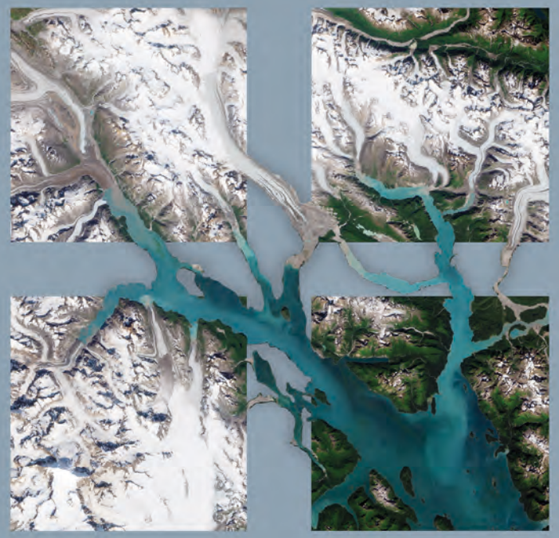
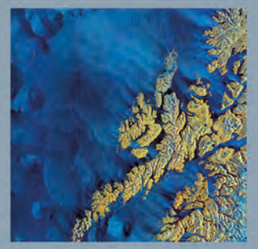
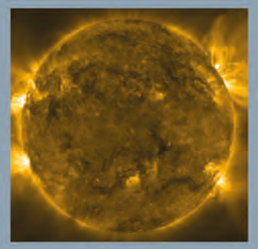
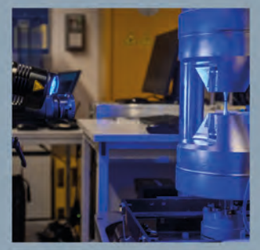
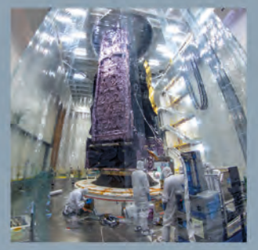
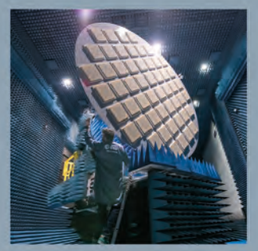
ESA Member States

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





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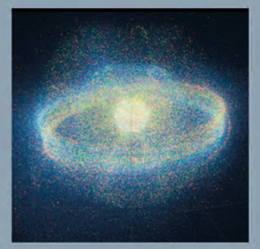

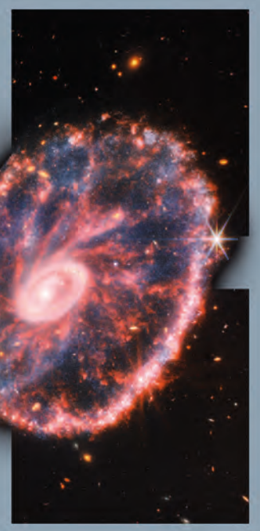
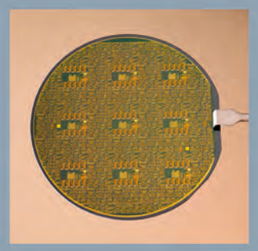

ANNUAL REPORT 2022

ESA HIGHLIGHTS 2022 covers a year of ESA activities, images and events, from 1 November 2021 to 31 October 2022

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ESA Director General Josef Aschbacher at the new Space Safety Centre at ESA's ESOC establishment.

→ THE EUROPEAN SPACE AGENCY

2022 was a year full of highlights for the European Space Agency. ESA performed its tasks – be they scientific, technical, administrative or political – with an extraordinary degree of professionalism, dedication and efficiency.

Just as we emerged from the worst of the COVID pandemic, we faced a new global crisis with the outbreak of war in Ukraine in February 2022 impacting our work both directly and indirectly, for example through the non-availability of the Soyuz launcher in Kourou, the interruption of missions such as ExoMars, and supply chain difficulties.

Despite these considerable challenges, ESA found a way to adapt to the new situation in which it found itself, going on to deliver an impressive string of successes. There was the inaugural flight of Vega-C, the launch of the European Service Module (ESM) on Artemis-I, the first images from the James Webb Space Telescope with European instruments on board and the start of operations of the Meteosat Third Generation I-1 satellite. Then we had the Space Summit in Toulouse in the presence of President Macron, while November saw CM22 – the Council meeting at ministerial level in Paris – secure a record budget of €16.9bn.

There were projects that did not go as planned, notably when the inaugural flight of Ariane 6 was postponed, but ESA will learn from these experiences to become even more capable and agile in the future. One thing we will never compromise on, however, is the quality of our missions. In the long run our focus on robust and reliable technology will pay dividends.

Throughout the year, Agenda 2025 demonstrated its value as a constant touchstone guiding our actions. It has allowed us to adapt our strategic focus to changing conditions while sticking with the established and time-honoured working methods that have made ESA the successful Agency it is today. Agenda 2025 will continue to shape our course of action in the years to come.

This 2022 ESA Annual Report presents the unique successes of the Agency in detail, proving that money invested in ESA is money well spent. ESA remains at the heart of European space activities, dedicated to its mission of bringing the benefits of space to Europe's citizens and the people of the world.

Josef Aschbacher
ESA Director General
@AschbacherJosef

CM22: EUROPE'S SPACE AMBITION

As 2022 drew to a close, ESA's Council at Ministerial level provided the perfect forum for discussing the future of European space.

ESA's Council at Ministerial level is held every three years. It brings together government ministers from ESA's Member States, Associate States and Cooperating States to determine Europe's programme of space activities for the coming years and even for decades ahead.

This year, ESA's Council at Ministerial level was held in Paris, France, on the 22 and 23 November 2022. The event, known as CM22, represented a crucial moment for Europe's future in space and the extent of its space ambition.

At the Ministerial Council, ESA presented proposals across every area of European space activity, together with requests for the funding to realise them. These proposals reflected the ambitions set out in ESA's Agenda 2025

Government ministers from ESA's Member States gathered at CM22 to discuss how to strengthen Europe's space sector for the benefit of all.

Discussions focused on climate change, secure communications and crisis response, as well as the ESA budget for the next three years.

and had been elaborated upon with Member States in the run-up to CM22. The Council itself marked the moment for making critical decisions to invest in and strengthen Europe's space sector, ensuring it continues to serve Europe's citizens.

CM22 took place against a backdrop of geopolitical instability, including the war in Ukraine, as well as an energy crisis, financial uncertainty and the ongoing climate crisis. These challenges have only made it clearer how vital space is for safeguarding our daily lives. They have underlined ESA's timely focus on autonomous access to space, climate change monitoring, and secure communications. Europe has showed it is ready to meet these challenges.

Read more about the outcomes of CM22 on the next page.

BUILDING ESA'S VISION

The decisions made at CM22 strengthened Europe's autonomy, leadership and sustainability in space, ensuring a continued effort to serve European citizens.

The overall outcome of CM22 in Paris was a decision to increase ESA's budget by a record 17%. This funding will help boost space in Europe, kicking off a new era of ambition, while enabling ESA to continue to invest in industries that create jobs and prosperity in Europe.

Some of the key outcomes of CM22 include:

- Ministers agreed to devote €2.7 billion to ESA's Earth observation programme, including a major commitment for FutureEO, ESA's world-leading Earth science, research and development programme.
- With €3.2 billion dedicated to the scientific programme, ESA will implement the missions from its Cosmic Vision programme while preparing the new space science programme, Voyage 2050, which defines the broad scope of ESA science from 2035 to 2050.
- Ministers approved €2.7 billion for the next phase of Terrae Novae, ESA's new worlds space exploration programme that focuses on three destinations – low Earth orbit, the Moon and Mars. Terrae Novae leads Europe's human journey into the Solar System using robots as precursors and scouts.
- It was also decided to extend European participation in the International Space Station up to 2030.
- Some €1.9 billion was allocated to improving life on Earth through always-on-everywhere connectivity. Most of this will be channelled through ESA's Advanced Research in Telecommunications Systems programme, which supports innovation in the European space industry.
- The proposed budget for navigation was confirmed, enabling ESA's Navigation Innovation and Support Programme to continue to promote the development of innovative positioning, navigation and timing technologies and foster commercialisation in Europe.
- A budget was also agreed for projects funded under ESA's space safety programme. These include the Vigil mission to monitor solar activity, the Hera probe to survey an impacted asteroid, and a mission to remove space debris from orbit.
- ESA's budget for space transportation increased to €2.8 billion, which will strengthen the competitiveness of the Ariane 6 and Vega-C launchers, as well as furthering development of the reusable Space Rider.
- Finally, the ESA budget for technology increased to €542 million. A new ESA programme called ScaleUp was also announced. This will support space commercialisation and the development of a new space ecosystem in Europe.

Following the close of CM22, ESA presented its 2022 class of ESA astronauts – 17 new astronaut candidates selected from more than 22 500 applicants across its Member States. These new ESA astronauts include five career astronauts, eleven reserve astronauts and one parastronaut – an astronaut with a disability.

WE ARE THE EUROPEAN SPACE AGENCY

More than 5000 people work across ESA, including engineers, scientists and support staff. Together we embody a spirit of international cooperation and have contributed to Europe's proudest achievements in space exploration, maximising the value space brings to our daily lives.

FR

ESA HQ

ESA's headquarters is located in Paris, France, and is where ESA's space strategy and policy are developed. It is also where the agency's administrative function is based.

NL

ESA ESTEC

The European Space Research and Technology Centre in Noordwijk, the Netherlands, is the technical heart of ESA. Its vast site includes facilities for testing satellites and space technologies.

IT

ESA ESRIN

The European Space Research Institute in Frascati, Italy, is ESA's centre for Earth observation and home to the Vega space transportation programme.

DE

ESA ESOC

The European Space Operations Centre in Darmstadt, Germany, is where we control our missions and build the systems on the ground that manage our fleet of spacecraft in orbit.

DE

ESA EAC

The European Astronaut Centre in Cologne, Germany, is home to ESA's astronauts. This is where European astronauts receive their training for space missions.

BE

ESA ESEC

The European Space Security and Education Centre, at Redu, Belgium, is a centre for space cybersecurity services and education. It hosts part of ESA's satellite tracking network, as well as the Space Weather Data Centre.

ES

ESA ESAC

The European Space Astronomy Centre near Madrid, Spain, is home to ESA's astronomy, fundamental physics, solar science and planetary missions, as well as extensive data archives.

UK

ESA ECSAT

The European Centre for Space Applications and Telecommunications in Harwell, UK, focuses on telecommunications and business applications, as well as climate change, technology and science.

FR

EUROPE'S SPACEPORT

Europe's Spaceport in Kourou, French Guiana, is the European gateway to space. At 5° north of the equator, it is ideally placed for launching spacecraft to any required orbit.

WHERE SPACE TAKES PLACE

INSIDE ESA

Four pillars. One ESA.

ESA's directorates work together to realise Europe's ambitions for space. We develop launch systems and new generations of satellites for Earth observation, communication and navigation. We devise science and exploration programmes that inspire, while here on the ground we operate space missions and protect our planet from space hazards.

We ensure Europe's space industry gets the support it needs and, of course, we develop the technology needed to do all of this. Whatever we do, whichever part we play, we work together as One ESA.

SCI

SCIENCE

Space science addresses humanity's big questions and pushes the frontiers of our knowledge. It also drives innovation and leads to scientific progress as well as economic development, inspiring future generations of scientists and engineers.

STS

SPACE TRANSPORTATION

Accessing space through our own space transportation is vital, as this enables independent decision-making, unrestricted by foreign intervention. ESA's strategic space transportation roadmap includes long-term investment in European solutions.

EOP

EARTH OBSERVATION

Space gives us an unparalleled view of our home planet and environment. Satellite insights are vital to understanding how our planet's climate is changing. These data feed into European priorities such as the Green Deal and decarbonisation.

NAV

NAVIGATION

Satellite navigation services, provided through ESA's position, navigation and timing technology, are used by citizens, businesses and scientists. ESA's expertise in this sector gives Europe a leading role in the global market for satellite navigation services.

CIP

COMMERCIALISATION, INDUSTRY AND PROCUREMENT

To make Europe a hub for space commercialisation, we must scale up the most innovative ideas and foster commercial success. ESA supports and shares its expertise with industry, businesses and start-ups.

HRE

HUMAN & ROBOTIC EXPLORATION

Exploration is at the core of human aspirations for knowledge and discovery. ESA's Human and Robotic Exploration programme, known as Terrae Novae, has ambitious objectives that include landing the first European astronaut on the lunar surface by 2030.

OPS

OPERATIONS

ESA's Operations teams control spacecraft in orbit, manage the agency's independent global tracking station network and design and build the systems on the ground that support missions in space. They fly the risky, first-of-a-kind missions that no one else in Europe can.

TEC

TECHNOLOGY

New technology is the starting point for everything ESA does. The directorate of technology, engineering and quality drives the ongoing innovation and technical excellence needed to achieve ESA's future goals.

TIA

TELECOMMUNICATIONS

Satellite communication underpins everyday life, enabling faster connectivity, as well as more efficient transport, healthcare, safety and security measures, environmental services and much more. ESA's directorate for telecommunications supports innovative technologies that boost European business.

S2P

SPACE SAFETY

The Space Safety Programme protects our planet, human society, and our vital infrastructure in space and on the ground from hazards originating in space. It contributes to the safety, resilience and autonomy of Europe and its economies.

Prior to launch, the James Webb Space Telescope was mounted on top of its specially-adapted Ariane 5 launcher. Webb was slowly raised 40 m and then carefully manoeuvred so technicians could bolt its launch vehicle adapter to the rocket. This delicate operation was performed behind a transparent 12-m curtain, to meet strict cleanliness requirements.

SELECTED HIGHLIGHTS

November 2021 to January 2022

In December, the launch of the Webb space telescope was the Christmas present the world's space community had been waiting for.

The last two months of 2021 saw two exciting missions lift off. The Webb space telescope began its journey on board an Ariane 5 launcher from Europe's Spaceport in Kourou, French Guiana. This was the first step of Webb's mission to study the origins of our Universe.

Earlier in December, the first two satellites in Galileo's third batch also launched from Kourou. They joined the constellation providing Europe's position, navigation and timing signals.

Europe's new heavy launcher, Ariane 6, also made headway in the new year, arriving at Kourou in January to continue preparations for its inaugural launch. The lower and upper stages, both built in Europe, were delivered safely by sea to the Ariane 6 assembly building at Europe's Spaceport.

Images from Copernicus Sentinels-1 and -2 highlighted the effects of too much or too little water on our planet, showing both flooding as well as arid sand dunes caused by drought around Sudan's White Nile.

The test-bed technology of ESA's new laser ranging station in Spain passed its final tests, while ESA's technology laboratories were busy testing the strength of materials. Progress was also made on developing techniques to 'bioprint' human bones in space, with a view to providing medical support for long-term space missions in the future.

GALILEO: NEXT BATCH

Satellites placed on launcher

Galileo satellites 27-28 were enclosed with the Fregat upper stage in their protective fairing. They were then placed on top of the other three stages of their Soyuz, prior to liftoff in December 2021 from Europe's Spaceport in French Guiana. Following a flawless launch, Fregat released the satellites into orbit. They are the first two of Galileo's third batch of satellites.

BIOPRINTED BONE

Emergency surgery in space

ESA is developing 'bioprinting' techniques to give astronauts on an extended mission access to the 'spare parts' needed for bone or skin grafts, and even internal organs. This artificial bone sample is an early exercise using this technology. The idea is that skin or bone could be bioprinted using a nutrient-rich 'bio-ink' of blood plasma taken from the astronauts themselves.

DEPARTING DRAGON

Beaming with science

In January, this SpaceX Dragon spacecraft was captured by ESA astronaut Matthias Maurer as it departed the International Space Station with more than 2000 kg of hardware and scientific experiments on board. This included several European experiments into subjects such as how human cells and muscle behave in the weightlessness of space and an experiment that monitors core body temperature.

COMET LEONARD

ESA's NEOCC gives the all-clear

This image from ESA's Near-Earth Object Coordination Centre (NEOCC) shows Comet Leonard in December 2021. Captured by Solar Orbiter, it shows the comet in transit and gives scientists clues about the rate at which it ejects dust as it travels. The NEOCC monitors comets and assesses them for risk of Earth impact. In this case, there was no cause for alarm.

WHITE NILE

Vegetation and sand dunes in Sudan

This false-colour image, captured by Copernicus Sentinel-2, shows plant life, flooding and sand dunes around the White Nile river, in Sudan. In this near-infrared image, vegetation appears bright red. Bodies of water from seasonal flooding are shown in turquoise and blue. Villages can be spotted near artificial reservoirs (recognisable by their rectangular shape).

BREAKING POINT

Testing to the limit

ESA engineers need to know if materials are tough enough for space missions – so they pull them apart with this machine. A sample is placed between two sets of jaws and subjected to a steadily increasing pull force until it fractures. The force and resulting deformation are tracked by measuring the images taken with the camera shown on the left, in a process called photogrammetry. The final fracture pattern is carefully analysed.

READY FOR ASSEMBLY

Arrival at Europe's Spaceport

The lower and upper rocket stages of ESA's Ariane 6 launch vehicle, made in France and Germany respectively, arrived in French Guiana by sea in January. They were transported in their containers to the new Ariane 6 assembly building at Europe's Spaceport. Once there, they were unpacked for assembly into the Ariane 6 central core.

TESTING JUVENTAS

Mini radar for asteroid mission

A new radar system, designed to be the smallest in space, was tested at ESA's technical facility, ESTEC. The compact radar is mounted on the Juventas CubeSat, which will travel on ESA's planetary defence mission Hera in 2024. On arrival at the two Didymos asteroids, Juventas will carry out the first-ever radar sounding of an asteroid's internal structure.

LASER FOCUS

Shining light on space debris

From its vantage point on top of the Izaña mountain in Tenerife, ESA's new IZN-1 laser ranging station uses pulses of green laser light to monitor the position of satellites and space debris, all to within a few centimetres. Operated as part of ESA's ongoing Space Safety programme, IZN-1 helps to protect life and safeguard infrastructure on Earth and in orbit.

A VIEW OF HOME

Matthias Maurer's first spacewalk

ESA astronaut Matthias Maurer conducted his first spacewalk in early 2022, alongside NASA's Raja Chari. Their tasks included upgrades to Station hardware and installing a power and data cable on the Bartolomeo science platform outside ESA's Columbus module. Understandably, Matthias described the spacewalk as "one of the most outstanding experiences of my life".

SATELLITE DATA FOR BETTER CLIMATE ESTIMATES

Accurate data on climate change is essential. ESA's new Earth observation missions will improve how countries estimate and report greenhouse gas emissions.

The message about climate change couldn't be clearer: if we hope to limit global temperature rise to 1.5°C above pre-industrial levels, we must reduce our greenhouse gas emissions as a matter of urgency. Strategies, accords and policies have been put in place, from the Paris Agreement to the European Union's Green Deal. The latter aims to reduce Europe's net greenhouse gas emissions to zero by 2050.

But what if the emission figures self-reported by countries to the United Nations Framework Convention on Climate Change (UNFCCC) are deeply flawed and underestimate the problem? This was the finding of research conducted by the *Washington Post* newspaper in 2021. The research concluded that scientific measurements from space could help to improve the accuracy of each country's reporting: "A key problem is that the UN reporting guidelines don't currently require any atmospheric or satellite measurements, known as a 'top-down' approach."

A group of researchers working at the Regional Carbon Cycle Assessment and Processes project (Reccap-2), which is supported by ESA, came to a similar conclusion. They found significant discrepancies between the values calculated using their data model, compared to self-reported national emissions. The Reccap-2 research, published in April 2022, processed data models of greenhouse gases in the atmosphere, together with measurements taken on the ground and from spatial remote sensing. These sources were used to establish a model for carbon dioxide suitable for evaluating the national greenhouse gas inventories submitted by countries to the UNFCCC. It modelled the data to show how the gases can move, or 'flux', between land and atmosphere, for example when carbon dioxide is absorbed by vegetation, released by wildfires, or transported by rivers.

