an updated schedule that preserves 60 working days of contingencies two years prior to launch. A proposal for a simplified Rover wheel-walking mode is expected from Airbus Defence & Space UK to improve the overall compliance to the locomotion requirements on critical terrains.

European Service Module (ESM)

Shipment of ESM-1 to the US is scheduled not earlier than March 2018 with a risk of further delays mainly because of delayed supplier deliveries. There are no margins in the ESM schedule so any problems in manufacturing,

integration and test activities on the critical path may result in further delay. The critical path is driven by the high-pressure gas valves delivery from a US supplier but several other pieces of equipment are just behind them. The functional test model was delivered and accepted in May by NASA/Lockheed Martin.

The procurement and manufacturing of ESM-2 hardware was authorised to maintain the schedule, while the qualification of the design is not complete and waivers are not all processed. This risk is controlled by the project through risk assessment at each of the equipment Manufacturing Readiness Reviews. For ESM-3, studies are ongoing to assess the design upgrades requested by NASA.

International Berthing Docking Mechanism (IBDM)

After signature of the ESA/SNC/QinetiQ agreement on IBDM for Dream Chaser in Colorado Springs (US) on 5 April, the IBDM contract with QinetiQ is under negotiation and the system delta PDR is ongoing with the participation of the potential US users.

European contributions to Luna-Resource lander

The PILOT Phase-B2 began in May. The Interface Emulator model of PILOT-D (Camera Demonstrator as payload on board Luna-Glob) was received by IKI at the beginning of June. The overall PILOT-D schedule remains very critical. The Interface Unit EM (also called CDIU) cannot

be delivered by mid-August as requested by IKI, but is expected in October.

The PROSPECT Phase-B2 began in April. An avionics optimisation exercise was conducted, leading to the standardisation of certain interfaces between the drill and the instrument. Phase-C/D is being prepared with Leonardo and the Open University, with a programmatic and planning review conducted on 30 June.

During a management meeting in April, Roscosmos confirmed the launch date of Luna-Glob as end of 2019 and announced that the launch date of the Luna-Resource Lander was shifted by one year to the end of 2022. This allows for a realistic Phase-C/D1 of PILOT and PROSPECT of three years until FM acceptance in Europe.

Exploration Preparation, Research and Technology (Ex-PeRT)

An AO for co-funded studies on user-driven research platforms in low Earth orbit was released on 2 June and is available for interested parties to submit outline proposals.

In April, MELiSSA activities for the period 2017–19 were defined and the contractual process has been initiated. The ArtEMISS hardware is ready for launch on 1 December.

Commercial partnerships

This first 'ICE Cubes' partnership agreement was approved in May, followed by a signature at the Paris Le Bourget air show in 20 June. The first applications were approved using the new 'Procedure for the Evaluation of Commercial Activities'. Technical and business reviews for 'Bartolomeo' will be completed in the coming months, followed by an expert independent assessment, an ESA independent assessment and subsequent Integrated Project Review.

→ SPACE SITUATIONAL AWARENESS (SSA)

Space Weather (SWE)

SWE services to the end users have been enhanced by deployment of new services from the Expert Service Centre network in May. The SWE Service Portal now provides access to 21 space weather services in preliminary configuration.

In April, the SSA programme, along with the Expert Service Centres and the SSA SWE Coordination Centre (SSCC), organised the first exercise to practise coordinated communications protocol for a situation when a major space weather event is in progress.

The objective of the exercises is to ensure that the end users of the ESA SSA SWE system will receive objective and reliable information throughout the event. In parallel, the SSCC carried out service test campaigns with end users from

aviation, spacecraft operation and power systems operation domains. Two user workshops focusing on satellite operations were organised in June at ESOC and at Inmarsat in London.

The implementation of the two hosted payload missions, Next Generation Radiation Monitor (NGRM) on board EDRS-C and Service Oriented Spacecraft Magnetometer (SOSMAG) on board GEO-KOMPSAT-2A, continued. NGRM has already been integrated on EDRS-C. SOSMAG FM delivery is expected in July. Preparation for a dedicated space weather mission to the L5 point is also progressing with the release of the ITTs for the Phase-A/B1 mission studies and the instrument pre-development studies in June.

Near Earth Objects (NEO)

In May, the biannual IAA Planetary Defense Conference was held in Tokyo, Japan. ESA participated actively in the preparation, and took the opportunity to present its work to the community. A simulated asteroid impact threat scenario took place, which involved not only the conference participants but also external players. Representatives of the German and Swiss emergency response agencies were involved.

Space Surveillance & Tracking (SST)

Procurement of Period 3 activities started. Activity for establishment of an expert centre for federated laser and optical systems is finishing with deployment at ESOC and the completion of sensor evaluation of optical systems. Data acquired from the test campaigns with the two test-bed radars have been processed. Integration, testing and validation of the data processing, planning, scheduling, catalogue querying, and event detection software is progressing. International standardisation activities are continuing within CCSDS and the CEN/CENELEC.

Data Centres and Data Systems

Studies are being conducted of a hybrid architecture combining on-premises and owned hardware resources with additional non-proprietary resources. This would give SSA Data Centres the flexibility to easily and quickly adapt to the increasing demands of system resilience, backup, data management capacity and capability, and long-term data preservation, as well as the possibility to scale up and scale back the infrastructure along segments' needs.

Rationalisation of processes for managing, operating and maintaining the SSA hardware and software infrastructures has been ongoing since early 2017 with the objective of aligning with a modern continuous integration and delivery solution. This transition started with configuration management and software lifecycle management, but the same approach will be adopted in other key Data Systems and Data Centres management areas (for example, assets, testing, intellectual property rights and security management).

→ ESA PUBLICATIONS

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