From the Himalayas to the Ganges Delta, this Copernicus Sentinel-3 image shows us an area that is extremely vulnerable to climate change and is also home to more than 100 million people. These residents are at risk of flooding due to meltwater from the Himalayas, as well as intense rainfall during monsoon season, and sea-level rise.

According to Clement Albergel, Climate Applications Scientist at ESA, the research could improve the accuracy of emissions data reported by countries to the UNFCCC. He says: "This paves the way for countries and the global community to improve checks and the consistency of national inventories to accurately reflect global emissions. Satellite data give us accurate figures of greenhouse gases in the atmosphere, but you also need to identify the source of the emissions with a data model."

Carbon reporting

Satellite data are fundamental to ensuring we have a clearer picture of the emissions from human activity that cause climate change. The Copernicus Anthropogenic Carbon Dioxide mission (CO2M) is being designed to measure just that. Specifically, the mission will be the first to measure anthropogenic carbon dioxide in the atmosphere – in other words, carbon dioxide generated by human activity. This data will be used by the new CO2M Monitoring and Verification Support Capacity (CO2MVS), which will support policy and decision-making on carbon dioxide emissions, at local, national and European level. The system is expected to be fully operational by 2026, in time for the second Global Stocktake – a five-yearly United Nations-led review to manage national actions on climate change – in 2028.

The aim of the CO2MVS, according to ESA's CO2M Mission Scientist, Yasjka Meijer, is to provide actionable information supported by consistent data from space. He says: "At the moment we rely on countries to report everything based on statistics, but obviously they can only report what they know and there may be emissions they haven't fully accounted for. This is exactly why the CO2MVS can support them. The system aims to support reporting, not to police it, and will provide a consistent global data set that is updated on a regular basis."

So how do CO2M's instruments – a near-infrared and a shortwave-infrared spectrometer – distinguish between anthropogenic carbon dioxide emissions and the carbon dioxide released by natural environments such as wetlands? Yasjka explains that, in effect, they don't and don't need to. "The mission's instruments will measure carbon dioxide at a relatively high spatial resolution, so they will be able to detect plumes of enhanced carbon dioxide concentrations that are emitted from cities and power plants. Furthermore, we measure nitrogen dioxide, which is co-emitted during high-temperature combustion and is more clearly visible, allowing us to magnify the plume location. The CO2MVS will use this information, in combination with ground-based observations, in a model to estimate the anthropogenic emissions of carbon dioxide (and actually also methane). This will support future Global Stocktakes as agreed in the Paris Agreement and required transparency framework."

CO2M is one of six Copernicus Sentinel Expansion missions that ESA is developing on behalf of the EU. The foundation of Copernicus was key in turning the data provided by Earth-observing satellites into services relevant for government stakeholders and policy-making. Copernicus is now the world's biggest supplier of Earth observation data. Missions such as CO2M represent a step change in the volumes of data that monitor greenhouse gas emissions.

Future Earth observation

While the Copernicus Sentinel missions provide critical input data for services we rely upon, ESA's Earth Explorer satellites address challenges in Earth observation with new observation techniques. They are part of ESA's Future Earth Observation (FutureEO) programme, which fosters the innovation and scientific understanding needed to tackle today's urgent climate needs. "Earth Explorers give us the opportunity to develop both the science and the technology, and that ultimately provides the foundation upon which to build missions such as CO2M," says Mark Drinkwater, head of ESA's Earth & Mission Sciences Division.

Three new upcoming Earth Explorer missions are designed to increase our understanding of carbon and radiation in our planet's ecosystem. The Earth Cloud Aerosol and Radiation Explorer mission (EarthCARE) will study a key aspect of global warming: water vapour and microscopic solid particles suspended in the atmosphere. By studying how aerosols and vapour clouds form and interact with radiation, the mission will give us a better understanding of how heat is trapped in the atmosphere and how solar radiation is reflected back out into space.

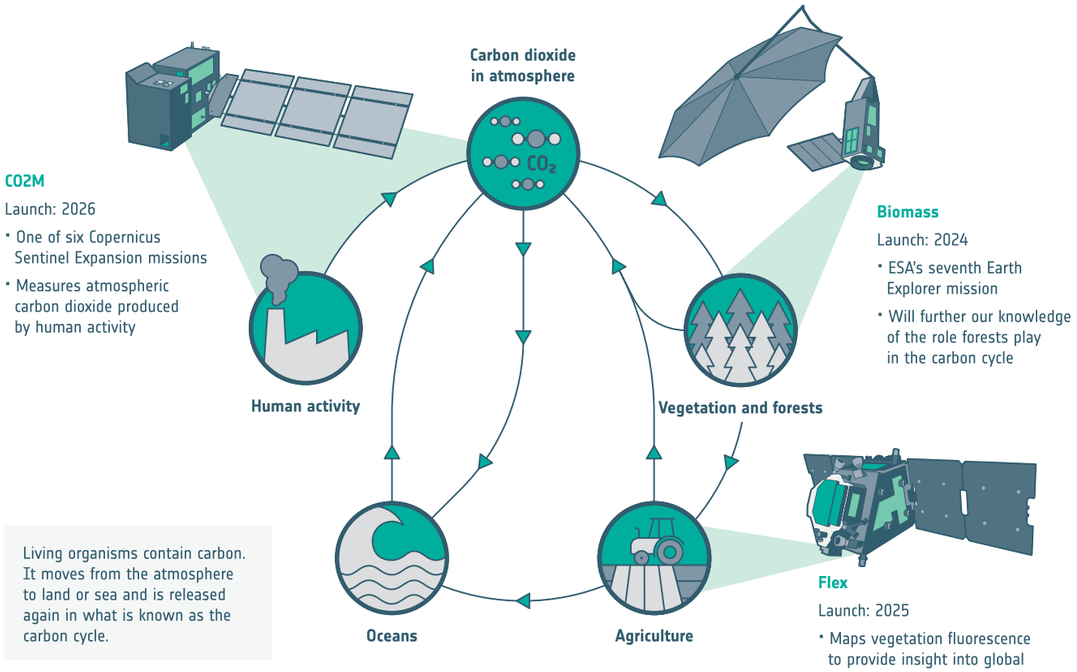
The Fluorescence Explorer mission (Flex) detects the faint fluorescence emitted by plants. These data will give us a better understanding of the health of plant life and how carbon moves between vegetation and the atmosphere. And the Biomass mission will use long-wave penetrative radar that can detect and quantify biomass stored in trees and tropical regions at a level of detail not previously possible. It can detect objects buried below vegetation and will further our understanding of how forests are changing, and the role forests play in the carbon cycle.

Mark adds: "It's not only about routine monitoring, but also about verifying data models for compliance reasons, then delivering the data and information products in a form that's useful for policy-making. To achieve carbon neutrality, we need to look at a multiplicity of strategies to boost a green

A major sea-level rise from the melting of the Greenland ice cap is now inevitable. Even if we stop burning fossil fuels immediately, sea levels will rise by at least 27 cm. Earth observation satellites are key to monitoring ice and this Copernicus Sentinel-2 image captures melt ponds on the Greenland ice sheet.

MONITORING THE CARBON CYCLE

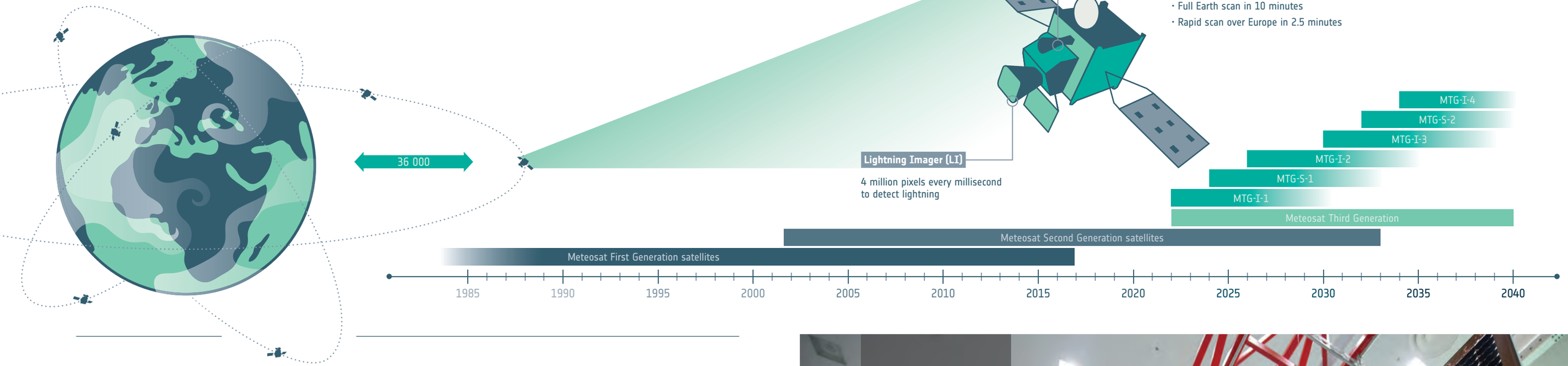
These three upcoming missions, due for launch by the end of 2026, will improve our understanding of the carbon cycle and how the greenhouse gas carbon dioxide is affecting Earth's climate.



Living organisms contain carbon. It moves from the atmosphere to land or sea and is released again in what is known as the carbon cycle.

WEATHER FORECASTING FROM SPACE

The Meteosat Third Generation (MTG) satellite system will place a total of six satellites in orbit. They will provide fast and accurate weather images, ensuring continuity of data for weather forecasting and important continuous data about our climate.



economy. Satellite data can be used to help locate wind farms, improve shipping safety, efficiency and sustainability, or support agriculture and biodiversity."

Satellite data are also important in influencing and changing people's day-to-day lifestyles. Phone applications that indicate levels of pollen or air pollution, the quality of sea water at the local beach, or information about UV levels make space data instantly available at our fingertips. "We need to continue developing such tools so that people on the street can see, use and benefit from these sources of openly available satellite information," says Mark. "This is necessary because it's not governments that bring about changes in human nature."

He adds: "I am genuinely concerned about what the environment will be like in the future, but we're equipping the next generation with sources of knowledge and information that we didn't previously have access to. I'm optimistic we have better tools for informing future policy decisions and seeking smart solutions to the climate crisis."

Weathering the storm

Much of the long-term data that climate science is based upon comes from short-term weather forecasting. At the end of 2022, ESA is launching a mission that will guarantee both the short-term forecasts and the continuity of long-term data for climate science. The Meteosat Third Generation satellite system (MTG for short) is a huge leap forwards in terms of accuracy and advance warning of dangerous storms.

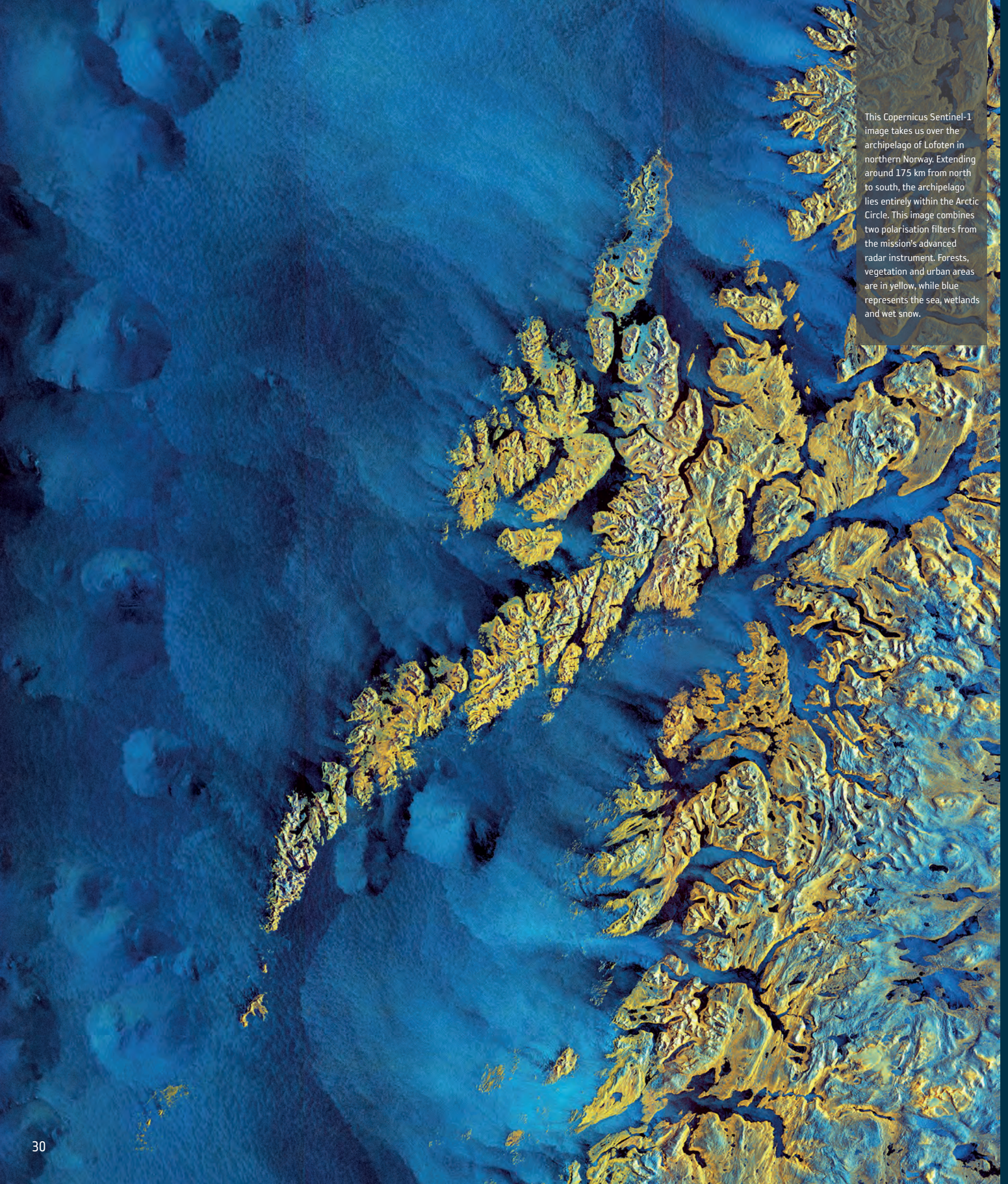
The mission has been developed by ESA together with its long-standing partner, the European Organisation for the Exploitation of Meteorological Satellites (Eumetsat).

"MTG represents a substantial step forward in terms of performance," says Paul Blythe, ESA's Meteosat Programme Manager. MTG's images will have a resolution four times greater than its predecessor, Meteosat Second Generation (MSG). And with a download capacity of up to 200 megabits per second, it can transmit 100 times more data back to Earth compared to MSG. This significantly higher performance is explained by MTG's stable attitude in orbit, which enables it to point towards Earth 100% of the time. In comparison, MSG is a spinning satellite that focuses on Earth for less than 5% of the time.

From its vantage point at an orbit 36 000 km from Earth, MTG can perform a full scan of Earth's atmosphere in just 10 minutes. The mission is designed to have a trio of satellites working together (two batches of this configuration will be launched in stages to ensure the mission's operational life will be in excess of 20 years).

First launched in 1977, the Meteosat programme has a continuous dataset, including measurements of cloud temperature, ground temperature, wind speed and direction, as well as gases such as ozone, methane and carbon dioxide. "The Meteosat programme wasn't designed to specifically monitor climate, but the dataset spanning 45 years is hugely beneficial for climate applications," explains Paul. "MTG will enable the continuity of this important programme for another 20 years, guaranteeing a very strong tool to support climate models and an analysis of what's happened since the 1970s."

The Meteosat Third Generation Imager-1 satellite is seen here on display in the cleanroom at Thales Alenia Space's facilities in Cannes, France, before its three-week voyage to Europe's Spaceport in Kourou, French Guiana.



This Copernicus Sentinel-1 image takes us over the archipelago of Lofoten in northern Norway. Extending around 175 km from north to south, the archipelago lies entirely within the Arctic Circle. This image combines two polarisation filters from the mission's advanced radar instrument. Forests, vegetation and urban areas are in yellow, while blue represents the sea, wetlands and wet snow.

SELECTED HIGHLIGHTS

February to April 2022

Despite disruption caused by events in Eastern Europe, many space activities still went ahead. In April, two ESA astronauts were part of the international crew on the Space Station.

This quarter saw a double bill of European astronauts in orbit. At the end of April, ESA astronaut Samantha Cristoforetti returned to the International Space Station to start her second mission, Minerva. She was greeted on arrival by fellow ESA astronaut Matthias Maurer and they had a brief chance to catch up before he returned to Earth at the start of May.

Back on the ground, we saw how space technology can protect us and even help to save lives during emergencies. One example was 406 Day on 6 April, which celebrated the role of emergency beacons and satellites in getting help to people in trouble, anywhere in the world.

Another example was the opening of ESA's new Space Safety Centre, dedicated to monitoring and responding to space weather hazards. The centre demonstrates ESA's commitment to protecting Europe's space missions and ground infrastructure from unpredictable solar outbursts.

Technological developments included the successful testing of a new antenna for MetOp-SG meteorological satellites, while the new European Robotic Arm made its first moves on the International Space Station. March brought us the impressive spectacle of NASA's new Orion spacecraft and its European Service Module on the Space Launch Systems rocket, ready for a test 'rollout' to the launchpad at Kennedy Space Center.

CREW-4 HEADS OUT

Samantha's Minerva mission starts

In April, ESA astronaut Samantha Cristoforetti returned to the International Space Station for her second mission, Minerva. She was welcomed on board by ESA astronaut Matthias Maurer, enjoying a brief handover in orbit before Matthias returned to Earth with Crew-3. Samantha is pictured here alongside NASA's Jessica Watkins as Crew-4 prepared to board the SpaceX Crew Dragon *Freedom*.

406 DAY

Emergency beacons save lives

Europe's Galileo satellite navigation system can pick up distress messages from anywhere on Earth and relay them to search and rescue services. SOS messages can be transmitted by flashlight-sized emergency beacons and picked up by a satellite, which routes the signal through the international Cospas-Sarsat system. Annual 406 Day celebrates the life-saving importance of emergency beacons, and is named after the radio frequency upon which they operate.

HOME FOR EARTH'S PROTECTORS

New Space Safety Centre

Space weather – electromagnetic radiation and charged particles hurled into space by the Sun – can disrupt or harm satellites, astronauts and infrastructure on the ground, such as power grids. ESA's new Space Safety Centre is dedicated to mitigating the effects of space weather. Information and warnings are provided, and new tools and weather forecasting models are developed here.

CRISIS RESPONSE

Europe reacts to war in Ukraine

Russia's invasion of Ukraine at the end of February drew strong condemnation from European countries. ESA immediately implemented the sanctions imposed on Russia by its Member States and, following a comprehensive review, terminated cooperation with the Russian state space agency, Roscosmos. ESA has since worked to redirect programmes affected by the crisis. Ukraine's capital, Kyiv, is shown in this Copernicus Sentinel-2 image taken in 2020.

MARS MISSION

ExoMars rover delayed

The second part of the ExoMars mission will land Rosalind Franklin – a robotic rover named after the British chemist – on Mars. The mission faced a major hurdle when cooperation between ESA and Roscosmos ended in 2022. ESA and European industry subsequently sought ways to complete the mission. Launch is now expected in 2028, ensuring the rover's unique drilling capability will be in place by the early 2030s. The Red Planet is pictured here in this image from ESA's Mars Express mission.

ANTENNA DEPLOYMENT TEST

MetOp-SG is put through its paces

In April, MetOp Second Generation's scatterometer antenna completed its deployment test at Airbus in Madrid. The instrument's testing campaign lasted four months, during which it was subjected to the extreme conditions that it will encounter during launch and in orbit. The scatterometer will be used to monitor ocean winds and continental ice sheets, and check land-surface soil moisture.

VEGA-C INTEGRATION

Preparing for flight

Assembly of the launcher (a process known as integration) for the inaugural flight of ESA's Vega-C began with delivery of the P120C solid-fuel first stage to the Vega Launch Zone at Europe's Spaceport. Here we see the interstage segment that joins the first stage to the Z40 second stage. Vega-C will significantly increase performance with no increase in launch and operating costs.

ERA'S FIRST STEPS

A helping hand

The European Robotic Arm (ERA) recently made its first moves in orbit. Two spacewalkers released the transport locks, while a crewmate monitored its first commanded movements from inside the Station. ERA is the first robot capable of 'walking' around the Russian modules of the orbital complex. It can handle heavy components very precisely, and transport astronauts from one site to another.

EARTH'S NEW FOLLOWER

Second 'Earth Trojan' asteroid

Astronomers confirmed that an asteroid discovered in 2020 is an 'Earth Trojan': it follows Earth's path around the Sun. Using telescopes, including ESA's Optical Ground Station in Spain, they were able to establish that 2020 XL5 is larger than the only other known 'Earth Trojan'. In this illustration, the two bright points near the asteroid are Earth and the Moon.

STANDING TALL

Orion ready for rollout

ESA's European Service Module (ESM) is the ground-breaking powerhouse designed to take Artemis I to the Moon and back. This picture shows NASA's Space Launch Systems rocket with the Orion spacecraft and ESM in the Vehicle Assembly Building at the Kennedy Space Center. With everything in place, the rocket made the slow journey to the launchpad on a 'crawler'.

SPACE FOR INNOVATION

New ideas for space technology that will shape the future of space exploration, and a smart use of satellite data to help detect marine pollution.

How can we generate fuel on Mars? How can the study of natural materials on Earth help us build objects sustainably in space? And how can data analysis of satellite images give us insights into plastic pollution on Earth? These are just some of the questions that ESA is exploring with the use of innovative research ideas and techniques.

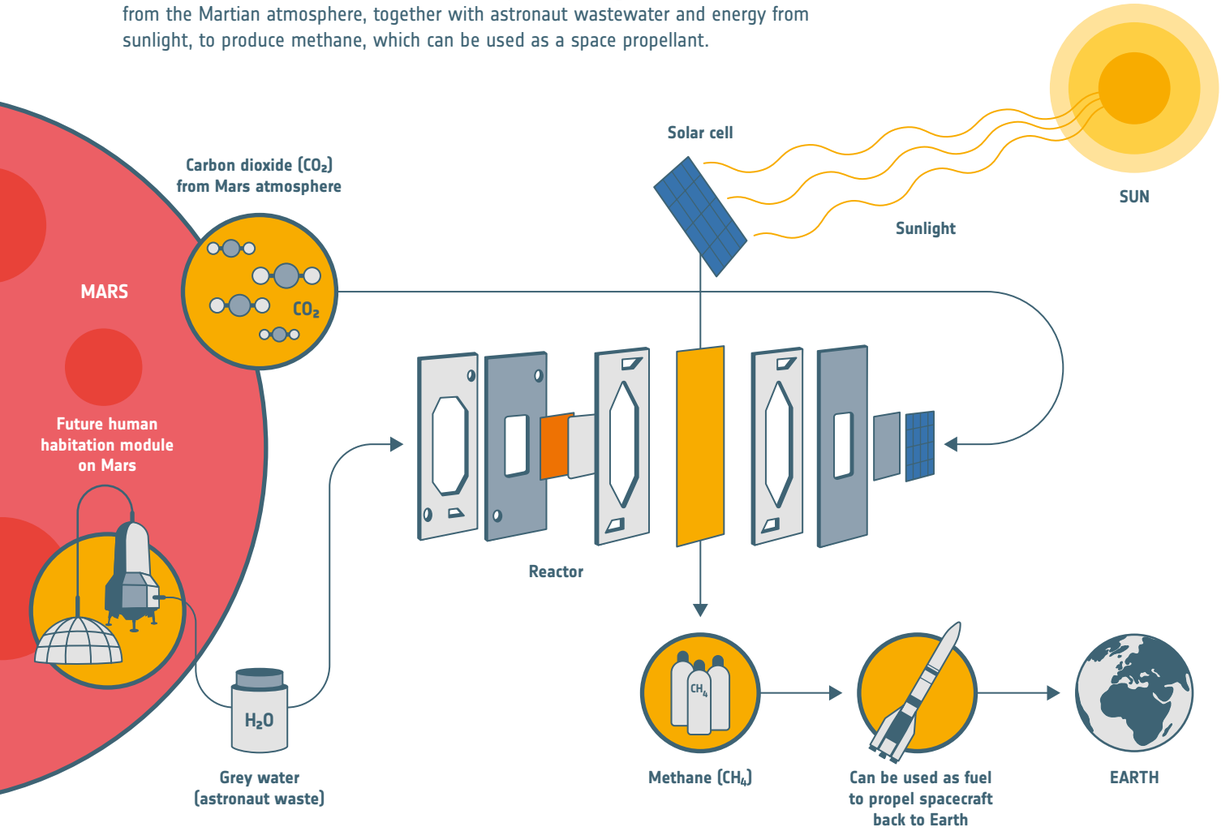
Much like a greenhouse where young plants are nurtured and given the conditions they need to grow, ESA ensures that early ideas for technology development, research and the innovation needed for future space programmes are given resources to develop. By doing this, ESA is strengthening the foundations for future European space activities and supporting the competitiveness of the European space industry.

ESA's Open Space Innovation Platform (OSIP) is a starting point where innovative ideas for research projects can be submitted and explored by researchers and scientists. The platform is the main entry point for new activities run by the Discovery element of ESA's Basic Activities, which supports the development of disruptive space technologies and novel applications. This article looks at some recent ideas that have been selected through the platform.

3D printing is a key technology that would make it possible to build a lunar base. Research funded by ESA's Discovery element explores how natural materials could be used to print structures in space. Other research is developing a way to make fuel on Mars and how to make steel with low-grade raw materials.

FUEL ON MARS FROM ASTRONAUT WASTEWATER

This example of a photoelectrochemical (PEC) system is designed to use carbon dioxide from the Martian atmosphere, together with astronaut wastewater and energy from sunlight, to produce methane, which can be used as a space propellant.



Making fuel on Mars

A proposal for an innovative fuel-generation system was presented to the Discovery element through the Open Ideas channel on OSIP by the technology innovation company Tekniker, based in northern Spain. It is one of a number of projects the research institute is working on that aim to improve future missions to outer space. The system, which has been under development during 2022, uses two resources that are abundant on Mars. One is sunlight and the other is carbon dioxide, which makes up 95% of the planet's atmosphere.

The other material required for the system is not so readily available on Mars: water. However, if one day humans are able to visit the Red Planet for prolonged periods, they will produce 'grey' wastewater, for example from showers.

The coordinator for Tekniker's space sector, Borja Pozo, explains how they have developed a reactor that turns astronaut wastewater (plus carbon dioxide) into methane using sunlight. While methane is one of the primary greenhouse gases on Earth, in its liquid form it is also a powerful rocket fuel.

Borja explains, "This reactor combines carbon dioxide and wastewater. A chemical reaction is needed to produce energy and this process takes place inside the reactor, which currently consists of layers of a metal oxide and titanium dioxide at the photoanode and copper at the cathode. Energy is needed, in the form of sunlight, to initiate the process. The output is a propellant – in this case, methane – which could potentially be used as fuel by rockets to launch from the surface of Mars, making it possible for future astronauts to return home."

He adds, "Our goal now is to substantially improve the reactor's efficiency. Currently, during the trade-off developments and without system optimisation, we are achieving a 6.55% of system efficiency and 46.7% of methane production efficiency, surpassing the current state of the art for this kind of system. We also want to ensure that the reactor can be manufactured independently within Europe. We are working on a prototype and will also test how it will work with simulated Mars dust, which is heavily present in the planet's atmosphere."

Green steel in space

Last year, ESA's Discovery element issued a call for ideas on using space innovation to boost Europe's green future. One of the ideas proposed was from a Luxembourg-based space engineering firm, Maana Electric. With funding from ESA, the company is now exploring how to produce low-grade steel that is also carbon neutral. The technique would address one of the challenges of long-term space missions as well as enabling greener construction on Earth. During future space missions it will be important to use materials at the destination, rather than transporting materials from Earth – a practice known as in-situ resource utilisation (ISRU). On Earth, the same technique would make the production of low-grade steel economically viable, significantly reducing emissions in the steel industry. The industry currently accounts for 5.7% of total greenhouse gas emissions in the European Union. This project shows how ESA's Discovery element supports new business opportunities and innovative companies.

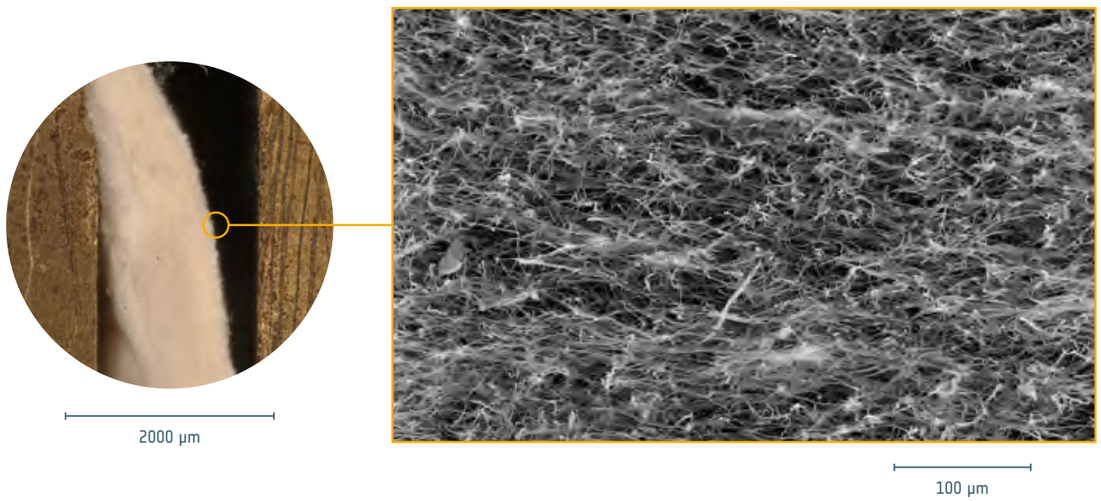
Building with mycelium

Another innovative idea being researched has its roots beneath our feet. Just think back to the last time you walked through a forest. You may have listened to birds and enjoyed the green shade. You probably also trod on some organisms that might one day help us build on the Moon – namely fungi. We are familiar with mushrooms and toadstools, which are the fruits of these organisms, but it is the mycelium – the branch-like networks of tiny fungal threads below ground – that could play a vital role in developing sustainable and durable materials that can be grown and used in space.

The project, selected through OSIP and funded by ESA's Discovery element, studies the properties and potential uses of mycelium-based materials, which are made using the fungi's thread-like structures combined with nutrients such as agricultural waste matter. Mycelium-based bio-composite materials can be completely biodegradable, light, tough and resistant to both fire and water. The new composite material has great potential for space applications. Materials and process engineer Malgorzata Holynska, who is ESA's technical officer overseeing the project with the University of Maribor in Slovenia, says, "The material is surprisingly durable and can be modified, depending on which nutrients, known as substrates, are used to 'feed' the mycelium. If we can develop filaments that can be used in 3D printers, we will be able to create complex shapes."

Mycelium-composite materials are already used in furniture and packaging here on Earth. Their applications for space engineering are still being researched. Malgorzata adds, "We are trying to learn from nature to produce sustainable materials. Because of its mechanical properties, this is a good alternative for synthetic fibres. The ultimate goal is to develop a material that can be used commercially in the future. And even though we are at a very early development stage, we believe it has a lot of potential."

MYCELIUM UNDER THE MICROSCOPE



The large image on the right shows the microstructure of some mycelium material, taken with a scanning electron microscope (SEM) image. The smaller image on the left shows the macrostructure of mycelium, taken with digital microscopy.

Mapping marine litter

The innovations supported through the ESA Discovery and Preparation elements aren't only for use in space; some projects explore how space technology can be used in new ways on Earth. For example, scientists from the ESA Discovery Campaign on Remote Sensing of Marine Litter have been analysing satellite images to study plastic litter in our oceans.

Some of the images analysed by the project are from the Copernicus Sentinel-2 mission, which generates multispectral images of Earth's land masses and coastal waters on a five-day cycle. The main uses of Sentinel-2 data are for agriculture and the study of vegetation health or for mapping disaster areas.

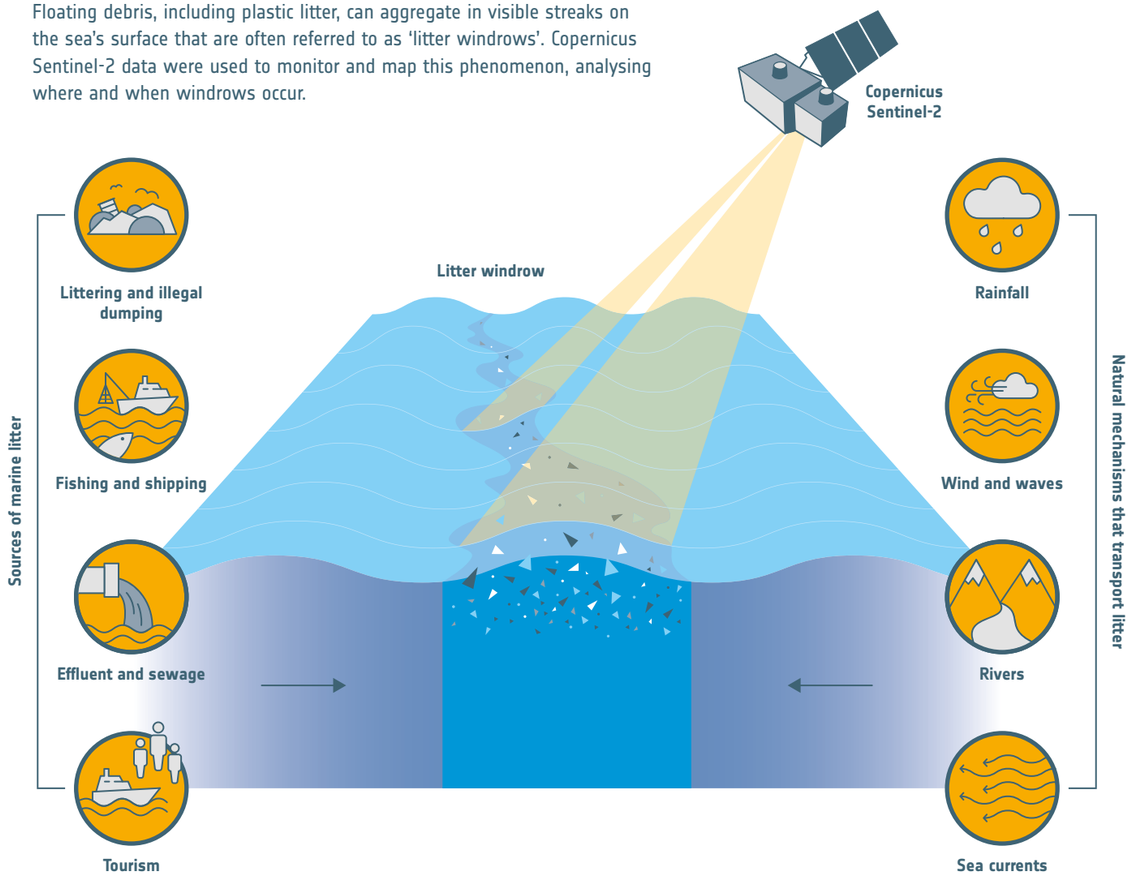
But some researchers working on activities selected through the marine litter Campaign have used this wealth of data for another purpose. For example, the UK company Argans Ltd, specialists in satellite-based Earth observation (EO) services, together with the scientists at the University of Cadiz, Spain, and the CNR-ISMAR Institute of Marine Sciences at Venice, Italy, knew that wind and ocean dynamics can accumulate floating debris, including litter, in long visible streaks on the sea's surface. These phenomena, which can be detected from space, are often referred to as 'litter windrows'.

> **"This is an innovative application of remote sensing that can benefit how we manage our environment"**

Scientists from ESA's Discovery Campaign on Remote Sensing of Marine Litter are using satellite data to study the presence of plastic pollution in the oceans.

MARINE LITTER FROM SPACE

Floating debris, including plastic litter, can aggregate in visible streaks on the sea's surface that are often referred to as 'litter windrows'. Copernicus Sentinel-2 data were used to monitor and map this phenomenon, analysing where and when windrows occur.



Although they can be a few metres wide and several kilometres long, windrows are unpredictable and ephemeral formations that are consequently difficult to see from the water's surface. So, this is where remote sensing and, in particular, satellite imaging step in. One of the difficulties in detecting marine litter in the satellite images, according to Paolo Corradi, ESA's coordinator of the marine litter Campaign and technical officer for the project, is knowing where to look and what to look for. He says, "We wanted a systematic way to detect high levels of marine litter pollution. We know, for example, that heavy rain and flooding in populated areas can send debris floating out to sea, so the researchers often focused on detecting large windrows in coastal waters near major cities or rivers."

While windrows mainly consist of natural organic matter such as seaweed or foam, they often also contain plastic debris, which can be an important indicator of increased plastic pollution in the surrounding area. The team from Argans was able to create time-specific maps of windrows that are more likely to contain marine litter. Together with other scientific data, these maps could be key to understanding the dynamics of marine litter and identifying local or regional sources of pollution, as well as hotspots for cleaning initiatives.

The analysis of the windrows as proxies (WASP) project focused on the Mediterranean Sea. By using its custom-developed EO data processor, Argans produced a map of windrows over a five-year time span. The project manager for Argans, Manuel Arias, explains, "There is potential for this technique to be used on a global scale. In total, more than 12 000 validated windrows were identified. It was established that the WASP EO data processor was able to identify windrows with an accuracy of more than 85%."

Paolo adds, "By advancing our satellite sensor technology, we might be able to estimate the higher plastic litter concentrations that form in windrows, as well as in accumulations on shores, rivers, and land close to waterways, and provide a more accurate global picture of plastic pollution in our aquatic environments. This is an innovative application of remote sensing that can benefit how we manage our environment."

ESA astronaut Samantha Cristoforetti is pictured on her first spacewalk, the first by a European woman and the first from the International Space Station by a European in an Orlan spacesuit. Samantha worked for seven hours with cosmonaut Oleg Artemyev on tasks that included deploying 10 small satellites by hand for a radio technology experiment and installing hardware.

SELECTED HIGHLIGHTS

May to July 2022

Among ESA's achievements this quarter were the inaugural flight of Europe's Vega-C launcher and the first spacewalk by a European woman.

This quarter, the effects of climate change became ever more apparent with a series of heatwaves causing disruption across Europe. ESA measured record-breaking land temperatures from space, highlighting the increasing importance of its Earth observation programme and how weather data can help to mitigate the effects of extreme weather events.

Meanwhile, the much-anticipated third data release from ESA's Gaia mission in June provided a goldmine of research material for astronomers around the world. Having already mapped more than two billion stars, Gaia offered even more detail and new discoveries, including details of the orbits of 155 000 asteroids.

Closer to home, ESA astronaut Samantha Cristoforetti achieved some firsts while in orbit on the International Space Station. Her first spacewalk was also the first by a European woman. On top of that, it was the first time a European astronaut had ventured outside the Space Station wearing an Orlan spacesuit.

Looking to the future, this quarter saw successful milestones in ESA's space transportation programme. Progress was made on Europe's new Ariane 6 launcher. And the inaugural launch of ESA's new Vega-C rocket marked the start of an exciting new era of European spaceflight.

GLACIERS RETREAT

Satellites monitor changing landscapes

Prolonged heatwaves affected many parts of the globe this summer. Glacier Bay on the southeast coast of Alaska was just one of many areas suffering from the effects of global warming. The Glacier Bay National Park and Preserve, shown in this Copernicus Sentinel-2 image, is expected to become warmer and drier over the next century, with retreating glaciers, reduced sea ice and shoreline erosion.

ASTEROIDS MAPPED

ESA's Gaia shows us what's out there

Gaia's third data release plotted the orbits of nearly 155 000 asteroids. This plot shows the positions on 13 June of all the asteroids near Earth, with the Sun at the centre. In blue, the inner Solar System is where near-Earth asteroids, Mars crossers, and terrestrial planets are found. The Main Belt, between Mars and Jupiter, is green. Two orange 'clouds' show the Trojan asteroids of Jupiter.

MADE OF PEOPLE

ESA seen from space

A unique group photo was taken in June on the ESA Teams Day to welcome everyone back on site after the pandemic. It was captured by a Pléiades Neo Earth observation satellite, orbiting at an altitude of 700 km. More than 1000 ESA personnel at ESA's ESTEC establishment in the Netherlands stood in formation holding up paper to spell out 'esa' as the satellite passed overhead.

LIVING PLANET

Earth observation for everyone

ESA's Living Planet Symposium, held in Bonn, Germany, in May, is one of the world's biggest Earth observation conferences. It brought together over 4000 scientists, academics, space industry representatives, institutional stakeholders, data users, students and citizens. Among the many topics covered were the latest findings on our changing planet, advances in satellite technologies, new commercial opportunities and ESA's future plans.

DOUBLE DELIVERY

Liftoff for telecoms satellites

Ariane 5 launched on its 113th mission in June, lifting two telecommunications satellites into their planned geostationary transfer orbits. The first payload delivered was MEASAT-3d, a telecommunications satellite whose multi-mission capabilities include providing broadband services to hard-to-reach areas of Malaysia. The second was GSAT-24, which will provide television, telecommunications, broadcasting, and other services to customers in India.

DESERT CRATER

Marking Asteroid Day

To mark Asteroid Day, a Copernicus Sentinel-2 image took us over the Tenoumer Crater in the Mauritanian Sahara. At 1.9 km wide, this almost-perfectly circular impact mark could be up to 30 000 years old. The meteorite's impact is thought to have melted nearby rocks. ESA's Planetary Defence Office forms part of a global network watching out for incoming asteroids.

VEGA-C SUCCESS

New era for European launchers

ESA's new Vega-C rocket completed its inaugural flight in July, lifting off from Europe's Spaceport in French Guiana. Flight VV21 then successfully placed its main payload, the scientific satellite LARES-2, plus six small research CubeSats, into their planned orbits. Vega-C represents a major boost in lift capability and its launch marked the start of a new era of European launch solutions.

COSMIC CARTWHEEL

Snapshot of a galaxy in transition

This image of the Cartwheel and its companion galaxies is a composite made using two Webb instruments. The galaxy formed from a high-speed collision 400 million years ago. The two rings are expanding outwards like shockwaves. The 'spokes' were the arms of the rotating galaxy before the collision. The brilliant red hues are produced by glowing, hydrocarbon-rich dust.

EUTELSAT HOTBIRD

A boost for TV broadcasts

In July, the first satellite to be built under ESA's Eurostar Neo programme completed its mechanical tests in Toulouse, France. The Eutelsat Hotbird 13F satellite is one of an identical pair developed by satellite manufacturer Airbus for satellite operator Eutelsat in an ESA Partnership Project. The two satellites will improve broadcast services across Europe, Northern Africa and the Middle East.

NEW NORCIA

Spacecraft communicators

Construction is under way at New Norcia in Western Australia for ESA's fourth 35-m deep space antenna. Like the three antennas in Australia, Spain and Argentina, it will become part of ESA's global tracking station network, Estrack. Its ground stations send commands to spacecraft and receive information and science data from them. Together, they provide continuous coverage for spacecraft in our Solar System.

HOW DO WE MAKE COSMIC IMAGES?

2022 was a bumper year for incredible views of our Sun, other stars and faraway galaxies. So, what are the challenges in creating these images?

The James Webb Space Telescope arguably stole the show this year when it released stunning images of galaxies formed 13 billion years ago. Launched in December 2021 on an Ariane 5 rocket, Webb brought us its first images in July 2022 – and they were worth waiting for. Just like large telescopes on the ground, space telescopes such as Hubble and Webb (both missions in which ESA is a partner) use mirrors to collect the incoming light.

Webb's complex primary mirror – 18 beryllium hexagons plated in gold – focuses light onto the mission's four instruments, which detect light in the ultraviolet, visible and near infrared spectrums. It detects infrared light with 100 times the sensitivity of the Hubble Space Telescope. One of Webb's first images is shown opposite: a never-before-seen view of a star-forming region in the Carina Nebula. Turn to the next page to see how Webb 'sees' the light emitted by galaxies that were still forming and how that light carries information about the characteristics of these celestial objects.

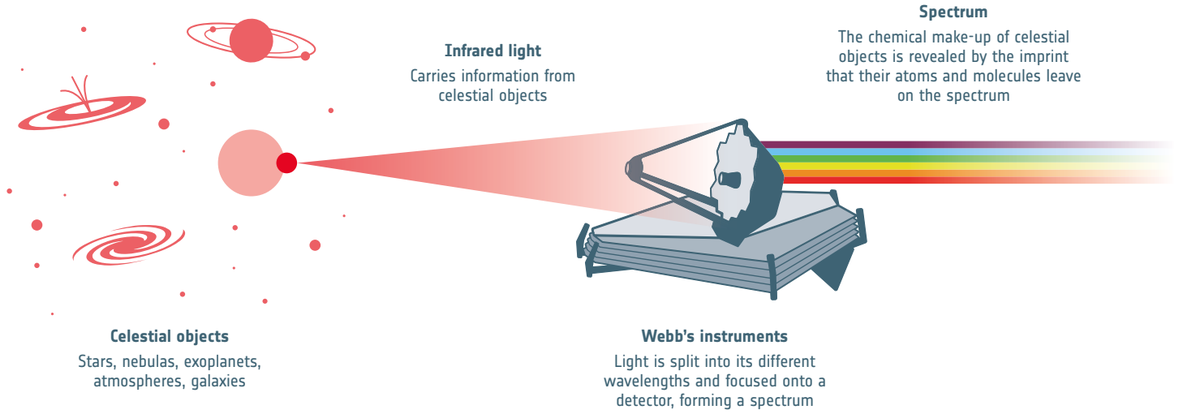
Images published by two other ESA missions were also greeted with enthusiasm by the science community and the general public. In March, Solar Orbiter released an image showing the Sun in unprecedented detail. And in June, Gaia's third data release brought us new and improved details of almost two billion stars in our galaxy.

The images created by Solar Orbiter and Gaia are very different to those of Webb, though they are all impressive and ground-breaking in their own ways. While Webb has captured light emitted by galaxies as the Universe was just being formed after the Big Bang, Solar Orbiter captures the live eruptions and ejections from our own star, the effects of which can be felt on Earth in the form of geomagnetic storms. And Gaia's ambitious star map gives us a view of our own Milky Way's disc and how it is revolving in space. So how are these diverse images made and what are the technical challenges involved?

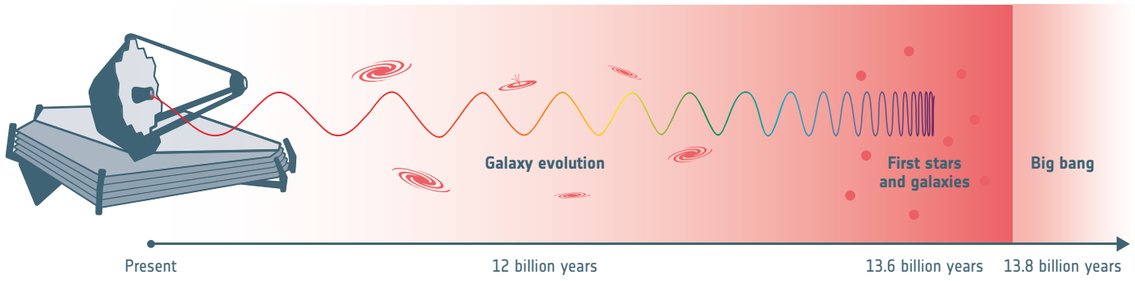
This image reveals previously invisible areas of star birth in the Carina Nebula. It was captured by Webb's instruments in infrared light by the Near-Infrared Camera (NIRCam) and Mid-Infrared Instrument (MIRI). Webb is an international partnership between NASA, ESA and CSA.

WEBB'S INFRARED VISION

Studying the physical composition of celestial objects:
Webb has four instruments on board, all of which detect infrared light from faraway objects in the Universe.



Looking back in time:
The light from galaxies that are billions of light-years away travels to us through space that is expanding. This expansion stretches the light's wavelength into the infrared allowing Webb to see light emitted by some of the very first stars and galaxies.



Flying close to the Sun

The highest-resolution image ever made of the Sun and its outer atmosphere, or corona, was taken this year by the ESA/NASA Solar Orbiter spacecraft. The picture was taken as the spacecraft crossed directly between Earth and the Sun at a distance of around 75 million km from each.

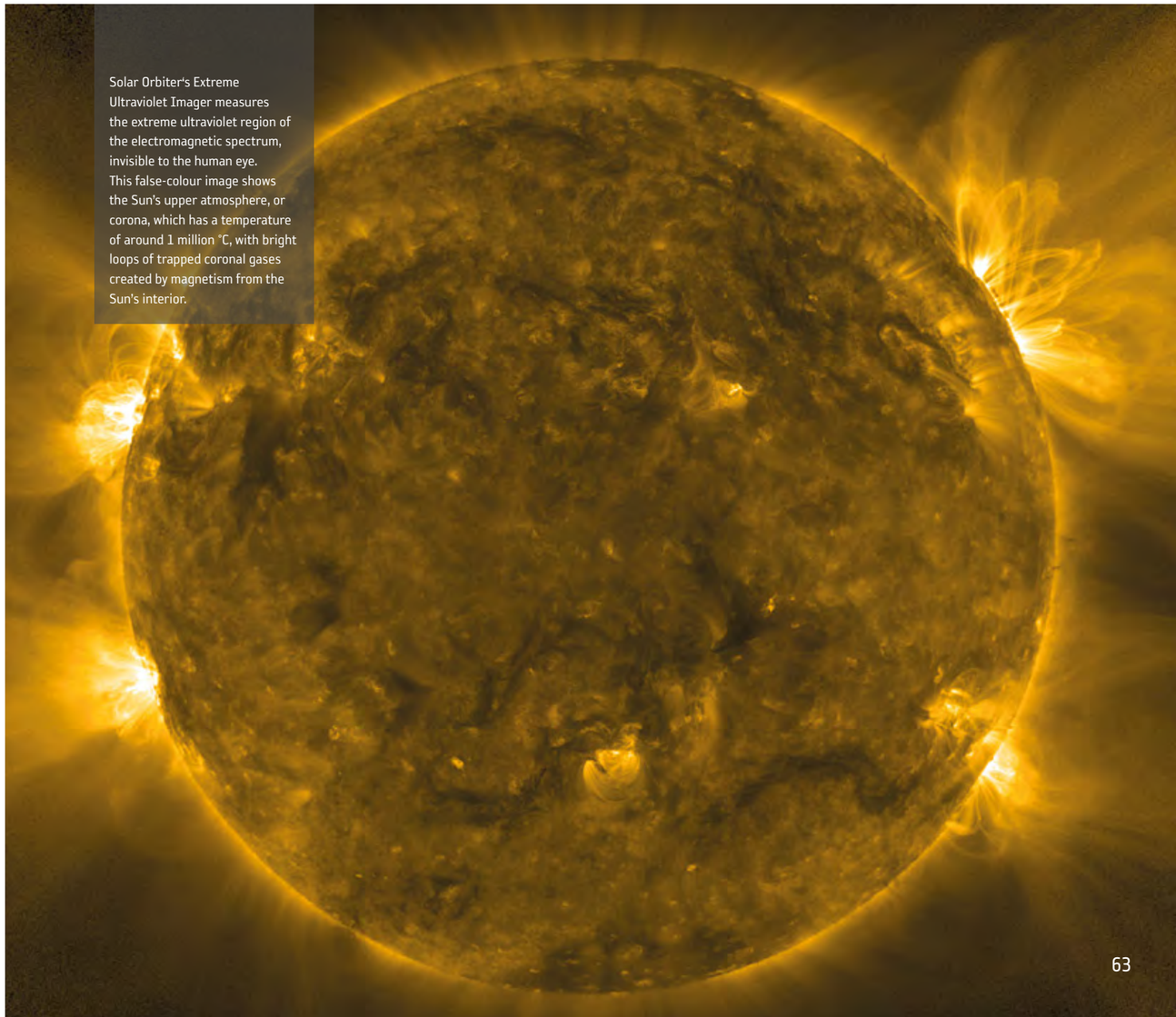
The spacecraft then had an even closer encounter – reaching its closest distance to the Sun, or perihelion point – about 42 million km from the Sun's surface. From that vantage point, it produced the image shown opposite. Both images were 'snapped' by the Extreme Ultraviolet Imager (EUI).

Of course, 'snapped' doesn't come close to describing the complex planning and processing required to obtain these images, involving the team of Solar Orbiter operations scientists and the team of heliophysicists behind the 10 instruments on board the spacecraft. The mission's instruments fall into two categories: remote-sensing instruments (which observe the Sun's surface) and in-situ sensors (which measure conditions around the spacecraft). Anik De Groof, Science Operations Scientist for ESA's Solar Orbiter Science Ground Segment, explains, "Our science objectives require all 10 instruments to work together. We have to coordinate the measurements, so we get one data set that is tailored to a specific science objective."

The perihelion point is important because it's also where Solar Orbiter is closest to the origin of the solar wind. David Williams, Science Operations Scientist for Solar Orbiter, says, "Many of Solar Orbiter's instruments are designed to work in pairs, so we can make the connection between outflows or eruption events from certain areas of the Sun and the measurements of electrons and protons in the solar wind as they pass the spacecraft. This means we can build up a much better model for how the gas that leaves the Sun's corona eventually flows out into the Solar System – and can also be detected at the Earth."

Due to its complex trajectory, downloading data from the spacecraft's onboard computer is one of the mission's challenges. Anik says, "We do not have a direct contact with the satellite all the time and during the contact periods downlink rates are limited. So, when the spacecraft is very far from Earth, data have to be stored on board for weeks or even months until we can download it to an Estrack ground station. From there, the data are sent to ESOC in Germany, and then passed to the instrument teams to process, decode and decompress the images and other measurements." Anik adds, "Positioning the spacecraft to capture an exact region of the Sun is also a challenge for this mission. All instruments point in the same direction and some have a very small field of view. To create the image of the Sun in high resolution, we had to create a mosaic of 25 separate images, so it is a complex process."

Solar Orbiter observes the Sun's behaviour in real time, both at the Sun's surface and at the spacecraft. In this respect it is much more immediate than data from Gaia or Webb. David says, "This is another one of the challenges because we have to make sure we get the corresponding measurements of the solar wind from Solar Orbiter's in-situ sensors at exactly the time we expect it to arrive at the spacecraft, after leaving the source region observed at the surface. This also requires complex calculations and planning the commands that we send to the satellite."



Solar Orbiter's Extreme Ultraviolet Imager measures the extreme ultraviolet region of the electromagnetic spectrum, invisible to the human eye. This false-colour image shows the Sun's upper atmosphere, or corona, which has a temperature of around 1 million °C, with bright loops of trapped coronal gases created by magnetism from the Sun's interior.

Five years in the making

The goal of ESA's Gaia mission, which was launched from Europe's Spaceport in 2013, is to create the most accurate and complete multi-dimensional map of the Milky Way. This means mapping not only the position of stars spatially in three dimensions but also, by making repeat measurements of the same stars, showing their velocity and direction. According to Timo Prusti, ESA's Project Scientist for Gaia, "The really valuable thing about this Gaia data is that we provide fundamental information about astrometry, in other words: the positions and distances but also movements of stars and celestial bodies. So, we are really looking at how the stars are moving."

Both Webb and Gaia orbit around Lagrange point 2, which is 1.5 million km from Earth. But while Webb observes galaxies outside our own, Gaia is focused on the stars inside the Milky Way. As we know from walking around a big city, as opposed to seeing the layout of a city from above, viewing an object from inside makes it much more difficult to see clearly what is happening. The data represented in the images on these pages were collected between 25 July 2014 and 28 May 2017. It took five years to process the data and produce the images.

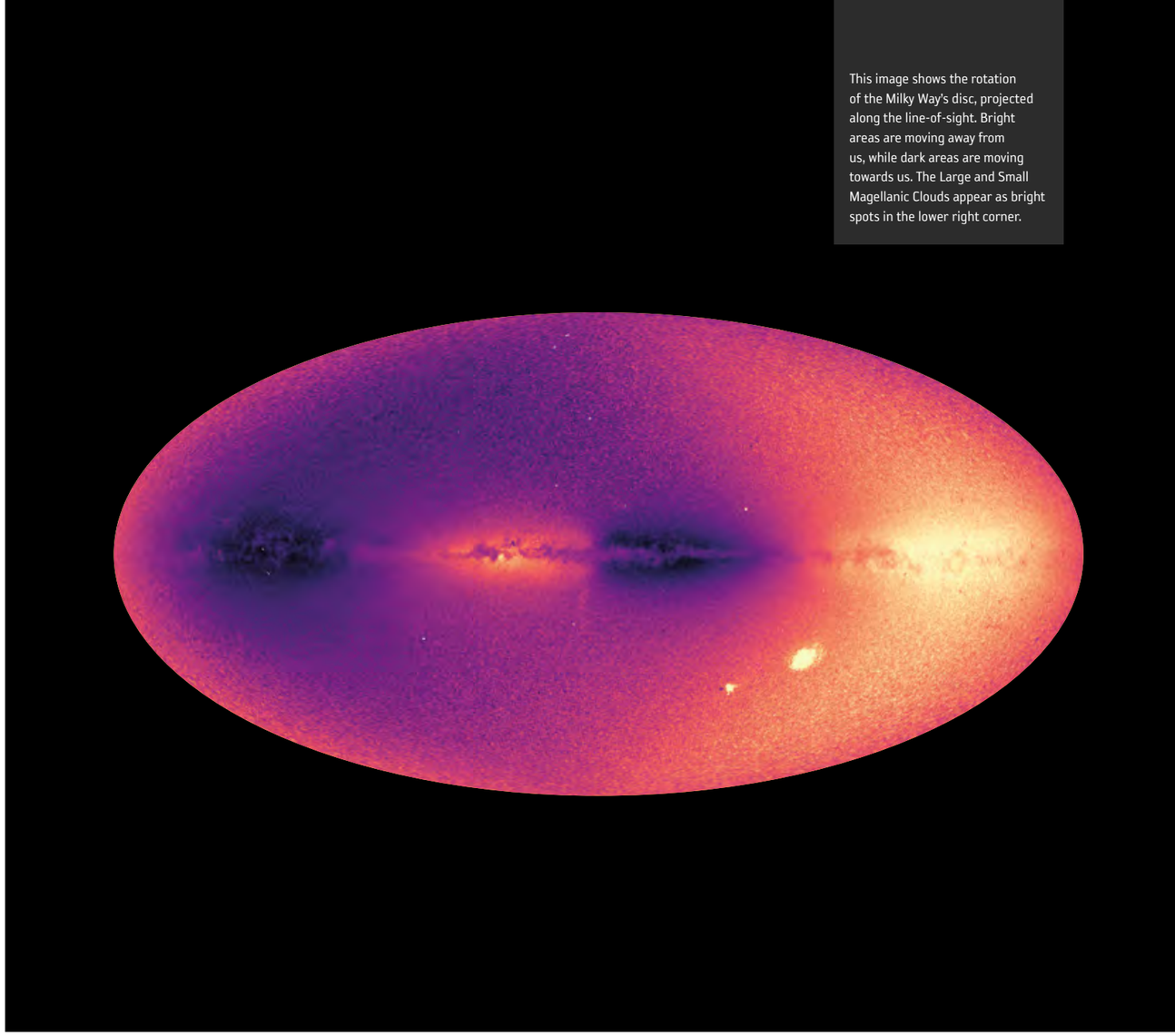
The data is analysed by a data processing and analysis consortium of 450 people, based mainly in European institutes. Timo says, "One of the challenges is managing so many people and agreeing common goals. I think it has worked well so far because the science is exciting and Gaia is really making a mark. Everyone feels they are working on something unique that will stand the test of time for decades to come."

Gaia's two telescopes have 10 mirrors of different shapes and sizes. They focus and direct light into Gaia's three science instruments, which measure distance, position and motion; brightness and colour; and chemical composition. The instruments can detect to a resolution of 1 billion pixels and every day they record 17 million observations of 40 million objects. Timo explains, "Gaia is in constant motion so we need to control the satellite's movement very precisely and move the image on the detector with exactly the same speed."

Collecting information about the stars and transmitting data back to ground stations so it can be analysed, calibrated and used to create images and maps, is a complex process. "The sheer volume of data we generate is both impressive and challenging," says Timo. "Gaia is by far the biggest user of ESA's deep space network in terms of tracking time because we transmit so much data to Earth. We typically need five years to convert the telemetry into products and ensure everything is calibrated, so it's a massive operation."

While the Gaia spacecraft is due to end its active mission in about 2025, the data gathered until that time will continue to be studied long afterwards. A fourth data release is already being processed and is scheduled for release in around 2025, with the final data release in 2030.

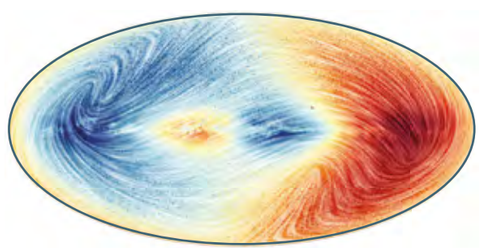
> **"The science is exciting and Gaia is really making a mark. Everyone feels they are working on something unique"**



This image shows the rotation of the Milky Way's disc, projected along the line-of-sight. Bright areas are moving away from us, while dark areas are moving towards us. The Large and Small Magellanic Clouds appear as bright spots in the lower right corner.

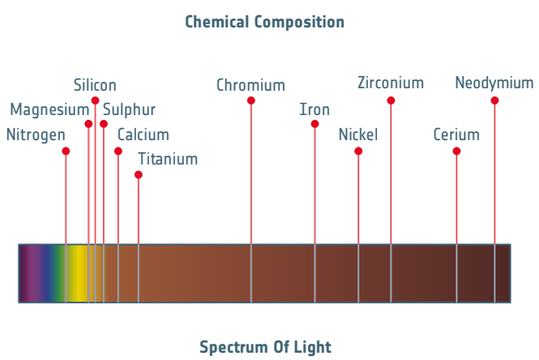
HOW GAIA CREATES A MULTI-DIMENSIONAL MAP OF THE MILKY WAY

This sky map shows the movement towards and away from us of around 26 million stars in the Milky Way. It is one of the maps that Gaia can create using the techniques shown on the right.



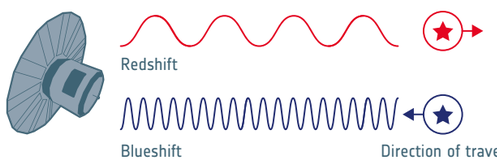
SPECTROSCOPY

What do light and radiation from objects tell us about their physical composition?



DOPPLER SHIFT

Light is compressed or stretched as the object moves towards or away from us.

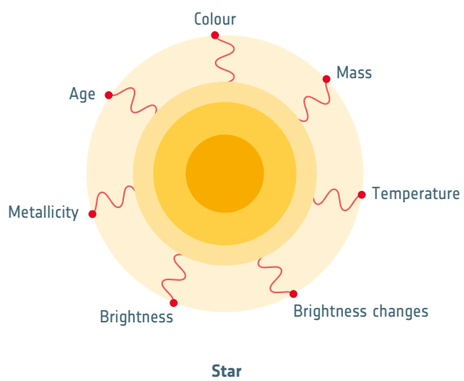


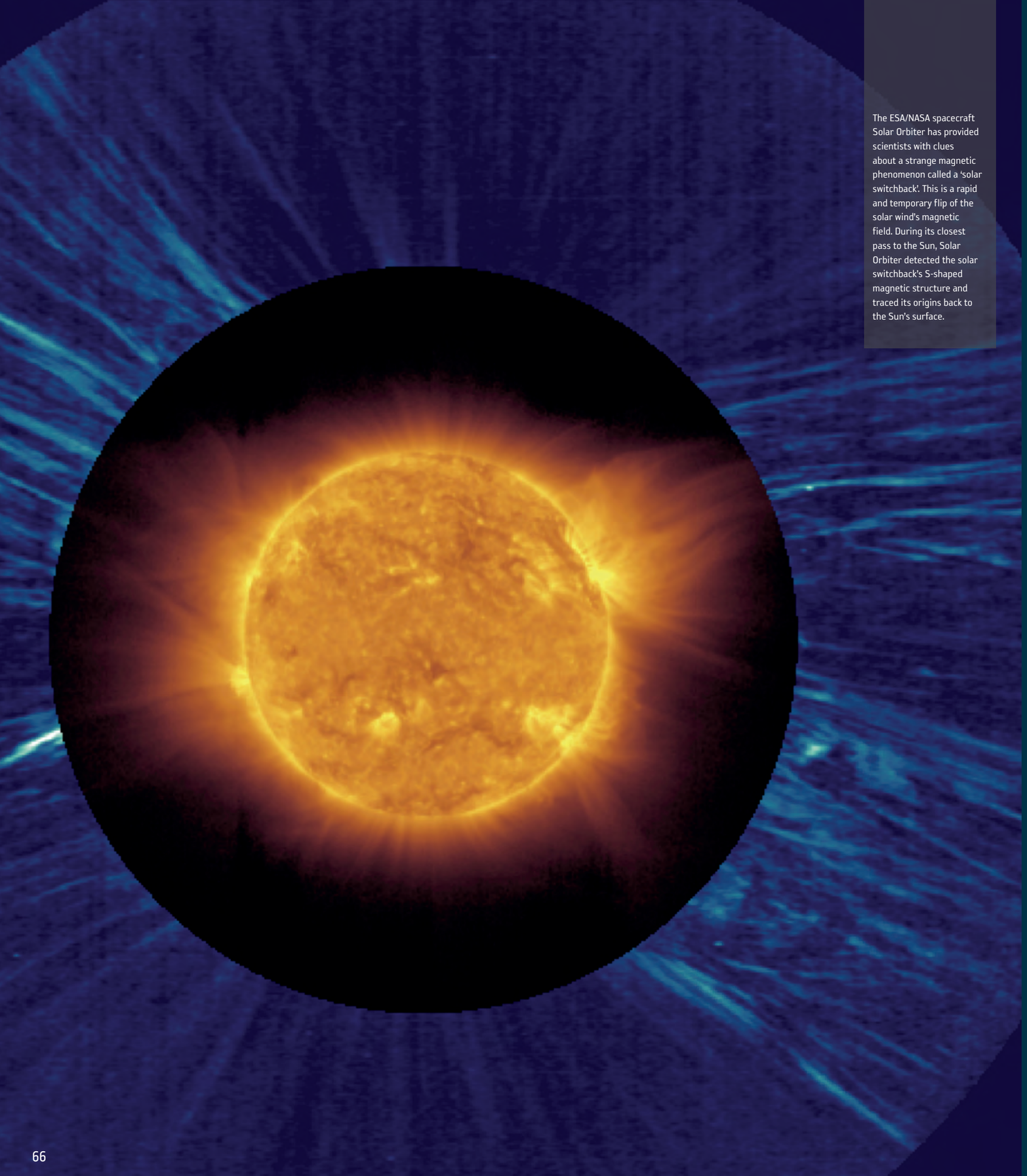
ASTROMETRY

Precise measurements of the positions and movements of stars.

PHOTOMETRY

The measurement of light, in terms of its perceived brightness to the human eye.





The ESA/NASA spacecraft Solar Orbiter has provided scientists with clues about a strange magnetic phenomenon called a 'solar switchback'. This is a rapid and temporary flip of the solar wind's magnetic field. During its closest pass to the Sun, Solar Orbiter detected the solar switchback's S-shaped magnetic structure and traced its origins back to the Sun's surface.

SELECTED HIGHLIGHTS

August to October 2022

From flooding to hurricanes, extreme weather events connected to climate change were felt by everyone.

In August, while many parts of Europe experienced drought and heatwave temperatures, torrential monsoon rains triggered the worst flooding in Pakistan's recent history. The Copernicus Sentinel-1 satellite provided data for maps used to support relief efforts. Many villages across the country were washed away and millions of people were in desperate need of assistance.

In many areas of space activities, ESA's achievements and progress were wide-ranging this quarter. Hubble continued to deliver scientific surprises with a superbly detailed image of a spiral galaxy 300 million light years away, while Solar Orbiter probed the magnetic mysteries of the Sun.

The successful launchpad tests of the central core of Europe's new Ariane 6 launcher were a milestone achievement in securing the future of Europe's independent access to space. Meanwhile, the capabilities of the next generation of Galileo satellites were tested in ESA's labs and a pilot scheme for space-enabled broadband was evaluated.

Final preparations for the launch of Artemis I were completed. With ESA's European Service Module in place, ESA's Estrack network of deep space antennas was readied to support six CubeSats set to be dispersed during Orion's flight. Artemis I launched on 16 November.

PAKISTAN FLOODS

Monsoon floods seen from space

In August, Pakistan suffered the worst flooding in its history due to monsoon rainfall 10 times heavier than usual. Thanks to its radar instrument, Europe's Copernicus Sentinel-1 satellite was able to 'see' through the stormy clouds to provide maps from space and help relief efforts. The blue and black areas on this image show the extent of the floodwaters.

SPIRAL STUDY

Hubble image helps astronomers

The NASA/ESA Hubble Space Telescope continues to provide images that get astronomers in a spin, including a view of the spiral galaxy NGC 5495. Hubble's detailed image reveals the galaxy's spiral arms surrounding a bright central area. This luminous core is created by light emitted as dust and gas fall into the supermassive black hole at the centre of the galaxy.

TO THE MOON AND BAAACK

ESA names Artemis I ‘astronaut’

In August, ESA announced that a specially trained astronaut had been assigned a seat on the Artemis I Moon mission. ESA’s woolliest astronaut, Shaun the Sheep, got ready to board the otherwise uncrewed test mission. “It’s a giant leap for lambkind,” said ESA’s Director for Human and Robotic Exploration, Dr David Parker. Fans have been following Shaun’s training through ESA blog posts.

ESTRACK SUPPORT

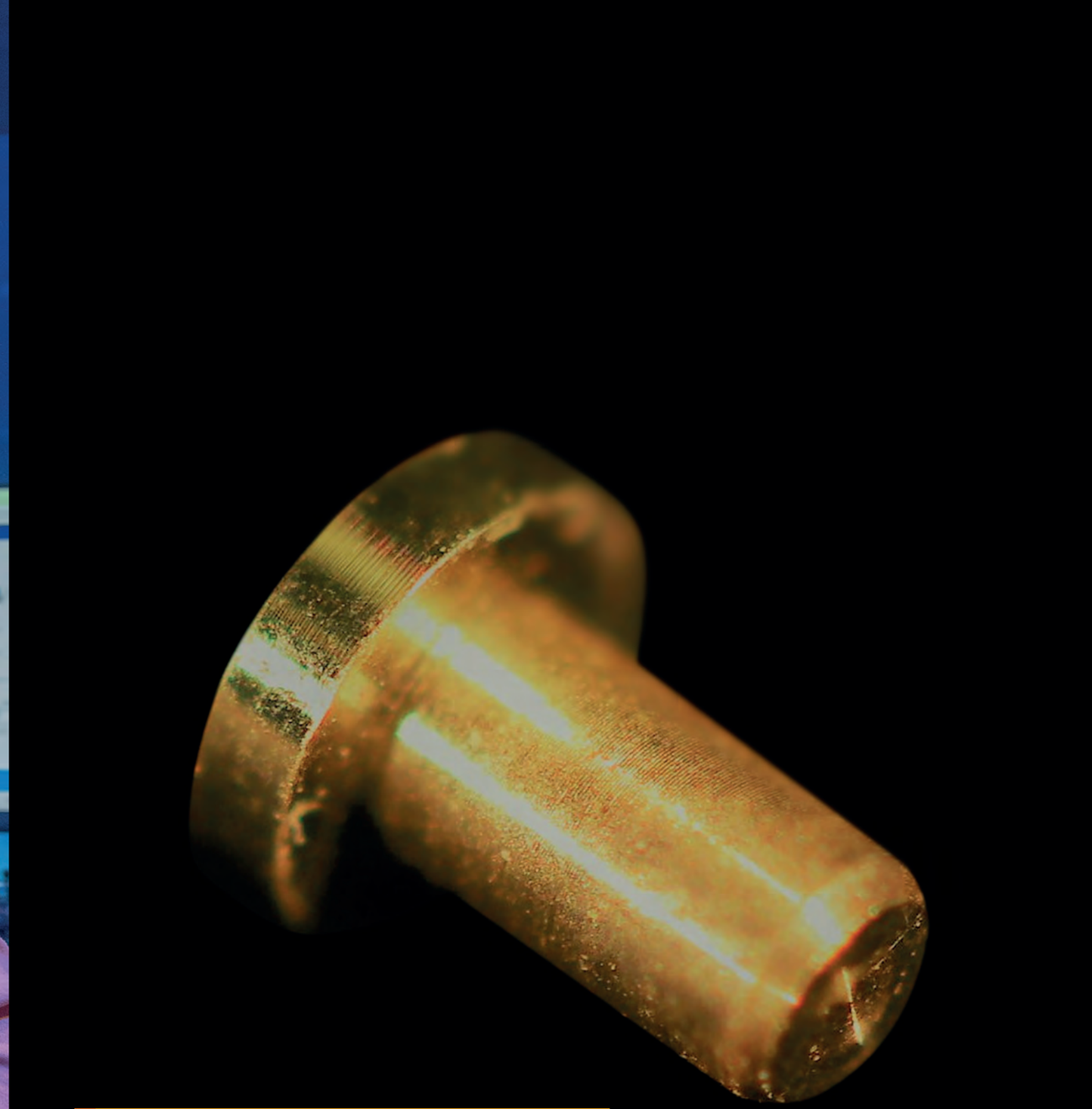
Tracking Orion’s CubeSats

NASA’s Orion spacecraft will disperse 10 CubeSats into orbit – their missions are to study the space environment, from asteroids to space radiation, while demonstrating new technologies for future missions. Europe’s Estrack deep space antennas and the Goonhilly Earth Station in the UK will play a key role by determining trajectories for six of the CubeSats and receiving their data.

A PEEK INTO THE FUTURE

A digital twin for ESRIN

ESA Φ-lab (phi-lab) has developed a 'digital twin' of the agency's ESRIN establishment. Seen through a virtual reality headset, this immersive experience shows how combining data from sources such as drones and ground sensors can provide a real-time picture of a location, including its air quality and vegetation health. A Living Planet Symposium visitor is shown here 'virtually exploring' ESRIN's olive groves.



GOOD AS GOLD

Gold standard testing at ESTEC

This gold pin is no bigger than the tip of a pencil, yet its resistance to corrosion makes it a key component of ESA's low-Earth orbit simulator (LEOX) at ESTEC in the Netherlands. This facility tests how the candidate materials for spacecraft can withstand atomic oxygen. Such highly erosive oxygen atoms make up most of Earth's outer atmosphere and are a hazard for satellites.

ASSEMBLING ARIANE 6

Launchpad tests of new rocket complete

An exciting summer of technical milestones in the development of ESA's new Ariane 6 launcher culminated in the horizontal assembly of the rocket's central core. Once complete, it was carefully transported to the launchpad at Europe's Spaceport in French Guiana and lifted upright. This was followed by 'combined tests' – a kind of launch rehearsal that successfully validated the complete system.

GALILEO NEXT GENERATION

Upgrade on the ground

This summer, as the latest pair of Galileo satellites entered service, improving positioning accuracy and data delivery of the Galileo system, the corresponding ground segment also underwent an upgrade to prepare for Galileo Second Generation. Seen here is the Galileo Sensor Station on desolate Jan Mayen Island in the Norwegian Arctic. Galileo's Sensor Stations are essential to maintaining the metre-scale accuracy of the Galileo system, currently the world's most precise.

ASTEROID IMPACTORS

International collaboration

On 27 September, NASA's Double Asteroid Redirect Test (DART) spacecraft struck the 160-m diameter asteroid Dimorphos at 6.1 km per second. This was humankind's first test of the 'kinetic impactor' method of planetary defence. ESA's Hera spacecraft will launch in 2024 to gather important information, such as the size of DART's crater, the mass of Dimorphos, its make-up and internal structure.

COMMERCIALLY CONNECTED

ESA tests next-generation networks

ESA has teamed up with OneWeb, the University of Surrey, and the IT and business services company CGI, to test a space-enabled broadband network. This pilot project linked satellites with ground-based 5G mobile networks to maximise broadband coverage. In the future this technology could provide high-bandwidth global connectivity for everything from remote working, tele-education and e-commerce, to driverless cars.

PROTECTING SPACE SERVICES FROM CYBER RISK

As the risk of cyberattack increases, ESA is developing two new security capabilities to protect critical space assets and support the wider community.

Society is more vulnerable to cybersecurity threats than ever before as confirmed by the Global Risks Report 2022 from the World Economic Forum (WEF). The WEF report states that malware and ransomware attacks are increasing at a much faster rate than society can effectively prevent or respond to. For ESA, cyber resilience is an ongoing project and accelerating the agency's response to cybersecurity risks is part of Agenda 2025.

Europe's space infrastructure – satellites in orbit supported by sophisticated facilities on the ground – provides digital services that have become indispensable to our everyday lives, including satellite navigation, data relay systems, communications, internet access, information about the weather and climate, as well as advances in medical science. The satellites that ESA develops and operates are too important to our lives to leave exposed to cybersecurity risks.

Currently, the top five cybersecurity threats in the EU are ransomware, malware, cryptojacking (using hacked computers to mine cryptocurrency), email-related threats, and threats against data. This is according to the Threat Landscape 2021 report by the European Union Agency for Cybersecurity (ENISA), whose mission is to achieve a high common level of cybersecurity across Europe.

The report, which covers the period April 2020–July 2021, highlighted some worrying trends: ransomware is the prime cybersecurity threat in the EU and the average ransom demand has doubled; email attacks (such as phishing or spam) have increasingly exploited the Covid-19 pandemic as a means to dupe email recipients; and non-malignant incidents such as human error and system misconfiguration were

Europe's space infrastructure provides digital services for our everyday lives. As the level of cybersecurity threat increases, it is more important than ever to have systems in place that detect threats early and ensure continuity of services.

exacerbated by the pandemic in 2020–21. Disinformation and the spread of fake news – undermining democratic processes – plus distributed denial of service (DDoS) and supply-chain attacks are also on the list of prime threats in the EU.

In the context of the space community, it's not just the satellites in orbit that need protection from cybersecurity threats, but the entire infrastructure that supports them from the ground. ESA's network of ground stations, known as Estrack, provides more than 15 000 hours of tracking support a year to more than 20 space missions, which makes it a potential target for hackers. Data centres that process mission data are also possible targets, as are the complex systems that form the backbone of the Galileo navigation system. And there is much more.

In a recent example, an ESA ground station experienced a DDoS attack aimed at rendering it unable to relay data. No lasting damage was caused, but this type of incident underlines how important it is to ensure that space systems are protected against those with malicious intent.

What is ESA doing about it?

ESA and its partners in the space industry have an important role to play in the development of new cybersecurity solutions aimed at reducing vulnerabilities and enhancing cyber resilience in space-based applications. "Europe's space infrastructure has become increasingly important in the past 10 years – it's clear that space-based services are crucial to our economy, to security and in many other ways that impact European citizens. We cannot underestimate this risk," says ESA's Head of Security and Cybersecurity, Massimo Mercati.

ESA has responded to this urgent need by launching the development of two dedicated facilities for cybersecurity: the Security Cyber Centre of Excellence (SCCoE) and the Cyber-Security Operational Centre (C-SOC).

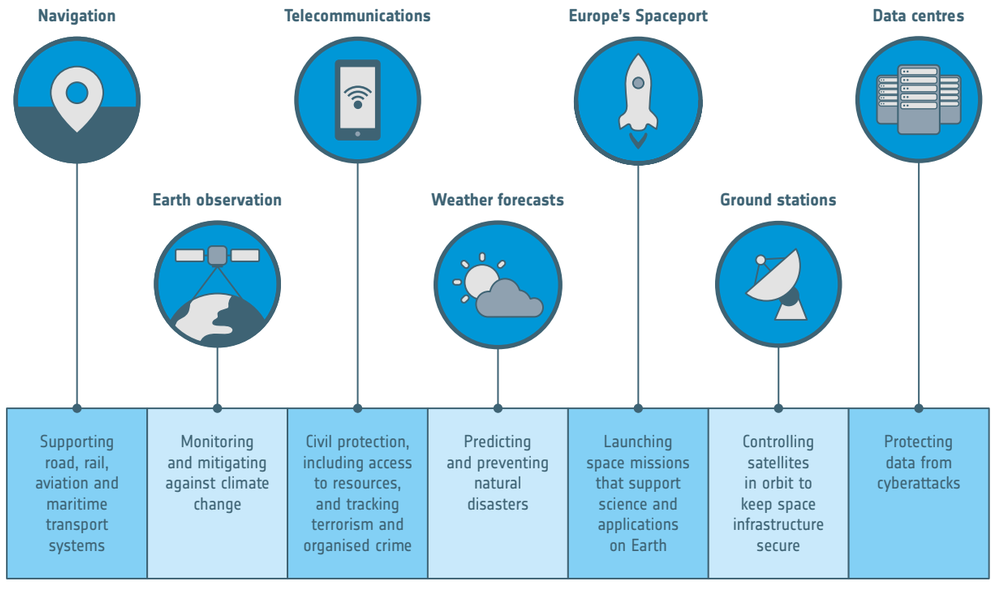
Security Cyber Centre of Excellence

The SCCoE will support the design and development of security for Europe's space systems by providing a realistic, emulated environment that can be tailored to any space mission, enabling hardware and software to be tested and validated against cyber threats. This will ensure that cybersecurity requirements are met and ESA's security operating procedures are validated. The centre, which will be based at ESA's ESEC establishment in Redu, Belgium, will enable collaborative cyber information sharing, cybersecurity training and education, as well as risk analysis of critical systems.

Continuity of service is essential for ESA's spacecraft operations. A serious cyberattack could cause a loss of service and connectivity from the ground. The Cyber-Security Operational Centre will prevent such a scenario from happening.

SERVICES PROVIDED BY SPACE INFRASTRUCTURE

Space programmes provide all kinds of services that are essential for society on a daily basis. Protecting space infrastructure from cyberattacks ensures continuity of these services.



The aim of the SCCoE is to support the wider community as well as European space infrastructure and services. Its tool kit will be made available to ESA Member States and partner institutions. The centre is scheduled to become operational in 2024 and Massimo has been appointed as its head. He says: "The centre will lead a set of measures to balance the threat landscape against space infrastructure and determine what action should be taken in the event of an attack."

Cyber-Security Operational Centre

The C-SOC will be split across two locations: at ESA's ESEC establishment it will mainly deal with the corporate IT infrastructure and other infrastructure not directly linked with spacecraft operations; while at ESA's ESOC establishment in Darmstadt, Germany, it will work closely with ESA's Network Operations Centre and will deal mainly with the ground segment and spacecraft operations. C-SOC's system will be able to detect malicious interference and recognise telemetry that has been tampered with or an anti-satellite attack – and will immediately raise the alarm. All ESA activities, be they operational or R&D activities for cybersecurity will be monitored by C-SOC. Support will be provided to ESA Member States through an innovative cyber threat intelligence sharing platform.

One reason for locating the C-SOC at two sites is to ensure business continuity, according to Octave Procope-Mamert, ESA's Head of Mission Operations IT at ESOC. "It's essential for ESA's spacecraft operations to be always available. In a worst-case scenario, a serious cyberattack could cause a loss of service and connectivity from the ground. If this happened, the spacecraft would be put in safe mode, before we re-establish the service. What the C-SOC will help us to do is prevent such a scenario from happening and demonstrate to our partners and industry that we are capable of handling the increasing threat that we observe worldwide in terms of cyber criminality."

The centre, which will also be operational from 2024, is being developed by a consortium of 19 European companies led by a prime contractor, the aerospace, defence and security company Leonardo, based in Italy. The consortium will design, implement, build, validate and operate the centre under the technical responsibility of ESA's Security Office. C-SOC's development is being supported through ESA's General Support Technology Programme, funded by Member States.

SCCoE and C-SOC together will provide ESA, its Member States and partners with a tool kit of cyber resilience capabilities that will be unique in Europe. The two centres support the objectives of ESA's Agenda 2025, which states the importance of ensuring security and protection of European space assets

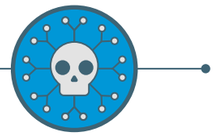
INCREASED VULNERABILITY

Cybersecurity threats are increasing in scale and diversity and involve a growing number of state and non-state actors. They can disrupt almost all areas of society, from our hospitals and power grids to government services and businesses, posing a risk to citizens and economies.

Space-based services are crucial to our economy, to security and in many other ways that impact European citizens. ESA's two new dedicated capabilities for cybersecurity will address cyber risk.

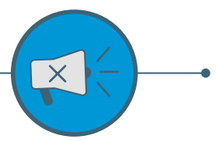
Through the 'Internet of Things', everyday items are connected and are becoming vulnerable to attack

European economies are increasingly dependent on satellites and their services



Hacking attacks are on the rise: on satellites, hospitals, power grids, water supplies, telecom networks and businesses

Cyberattacks are among the top 10 global risks, costing some €530 billion worldwide annually



Cyberattacks threaten democracy with disinformation campaigns, false/manipulated scientific data and fake news

'Denial of service' attacks & frequency jamming can come from anywhere, putting spacecraft, companies and government services at risk

from threats such as cyberattacks. "Both these centres will be up and running in 2024 and they will protect ESA's systems and services. In the medium term, SCCoE will become an important centre for cybersecurity research and development. And the C-SOC will enhance ESA's preventative-reactive security measures," according to Massimo. "My vision is to transform ESEC into a sort of European Silicon Valley for cybersecurity."

Supporting space-based services

Any complex space programme that aims to deliver a service to Europe needs to be protected with the basic requirements of cybersecurity. The ESA Security Office supports all ESA directorates in order to meet this requirement. It provides certification and accreditation security engineering to all major space programmes to assure ESA's Member States of the robustness of the systems developed by the agency.

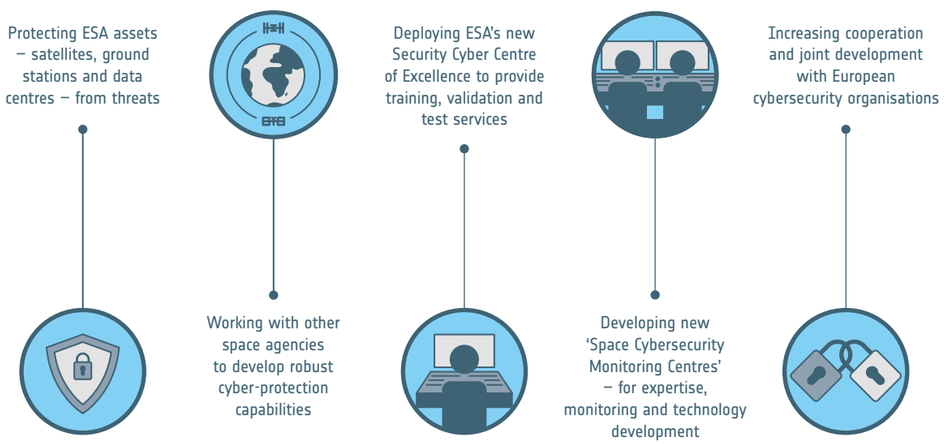
These new cybersecurity capabilities will work with ESA's technology, operations, telecommunications, navigation and IT directorates to develop secure systems in a secure environment. "This job is very difficult because hackers and terrorist groups are also extremely specialised. They use the same technology as we do and use this technology to attack, so it's a never-ending battle between the good and the bad," says Massimo.

Services for Europe

Towards the end of 2021, ESA signed an agreement with the European Defence Agency (EDA) to deepen their already close cooperation on cyber resilience, aiming to strengthen Europe's capacity to protect systems and networks critical for space. This will build on the work of the Cyber Ranges Federation project, led by the EDA and supported by ESA. The project takes the form of a practical exercise to show how cyber resilience and training at the national level can be greatly enhanced by sharing information and pooling cyber protection capabilities. Massimo adds, "Just as ESA has collaborated closely with the European Commission on key civil space systems such as Galileo and Copernicus, we are also developing cybersecurity principles to protect space infrastructure. There is a strong collaborative impetus to ensure Europe's civil infrastructure is protected from the threat of cyberattack."

ENSURING CYBER RESILIENCE

ESA is committed to protecting its assets in space and on the ground, as well as those of its partners and Member States. We are taking the following actions to ensure cyber resilience.



annual report

FOCUS ON PROGRAMMES ACTIVITIES AND DIRECTORATES

The Report is published in accordance with the terms of the Convention for the establishment of the European Space Agency, Article XII 1(b), which require the Director General to make an annual report to the Council.
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Anna Rathsman, Chair of the ESA Council

FOREWORD

The 2022 ESA Annual Report offers the opportunity to look back and take stock of what has been achieved in the course of the past year, both from a technical and a non-technical standpoint. The following pages contain a wealth of relevant information and bear testimony to the excellent work of the Agency.

This was a year full of important events, developments and successes for ESA. It was also marked by a difficult geopolitical context, which both had and continues to have serious implications for the space sector in general and the Agency in particular.

Overall, ESA is following the high-level orientations set out in Agenda 2025, whose implementation is being continuously pursued, monitored and reported on. The activities concerned are being carried out in partnership and coordination with Member States. It goes without saying that they are also fully in line with ESA's Convention.

The Council meeting at ministerial level in November was a major highlight for the Agency in 2022. ESA not only secured a record budget of 16.9 billion euros, but also received full political support for its course of action. Moreover, Member States aligned and announced their approaches in key domains such as space transportation.

Political backing had already been secured at the Space Summit in Toulouse earlier in 2022, with a warm welcome also being given to the Accelerator and Inspirator concepts and agreement reached on setting up a High-Level Advisory Group on Space Exploration, whose final report will be an essential input for upcoming decisions.

Both meetings also demonstrated the close and growing relationship between ESA, the European Union and other European partners. The European Union remains a crucial partner for joint space projects. ESA activities in the context of the EU Secure Connectivity initiative, now set to develop into yet another flagship space programme, provide a clear example of this.

So ESA is well equipped for the future. With substantial programmes and missions, solid political backing and a long-term vision based on partnerships with European and national entities, the Agency stands ready to exploit the enormous untapped potential of space in order to tackle the urgent and unprecedented societal, economic and security challenges Europe is facing at the present time.

Anna Rathsman
Chair of the ESA Council

MANAGEMENT STRUCTURE

DG
Director General
Mr Josef Aschbacher
HQ-Bertrand

D/DG
Director General's Services
Mr Josef Aschbacher
HQ-Bertrand

D/ELI
Directorate of European, Legal and International Matters
Mr Eric Morel de Westgaver
HQ-Bertrand

D/SCI
Directorate of Science
Mr Guenther Hasinger
ESAC

D/HRE
Directorate of Human and Robotic Exploration Programmes
Mr David Parker
ESTEC

D/STS
Directorate of Space Transportation
Mr Daniel Neuenschwander
HQ-Daumesnil

D/EOP
Directorate of Earth Observation Programmes
Ms Simonetta Cheli
ESRIN

D/NAV
Directorate of Navigation
Mr Francisco-Javier Benedicto Ruiz
ESTEC

D/TIA
Directorate of Telecommunications and Integrated Applications
Ms Elodie Viau
ECSAT

D/TEC
Directorate of Technology, Engineering and Quality
Mr Torben Henriksen (Acting)
ESTEC

D/OPS
Directorate of Operations
Mr Rolf Densing
ESOC

D/CIP
Directorate of Commercialisation, Industry and Procurement
Ms Geraldine Naja
HQ-Bertrand

D/HIF
Directorate of Internal Services
Mr Jean Max Puech
HQ-Bertrand

SCIENCE AND EXPLORATION

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HUMAN SPACEFLIGHT AND ROBOTIC EXPLORATION

Terrae Novae – Expanding Europe's Space Exploration horizons

ESA's newly selected astronaut candidates of the class of 2022 arrived at the European Astronaut Centre in Cologne, Germany, on 3 April 2023 to begin their 12-month basic training.

The European Exploration Programme (E3P) created in 2016 integrates Europe's space exploration ambitions in Earth orbit, the Moon and Mars. The programme was named *Terrae Novae*, taken from the Latin for new worlds, and refers to the three exploration destinations, while also symbolising new discoveries, opportunities and inspiration. In mid-2022, the Terrae Novae 2030+ strategy roadmap was published, providing a plan for possible new missions and capabilities well into the next decade.

2022 was a year of achievement and challenges. On board the International Space Station (ISS) the back-to-back missions of Matthias Maurer (Cosmic Kiss) and Samantha Cristoforetti (Minerva) provided high-impact scientific and educational benefits through Europe's high-visibility contributions to the ISS partnership. Cristoforetti became the first European woman to command the ISS on 28 September and also conducted an extra-vehicular activity (EVA) on the Russian segment. The European Robotic Arm (ERA) was commissioned in April, while the commercial Bartolomeo external platform on Columbus hosted its first commercial payloads.

Scientific research in the SciSpacE (Science in the Space Environment) programme strand continued throughout the year, including life and physical science investigations on the ISS, two parabolic flight campaigns and the TEXUS 57 sounding rocket flight. At the end of 2022, 278 distinct investigations were part of the SciSpacE experiment pool with 1,516 individual scientists from 37 countries involved. A recent research highlight was the observation of brain structure changes in astronauts after ISS missions which may help understand spaceflight-associated neuro-ocular syndrome, a challenge for long-duration spaceflight.

The successful flight of the uncrewed Artemis-1 cis-lunar mission in November–December including the first European Service Module (ESM) was an important milestone for Terrae Novae. The ESM provides essential power and propulsion for the Orion crewed spacecraft flying to cis-lunar space. With production under way of the first six ESMs involving firms from ten Member States, Europe is firmly on the critical path for the Artemis programme. In return for delivering ESMs to NASA, ESA secures access for both our science, technology and astronauts to both the ISS and the lunar Gateway. The second ESM for Artemis II (the first crewed mission) was delivered in 2021 and began integration with the crew capsule in 2022.

The Gateway will be humanity's most distant research outpost and a permanent space-dock for missions to the lunar surface throughout the next decade. ESA is contributing around half of the Gateway infrastructure. In 2022, detailed design and the start of manufacture of both the HALO Lunar Communications System and the International Habitation Module began. The concept for the European System Providing Refuelling, Infrastructure, and Telecommunications (ESPRIT) European Refuelling Module (ERM) was expanded to provide enhanced volume at the request of NASA as well as external viewing windows that will both provide an incredible view of the Moon and support vehicle operations.

The Russian invasion of Ukraine in February led the ESA Council to discontinue cooperation with Roscosmos on both the ExoMars 2022 Rosalind Franklin mission (which was ready for launch in September) – and the Luna-25 and Luna-27 missions. Following a rapid assessment of alternatives in order to secure the Rosalind Franklin life-search rover, a new approach using a European entry descent and landing module plus enhanced cooperation with NASA was approved by Ministers at the Council meeting at ministerial level, CM22 in Paris in November.

Meanwhile, the effort on the PROSPECT lunar ice drill and volatile detector for the Luna-27 mission was redirected to an already identified NASA CLPS (Commercial Lunar Payload Services) mission of opportunity, while work continued at speed on multiple other lunar surface science instruments for flight with NASA and other international partners. A key step forward in lunar commercialisation was achieved with the agreement for ESA to buy services from the SSTL (Surrey Satellite Technology Ltd) Lunar Pathfinder telecom satellite and a parallel agreement for NASA to launch the spacecraft as a rideshare on a CLPS mission.

ESA's fast and flexible response to this unprecedented challenge demonstrated the resilience of the exploration envelope programme through a combination of increased European autonomy and strong international partnerships, notably with the US. At the ESA Council meeting at ministerial level (CM22), vital decisions were also taken to continue existing projects and secure scientific goals through the ISS, Gateway and Mars Sample Return, while simultaneously meeting Europe's international obligations. Further, the go-ahead for the first Argonaut European Large Logistic Lander (EL3) will provide an autonomous European capability to land large payloads on the Moon. Europe will therefore be able to lead its own lunar missions but also contribute to Artemis human Moon exploration.

Towards the end of what was a remarkable year, Europe's new generation of space explorers was announced at CM22. Five career astronauts, 11 members of the astronaut reserve and one astronaut with a disability were introduced to the press. They will assume their respective duties in 2023.

APPLICATIONS

Earth Observation: page 96

EARTH OBSERVATION

Copernicus

Copernicus Sentinels missions continue to provide valuable data and information on the state and health of the planet. More than 650,000 users have registered on the open access hub and 436 PB of data have been downloaded since the start of operations with more than 100 million ESA-generated Earth observation data products available.

Following July's end-of-mission announcement for Sentinel-1B, progress was made on the analyses on a de-orbiting strategy.

Regarding the Sentinels first generation, the Sentinel-4 proto-flight model calibration and validation campaign was completed successfully, and the green light was given for instrument delivery and integration on Meteosat Third Generation (MTG).

ESA analysed options for addressing the shortfall in available European Union budget and, together with the European Commission, proposed a way forward in the form of a programmatic decision point in 2024 which would allow the continuation of work on the development of the six Expansion missions and the start of their respective Phase C/Ds.

Regarding Sentinels Expansion mission development, preliminary design reviews were successfully conducted for all six missions. Achievement of Technical Readiness Level-6 was confirmed for the vast majority of critical technologies. Thanks to the ESA Project teams' proactive management and cooperation with industry, it was possible to maintain the nominal schedule for all missions.

The service contract with Arianespace for the launch of five Sentinels in the 2024–2026 period was signed at the end of November.

The Sentinels Next Generation Sentinel-1 NG and Sentinel-3 NG Topo Phase A/B1 parallel studies made considerable progress during the year, with results reflected in the Copernicus Space Component-4 (CSC-4) Phase 2 programme proposal.

The Sentinel Application Platform (SNAP) toolbox has been widely adopted by the Earth observation science, applications, and education communities with more than 1 million downloads having been made to date.

The oversubscription of the Copernicus Space Component at CM22 demonstrates the continued support of Member States.

Earth Explorers / Science / Other Missions

The Earth Explorers in orbit continue to deliver crucial data for science, within the remit of their original scope and beyond.

For Aeolus, ESA's satellite mission to acquire profiles on Earth's winds on a global scale, the switch from the FM-B to FM-A laser was performed successfully and the mission continues to deliver crucial data for numerical weather prediction.

The success story continues for ESA's ice mission, CryoSat, with a timeseries of direct relevance to better understand climate change impacts in the Arctic, Greenland and Antarctica.

Swarm, ESA's magnetic field mission, ran smoothly throughout the year and improved versions of the Swarm Level-1 and Level-2 operational processors were successfully deployed into operations in September.

The SMOS radio frequency interference situation in Europe was considerably degraded by the geopolitical situation in eastern Europe and the Middle East. Nonetheless, ESA's water mission continues to be in excellent shape providing high-quality products to users.

Considerable progress was also achieved in 2022 with the missions in development.

For ESA's EarthCARE cloud mission, satellite integration continued throughout the year and the complete satellite is now undergoing environmental testing.

The build-up of the Biomass satellite platform in Stevenage and the instrument proto-flight model in Friedrichshafen are progressing well. The Large Deployable Reflector (LDR) on ESA's forest mission has been delivered and integrated. The satellite is completely assembled with the solar array.

On FLEX, ESA's photosynthesis mission, the Instrument Critical Design Review (CDR) and Satellite CDR were completed.

A major milestone was reached with FORUM, ESA's Far-infrared Outgoing Radiation Understanding and Monitoring mission, with the signature of the Phase B2/C/D/E2 contract.

Several milestones were reached on Harmony, the exciting new ESA mission that will comprise two identical satellites orbiting Earth in convoy with a Copernicus Sentinel-1 satellite, including a successful User Consultation Meeting in July, followed by a PB-EO decision and a sufficient subscription being obtained for FutureEO-1 Segment 2 at CM22. These allowed the Space Segment Phase B1 ITT to be released following the successful start of the instrument Phase B1 activities.

Regarding the two Scout missions in development, intense co-located engineering workshops continued for CubeMAP and substantial progress was achieved for HydroGNSS for which most units have reached Technical Readiness Level (TRL) 6.

On NGGM/MAGIC, ESA's mission to take measuring gravity from space to the next level, considerable progress was achieved in the Preliminary Requirements Review (PRR) kicked off with two industrial consortiums in mid-September.

Preparation of future missions is ongoing as planned and includes four Earth Explorer 11 candidates in Phase 0 and preparations to issue an ambitious Earth Explorer 12 Call in February 2023.

Although FutureEO-1 Segment 2 did not reach the optimal level of subscriptions at CM22, the annual funding for the envelope programme is the highest it has ever been.

ESA's EarthCARE satellite is being put through its paces at ESA testing facilities in the Netherlands – the largest satellite test facility in Europe, equipped to simulate every aspect of the space environment.

Successful MTG-I1 launch on 13 December was the result of more than 12 years of commitment and excellence on the part of ESA, EUMETSAT and the industrial teams.

Meteorological Missions

Every effort continued during the year to secure the launch of MTG-I1 on Ariane 5, with a successful launch eventually taking place on 13 December from Kourou.

As for MetOp-SG, all Satellite-A proto-flight model (PFM) platform units were integrated, as were the Radio Occultation PFM, METimage and Sentinel-5 IIM instruments. Regarding Satellite-B, considerable progress has also been made, with all instruments integrated except for the SCAtterometer. Environmental testing of the satellite is planned to start in 2023.

On 8–9 September, in the Aeolus mission and future Doppler Wind Lidar workshop, ESA and EUMETSAT representatives and experts convened to explore the successes of Aeolus, ESA's pioneering wind mission, and to discuss the scientific and operational benefits of continuing its legacy. Aeolus paved the way for the oversubscribed Aeolus-2 programme proposal at CM22.

Earth Watch Programme

The InCubed programme, which exists to promote Earth observation commercialisation efforts, achieved considerable success in 2022 with a portfolio of over 78 activities launched. InCubed-2 was also highly successful at CM22.

Regarding the TRUTHS mission, which aims to set the gold standard for climate measurements, Phase B1 was formally closed and Phase B1 extension system and design activities were started. The TRUTHS programme was approved at CM22 and subscribed to a level sufficient to allow the planned activities to be implemented.

Phase 2 Implementation of the Global Monitoring of Essential Climate Variables Climate Change Initiative (GMECV/CCI) has continued. The new climate initiative, CLIMATE-SPACE, was presented and oversubscribed at CM22.

For Altius, ESA's Atmospheric Limb Tracker for Investigation of the Upcoming Stratosphere, progress of the mission preparation was nominal in 2022 and full completion of the avionics qualification was accomplished during the summer.

Activities under the Global Development Assistance (GDA) Element are being implemented by ESA in partnership with key international financial institutions including the World Bank and the Asian Development Bank.

The Arctic Weather Satellite project continued to advance at a remarkable pace. The Preliminary Design Review was completed in early 2022 and preparations are now well advanced for the Critical Design Review to start in early 2023.

Transversal / Partnerships / International Cooperation

A major Earth observation event was the Living Planet Symposium (LPS) held in Bonn, Germany on 23–27 May 2022 playing host to over 5,000 participants from 81 countries and comprising numerous scientific sessions. The LPS had a great impact providing exposure across all areas and proved a great opportunity to present our missions and plans for the future.

The Climate Office saw the establishment of the Coupled Model Intercomparison Project (CMIP) Office at ECSAT in Harwell, which will provide an excellent instrument with which to bring climate data from space and modellers together.

ESRIN's Φ-lab proactively fostered the use of AI for Earth observation across a variety of multidisciplinary projects and use cases, in particular directly on board the Φ-sat-1 experiment.

2022 also saw the inauguration of the new EO Science Hub at ESRIN, the development of the first Green Transition Information Factory, and the consolidation of a whole new range of application domains, both scientific and policy-related.

Implementation began of the Italian "Piano Nazionale di Ripresa e Resilienza" (also known as the EO PNRR IRIDE project) after the signature of the Assistance Arrangement with Italy. This end-to-end system will consist of a constellation of small satellites with its ground operational infrastructure and service domains serving Italian public administration as well as fostering the development of new applications.

At the conclusion of the 2021 CEOS plenary meeting (1–4 November 2021), ESA took over the role of CEOS SIT Chair for a period of two years (2022–2023), succeeding Australia. In 2022, ESA organised two CEOS European Coordination meetings and the CEOS plenary.

The Earthnet Third-Party Mission (TPM) activity continues to be highly appreciated by scientists and applications developers. More than 10,000 research projects have used TPM data since 2008 and almost 1,000 new users registered in the last 12 months. Earthnet has also continued to successfully support the International Charter Space and Major Disasters.

2022 saw the first phase and kick-off of Destination Earth (DestinE) – a joint ESA/European Commission (DG CNECT) initiative. At CM22, the Digital Twin Earth programme proposal came close to reaching full subscription.

The CopLAC (Copernicus Capacity Support Action Programme in Latin America and Caribbean) and CopPhil (Copernicus Capacity Support Action Programme for the Philippines) Contribution Agreements were successfully negotiated with the European Commission (DG-INTPA) and were approved by the ESA Council. CopLAC was signed at Director General level as the first agreement with DG-INTPA in December.

Simonetta Cheli was appointed Director of Earth Observation Programmes and Head of ESRIN in Frascati, Italy, effective from 1 January. In May, the Directorate of Earth Observation Programmes was reorganised in order to accommodate new programmatic activities and to make the Directorate fit to support Agenda 2025 priorities.

Continued and intense consultation took place with Member States to prepare programme proposals for CM22 in November. At CM22, Member States stressed the strategic relevance and the importance of the Earth observation sector in supporting the climate and the environment with a 16% share of the total subscribed amount of €18.5bn going to Earth Observation (almost 90% of what was proposed).

Living Planet Symposium in Bonn, Germany. The conference was an enormous success with about 5,000 registered participants.

SPACE SAFETY AND SECURITY

- Space Safety: page 102
- Security and Cyber Resilience: page 106
- Telecommunications and Integrated Applications: page 108
- Navigation: page 110

SPACE SAFETY

ESA's Space Safety Programme is dedicated to the protection of Europe and its economies from disruption to critical space infrastructure and fostering new commercial opportunities in the European space sector. A total of €733m was subscribed to the programme at CM22, representing an increment of 68%, with Slovakia and Canada joining the programme for the first time.

The PROTECT Accelerator was defined and presented to the Space Summit and received recognition for the urgency of the topics it addresses. It will provide the actionable information and timely warnings that Europe needs to prevent damage and disruption to its economically vital space and ground infrastructure.

SPACE WEATHER

1 New Space Safety Centre inaugurated

Space weather — electromagnetic radiation and charged particles hurled into space by the Sun — can disrupt or harm satellites, astronauts and infrastructure on the ground, such as power grids. ESA's new Space Safety Centre is dedicated to mitigating the effects of space weather. Information and warnings are provided, and new tools and weather forecasting models are being developed.

2 ESA Space Weather Portal updated

The update included new capabilities, and the end-user training provided was highly appreciated, with all 100 available places booked.

3 Space Weather monitoring payloads

The Critical Design Review (CDR) of the MiniRMU (Mini-Radiation Monitoring Unit) hosted payload to fly on the Lunar Pathfinder mission was successful. Activities leading to the definition of requirements for the Aurora monitoring mission and nanosatellites for the Distributed Space Weather Sensor System (D3S) concluded successfully with very good results having been obtained. Also, two radiation monitors launched on board Eutelsat's HOTBIRD satellites, increasing the number of ESA hosted payload missions for space weather monitoring flying to four.

4 New mission name

The Lagrange mission is now called Vigil after a popular public naming campaign. Vigil is entering a new phase, following a baseline revision with a reduced set of instruments. Vigil will be the first of its kind. By keeping an eagle eye on the "side" of the Sun, the mission will give us advance warning of oncoming solar storms and therefore more time to protect spacecraft in orbit, and infrastructure on the ground.

PLANETARY DEFENCE

5 ESA's NEOCC gives the all-clear

This image from ESA's Near-Earth Object Coordination Centre (NEOCC) shows Comet Leonard in December 2021. Captured by Solar Orbiter, it shows the comet in transit and gives scientists clues as to the rate at which it ejects dust as it travels. The NEOCC monitors comets and assesses them for risk of Earth impact. In this case, there was no cause for alarm.

6 Second "Earth Trojan" asteroid

Astronomers confirmed that an asteroid discovered in 2020 is an "Earth Trojan": it follows Earth's path around the Sun. Using telescopes, including ESA's Optical Ground Station in Spain, they were able to establish that 2020 XL5 is larger than the only other known Earth Trojan. In this illustration, the two bright points near the asteroid are Earth and the Moon.

7 New Toolkit developed

ESA's Near-Earth Object Coordination Centre (NEOCC) — home to Europe's team of experts maintaining a watchful eye on potentially risky asteroids — has developed four freely available tools to better understand the small bodies scattered through our Solar System, and the risk they pose to Earth.

SPACE DEBRIS

8 International collaboration on DART/Hera

On 27 September, NASA's Double Asteroid Redirect Test (DART) spacecraft struck the asteroid Dimorphos at 6.1 km per second. A coordinated observation campaign of the DART impact and post-impact evolution of the binary system was carried out by ESA observers and significantly contributed to ground-based observations of the plume. ESA's Hera spacecraft will launch in 2024 to gather important information on the impact and comet and will demonstrate multiple novel technologies and gather important data to help scientists and future mission planners better understand impacts of asteroid deflections.

9 Shining light on space debris

ESA's IZN-1 station for laser ranging and optical communication in Tenerife has entered routine operations. From its vantage point on top of Izaña mountain on Tenerife, IZN-1 uses pulses of green laser light to determine the distance, velocity and orbit of defunct satellites and smaller dangerous space debris, all to within a few centimetres. Operated as part of ESA's ongoing Space Safety programme, IZN-1 helps to protect life and safeguard infrastructure on Earth and in orbit.

10 New webtool released

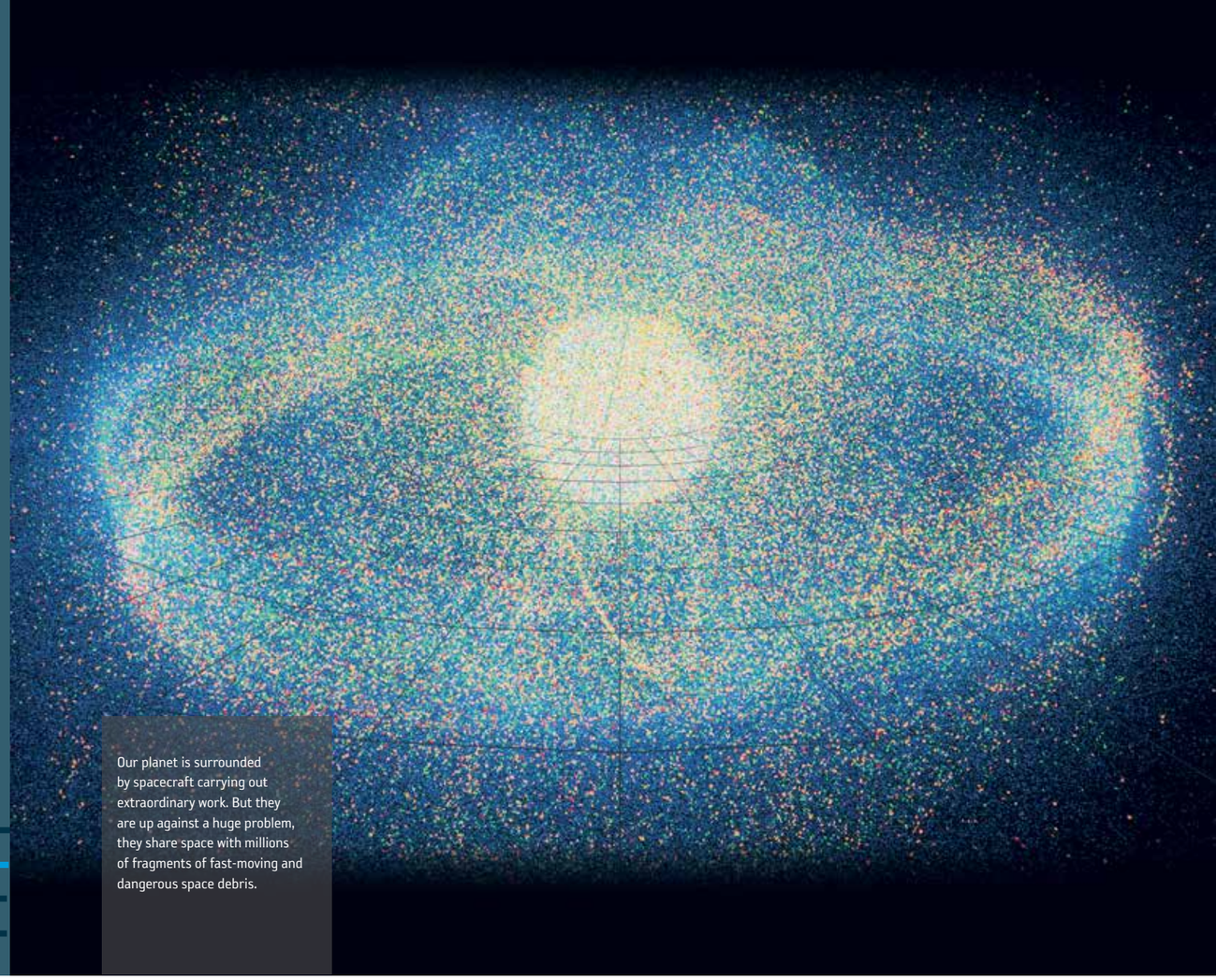
A beta version of a webtool designed to share the ESA environmental Life Cycle Assessment (LCA) database with industry was released, to support environmental assessments as part of industry's activities.

11 ADRIOS/IOS mission progressed

For In-Orbit Servicing (IOS), ESA worked closely with the four potential service providers to derive a CM22 proposal for a commercial European IOS Mission. The four IOS maturation contracts were finalised and represent the basis for the implementation of the IOS mission.

focus on

ESA ZERO DEBRIS APPROACH



Our planet is surrounded by spacecraft carrying out extraordinary work. But they are up against a huge problem, they share space with millions of fragments of fast-moving and dangerous space debris.

Earth's valuable orbits are becoming crowded. Traffic is growing exponentially, with more satellites due to be launched in the next three years than in the past sixty years combined. At the same time, many satellites that reach their end of life are not being disposed of, taking up premium "space real estate" together with fragments of space debris.

The current international space debris mitigation guidelines, technical standards and national space regulations are outdated, and the prevention of in-orbit break-ups has a low success rate. Space debris experts even announced that the point of no return has been reached: the debris population would now keep growing even if we stop launching objects into space altogether.

Zero Debris approach as the sustainable way forward

ESA recognises the urgent need to ensure the safe use of valuable orbits around Earth and has set the ambitious goal of implementing its new Zero Debris approach by 2030. This new goal will be key to achieving success with the implementation of ESA's Agenda 2025 and the new PROTECT Accelerator — working towards timely and accurate warnings of threats alongside measures to deal with them. The Zero Debris approach expands ESA's efforts within the Space Safety programme and its related Clean Space initiative. Both are managed at ESA's Directorate of Operations and are aimed at protecting life and infrastructure on Earth and in orbit. Taking Clean Space to the next level, the Zero Debris approach was put forward at the ESA Council meeting at ministerial level in 2022 and received widespread support from Member States.

The Zero Debris approach comprises a series of actions and initiatives aimed at helping ESA to take a strategic and proactive approach to safeguarding our space environment for future generations. ESA's world-leading Zero Debris approach will not only help protect the functioning of satellites and the safety of human life on Earth, but also ensure that the benefits of space activities are enjoyed by all nations for many years to come.

What is the Zero Debris approach?

ESA's Zero Debris approach will focus on four main pillars to improve and develop:

- Debris mitigation standards and guidelines.
- End-of-life technologies and collision avoidance capabilities.
- Reliable removal services.
- Operations and space traffic management.

The long-term vision of the Zero Debris approach involves the creation of a circular economy in space. By 2050, the aim is to make available a servicing ecosystem to repair, re-use and re-cycle space hardware.

The Zero Debris approach is a sustainable strategy for space operations and satellite end-of-life, boosting the success rate of disposal from valuable orbits and encouraging continued removal actions in the event that disposal fails.

Next steps to attaining Zero Debris

The next step for the Zero Debris approach is to kick off the necessary developments to ensure that the required technologies and standards are available by 2030.

In parallel, consultation will take place with relevant stakeholders such as national agencies, policy makers, commercial operators and industry to coordinate the implementation of the Zero Debris approach.

ESA is seeking to be a role model in driving space sustainability forward. The Zero Debris Approach is an essential step towards the Agency's technology strategy target of turning around Europe's contribution to space debris by 2030, showing our ambition to leave the precious space environment in a clean state for the future. The ESA Director General has made it one of his top priorities, proposing to apply the Zero Debris approach to all ESA missions as soon as possible, as he hopes to inspire other space agencies to propose or adopt similar strategies.

SECURITY AND CYBER RESILIENCE

Europe's space infrastructure — satellites in orbit supported by sophisticated facilities on the ground — provide applications, services, and critical infrastructures, without which the entire system of our economies and societies would be gravely impacted. The evolution of the international context and resulting threat landscape over the last years is clear. Space is key, and it is our duty to protect it.

Space Programme Accreditation and Certification

Any complex space programme that aims to deliver a service to Europe needs to be protected. The ESA Security Office (ESO) provides assurance to ESA's Member States on the robustness of the systems developed by the Agency, in supporting all ESA directorates through Mission Security Accreditation and Certification by applying Security Engineering and ensuring compliance with the ESA Security Framework. Security is embedded within the project life-cycle from its conception, providing adequately secured space systems (in terms of availability, integrity and confidentiality), developed in secured environments through a holistic, coordinated approach.

- Mission Security Objectives defined;
- Security Risks Assessment carried out;
- Risk Mitigation Measures applied;
- Risk tolerance verified;
- Secure Posture achieved.

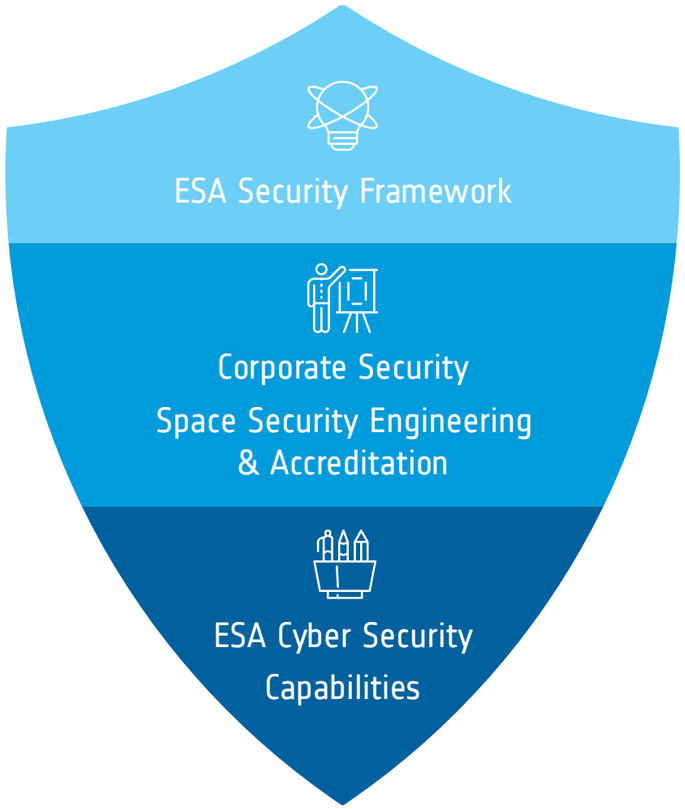
Corporate Security

- Security Risk Management is applied to all ESA business to ensure the security risk is accurately understood and appropriately mitigated to preserve ESA's security risk tolerance when carrying out ESA projects.
- Accreditation and Certification of ESA corporate tools.
- ESA Security Inspection Plan, providing assurance for ESA sites and assets.
- The preliminary results of an EU audit of ESA security in 2022 confirmed that ESA's security framework and implementation of security is outstanding.

Cyber Resilience

ESA's Cyber Security Strategy is designed to strengthen the Agency's cyber resilience from deliberate and malicious attack by adequately protecting the space domain. Two streams have been defined:

- Cyber Security Resilience – to establish an ESA Cyber Backbone:
  - Security Cyber Centre of Excellence (SCCoE)
  - Cyber Security Operations Centre (C-SOC)
  - ESACERT and ESOC NOC evolution
- R&D Technologies – by developing cutting-edge new technologies and establishing a unique cyber capability in Europe. A multi-domain, cross-directorate roadmap of cyber security activities has been established for development in the 2023–2027 period:
  - Quantum Certification Verification Platform (QCVP)
  - Cyber Security R&D Technologies



Find more information on pages 80 and 83

TELECOMMUNICATIONS AND INTEGRATED APPLICATIONS

Satellite communication underpins everyday life, enabling fundamental improvements not just in communication, but also in transport, healthcare, safety and security, environmental services, and many other industries. ESA and its Member States invest more than €400m each year nurturing innovation and competitiveness on the global market.

Partnering with industry to bring innovative solutions to market faster

ESA's Partnership Projects provide the satellite communication industry with the necessary environment to introduce innovative space-based solutions into the commercial market. The Neosat programme in partnership with Airbus and Thales is an impressive commercial success with more than 80 European companies involved and 16 satellites already sold on the commercial market. Two Neosat satellites were successfully launched in 2022. The Novacom I and II partnership programmes with Airbus and Thales are taking a step into the era of fully flexible telecommunication satellites with aggressive schedules and cost reductions. Thirteen satellites have already been sold on the commercial market. ESA also partners with smaller companies, such as SWISSto12, to develop geostationary satellites of just over one cubic metre in volume. Unprecedentedly, a first commercial HummingSat contract was signed in just eight months.

Preparing for Telecommunications of the Future

Through the ARTES 4.0 Programme, ESA is pursuing three areas considered to be of strategic interest for the future of telecommunications:

- Space for 5G/6G and Secure Connectivity

The next generation of mobile telecommunications requires different technologies to ensure the convergence of 5G/6G satellite and terrestrial networks, providing a positive impact on sustainability and the economy and addressing the growing need for reliable, ubiquitous connectivity. In 2022, the 5G/6G Hub Phase 1 was completed, providing a place for industry collaboration and innovation. Through the Sunrise public-private partnership with OneWeb, ESA is contributing to the next generation of the OneWeb satellite system. In the 5G-Emerge project led by the European Broadcasting Union (EBU), a 5G integrated satellite-terrestrial system is being developed, to allow satellite live and on-demand content delivery services for television networks.

- Space Systems for Safety and Security

Satellite communication is often the only available solution in support of crisis management, maritime safety, border control and other security domains. ESA's activities range from R&D to infrastructure and service development.
The European Commission is exploring the use of optical communication networks to generate and exchange cryptographic keys derived from quantum effects. The space segment is being designed within the ESA Security And cryptoGrAphic (SAGA) project in which the Phase A studies were finalised in 2022 and Phase B1 was initiated. CM22 subscriptions did not allow for a planned Phase B2/C/D implementation and a way forward is being defined.

- Optical and Quantum Communications

Optical communication technologies in space are expected to have a major impact on the satellite sector in the coming decade. ESA is supporting R&D development and providing flight opportunities ahead of the establishment of a commercial market for such technologies. ESA initiated the world's first high-throughput optical network (HydRON) project, with demonstrator missions carrying innovative optical technologies for satcom. Phase A/B1 began in 2022 and will be completed in mid-2023. Based on CM22 subscriptions, various options for the way forward are under assessment.
With the Business Applications – Space Solutions (BASS) programme, the focus has been on key vertical sectors where ESA anticipates strong needs, namely automotive, energy, maritime and the lunar economy. In the automotive sector, ESA has joined the 5G Automotive Association (5GAA), in the energy sector, ESA has convened a Task Force for Innovation in Energy in Space and in the maritime sector, ESA is developing a cooperation with the World Ocean Council, all with the objective of expanding the opportunities for space applications.
The Core Competitiveness programme assists industry in developing new technologies and products and capturing market opportunities and delivers a high return on investment. European industry, for its part, continues to pioneer disruptive technologies such as AI, cloud, virtualisation, user terminal miniaturisation and flat self-scanning antennas.

Bolstering connectivity, security and sustainability from space

ESA began three new programmes in 2022 dedicated to improving life on Earth through always-on-everywhere connectivity.

Secure Connectivity

At CM22, the ESA programme supporting the EU-led secure connectivity system Iris2, was well subscribed at almost €650m, to be confirmed in 2023. This is the third flagship cooperation with the European Commission, following Copernicus and Galileo. Activities have begun with a view to preparing for the development and validation of this European constellation of satellites.

Moonlight Programme

Dozens of commercial and institutional missions to the Moon are envisaged for this decade. ESA is now developing a constellation of lunar satellites with private European space companies to provide the communication and navigation signals for those missions, ensuring the necessary positioning services and constant connectivity are made available for ground control and scientists on Earth.

Civil Security from Space Programme

The Civil Security from Space programme will provide a space-based rapid and resilient response for real-time crisis management to serve European citizens. ESA is currently engaging with industry to implement related projects in 2023.

Signature of a partnership project with RHEA System Luxembourg S.A. to develop and demonstrate international use cases for quantum key distribution (QKD) in operational IT environments, as part of ESA's programme of Advanced Research in Telecommunications Systems (ARTES 4.0).

NAVIGATION

2022 was a successful year for European navigation programmes and activities. CM22 in November provided its culminating point with the adoption by ESA Member States of ambitious decisions and budgets that will underpin the future of positioning, navigation and timing (PNT) in Europe.

A new European navigation programme, FutureNAV, was initiated at CM22. FutureNAV will make an important contribution to the key strategic direction set out in the Director General's Agenda 2025, which consists in rapidly advancing technological innovation, creating and capturing new demand, in order to keep Europe at the forefront of the navigation domain, but also in science and knowledge acquisition.

FutureNAV provides a unique framework that is fully complementary with other programmes within ESA (NAVISP and other ESA initiatives) and the EU (FFPA, Galileo, EGNOS and Horizon Europe), enabling the Agency to respond more quickly and effectively to PNT market opportunities enabled by emerging technological trends.

FutureNAV consists of two programme components: LEO PNT and GENESIS.

The first component, LEO PNT, is aimed at maturing and demonstrating in orbit innovative space-borne, ground segment and user segment technologies and potential services, as an enabler towards LEO PNT operational programmes to be undertaken under separate commercial and/or institutional initiatives.

ASECNA/ESA Signature Event

The second component, GENESIS, consists in the first ever co-location of all space-based geodetic techniques within one single satellite with the aim of supporting the improvement of the Earth terrestrial reference system, which is one of the foundations of satellite navigation.

At CM22, the decision was also taken to continue the NAVISP programme, ensuring that the European PNT sector will remain at the forefront of worldwide competitiveness and innovation. In June, ESTEC, in the Netherlands, played hosted to a successful NAVISP industry days. This was a key element leading to the success achieved by NAVISP at CM22.

The Moonlight programme to bring PNT capabilities to lunar exploration missions, has been adopted.

In June, ESA and ASECNA, the Agency for Air Navigation Safety in Africa and Madagascar, signed an agreement to support the implementation of EGNOS in Africa. The related project activities are now under way. This will lead to the Augmented Navigation for Africa (ANGA) SBAS system serving the African continent.

Galileo continues to be the most high-performance, precise Global Navigation Satellite System in the world with more than 4 billion users worldwide. In the summer of 2022, the first pair of Galileo FOC Batch#3 satellites entered operation, further improving availability and continuity of service to users.

A new capability bringing faster time to first fix and more robust acquisition and time synchronisation to navigation users on the E1 INAV signal was introduced on a subset of the constellation and will be completed in 2023.

Production of the ten remaining Batch#3 satellites is almost complete, with the last satellite concluding the environmental test campaign at ESA ESTEC in October.
All the satellites are in storage at OHB Bremen awaiting the next launch opportunity.

Following the end to Soyuz launches from Europe's Spaceport in French Guiana (the CSG) due to Russia's attack on Ukraine, the two launches planned for 2022 could not go ahead and an alternative launcher is being sought to perform a launch in 2023 while waiting for Ariane 6 to become available.

Regarding Galileo Second Generation activities, the System Preliminary Design Review (PDR) covering the full scope of activities from In Orbit Validation up to Initial and Final Operation Capability was successfully completed in December.

The PDRs for the two Galileo Second Generation Batch#1 satellite contracts were concluded in early 2022 and a number of equipment/subsystem milestones took place throughout the year.

In 2022, the Financial Framework Partnership Agreement (FFPA), between ESA, the European Commission and EUSPA was implemented according to the planned schedule. Integrated teams have been created to foster EGNOS and Galileo programme development.

Upstream research for the development of Galileo and EGNOS continued to be supported in an efficient manner and carried out in 2022 through the Horizon 2020 and Horizon Europe EU framework programmes.

Left picture: The ESA Council at Ministerial level held in Paris on 22 and 23 November 2022 notably made the decision to increase ESA's budget by 17% compared to the last Ministerial meeting in 2019.

Right picture: The complete Galileo constellation will comprise satellites spread evenly around three orbital planes at an altitude of 23222 km and inclined at an angle of 56 degrees to the equator.

ENABLING AND SUPPORT

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- Operations: page 116
- Technical and Quality Management: page 120

SPACE TRANSPORTATION

ESA's new Vega-C rocket lifted off for its inaugural flight VV21 on 13 July at 15:13 CEST/13:13 UTC/10:13 local time from Europe's Spaceport in French Guiana.

Three Ariane 5s and the successful maiden launch of Vega-C on 13 July continued to provide access to space using ESA-developed launchers. All in all, six launches were carried out in 2022 from Europe's Spaceport, including a Soyuz in February and the second Vega-C launch on 20 December, which resulted in failure. The last two Ariane 5 vehicles are scheduled to be launched in 2023.

In preparation for the inaugural flight of Ariane 6, combined tests were begun at Europe's Spaceport with a fully integrated Ariane 6 on 13 October and a first successful hot-firing test of the Ariane 6 upper stage was conducted at the Lampoldshausen test facilities on 5 October. In terms of infrastructure, the new Ariane 6 transport ship, Canopée, set sail from Rotterdam at the end of December and reached French Guiana for the first time in January 2023, achieving its sea qualification and opening the prospect of halving the costs of shipping Ariane launch vehicle components while reducing the environmental footprint. ESA has been advancing the development of the Vega launch vehicle family. This included the successful close out of the Vega-E Launch System Requirement Review in February, completion of the test campaign of the new methane-powered M10 DM1 engine in May and the kick-off of the Launch System Preliminary Design Review (PDR) in December.

2022 launches were impacted by the war in the Ukraine and marked by a halt to Soyuz operations from Europe's Spaceport impacting Arianespace's and Europe's ability to meet its launch needs. Despite the low launch rate in 2022 and with the foreseeable gap in European access to space in the year 2023, Europe, through Arianespace, launched 40% in terms of payload mass of the accessible geostationary orbit (GEO) payloads launched worldwide over the year. Arianespace managed to win around 20% of the competed payload mass to be injected in non-GEO orbits and remains the only launch service provider aside from SpaceX to win contracts for launches of GEO payloads (two out of fourteen).

ESA's efforts to prepare the future of European space transportation services continued in the framework of its Future Launcher Preparatory Programme and the Commercial Space Transportation Services and Support Programme (Boost!). Two successful hot-firing tests were carried out in September and November of the Prometheus prototype engine, designed with the extensive use of new materials and manufacturing techniques and with the aim of reducing cost to just a tenth of the Vulcain 2 engine. Activities continued with the development and testing of reusable space transportation components, through Themis and Space Rider. Boost! provided support to industrial entrepreneurship within the privately led and funded space transportation sector in Europe, signing three additional contracts in 2022 to support the development of European commercial space transportation services.

At the ministerial-level meeting of the ESA Council in November, ESA's subscribed funding budget for space transportation amounted to €2.8bn, which will make it possible to strengthen the versatility of the current launchers, prepare their long-term evolution together with Vega-E development, complete development of the reusable Space Rider and support the development and testing of promising new space transportation technology disruptors and space logistics, while carrying out the flight demonstration test campaigns of the Themis reusable first stage and Prometheus and demonstration of the reusable upper stage element.

In addition, the Boost! programme was enlarged to cover the competitive selection and co-funding of European launch services for European IOD/IOV missions, to be implemented in cooperation with the European Commission (European flight ticket initiative).

In coordination with other ESA directorates, options were assessed for Europe to equip itself with sovereign human space exploration transportation capabilities. End-to-end architectural trade-offs in support of different exploration scenarios and time-critical technology maturation for European human space transportation were subscribed at CM22. These activities support the work of the High-Level Advisory Group (HLAG) on Human and Robotic Space Exploration for Europe and will inform decisions at the next Space Summit planned for November 2023.

Co-located with ESA's Directorate of Space Transportation office in Paris, a Space Transportation Hub was established in 2020 for closer and more efficient communication links with Europe's space transportation industry.

OPERATIONS

Ground Systems Engineering and Operations

ESA's Directorate of Operations and the European Space Operations Centre (ESOC) are recognised internationally as a centre of excellence for E2E ground segment engineering, flight dynamics and flight operations services. The Directorate currently operates 23 flying missions, including astronomy, Earth observation, and interplanetary, and is preparing for the launch of a dozen more, including the critical final activities for Juice and Euclid, launching in 2023. The independent capability to fly Europe's institutional missions is critical to Europe's autonomy and resilience as a space power.

1 Keeping everything nominal

Operations teams at ESOC keep our satellites safe above and beyond the routine challenges. For example, while performing a manoeuvre to avoid solar weather for two of ESA's Swarm satellites, the teams additionally had to deal with a piece of space debris at short notice. Increased solar activity is enlarging atmospheric drag and threatening to pull satellites out of orbit. The Solar Orbiter mission entered a special mode of operation to allow rapid steering pointing to follow a scientifically interesting feature on the Sun, while the spacecraft passed as close as 48 Mkm from our star.

2 Meeting Europe's cis-lunar and deep-space communication capacity needs

Construction has begun at New Norcia in Western Australia for ESA's fourth 35-metre-deep space antenna, where it will become part of Estrack, ESA's global tracking station network, and provide continuous communications coverage for missions exploring our Solar System, studying our Universe, and protecting Earth from solar hazards and risky asteroids.

3 Tracking Orion's CubeSats

NASA's Orion spacecraft dispersed ten CubeSats into orbit as part of the Artemis mission. Europe's Estrack deep space antennas and the Goonhilly Earth Station (GES) in the UK played a key role in determining trajectories for six of the CubeSats, ensuring they arrive where they need to be, and their data gets back home.

4 Enhancing ESA's Global Navigation Satellite System

A new GNSS station has been opened in Costa Rica. The new GNSS station is the first global network (EGON) station to be installed in Central America and ensures greater depth of coverage for this region. ESA'S Global Navigation Satellite System (GNSS) Observation Network is controlled by ESOC's Navigation Support Office, which provides precise and accurate timing data vital for a wide range of space applications.

5 Ultracool upgrade for ESA's ground stations

The 35-metre antenna in Malargüe, Argentina, became the second in the Agency's network to receive an upgrade that cools its antenna feed to minus 263°C. This improves the possible data transfer rates by up to 40% and will extend its range to support future missions such as ESA's Juice to Jupiter's icy moons.

6 Precise deep-space navigation

Flight dynamics and flight control teams at ESOC worked together to execute two tricky gravitational flyby manoeuvres. This helped BepiColombo navigate to within just 200 km of Jupiter's surface at a relative speed of 7.5 km/s. Soon after, Solar Orbiter (SolO) successfully flew by Venus for a gravity-assist manoeuvre that altered the spacecraft's orbit, bringing it even closer to the Sun.

7 Commercialisation in ESA's augmented station network

A contract for Deep Space Communication has been signed with the Goonhilly Earth Station, UK. The main objective is to achieve full integration of the GES ground station into the Estrack augmented network. This contributes to ESA's efforts towards commercialisation and will help meet the rising demand for deep-space communication bandwidth.

8 Automation in Operations with AI

The Artificial Intelligence for Automation (A^2I) Roadmap was developed with industry with the goal of identifying and developing AI-based solutions for automating a broad range of mission operations activities and to enhance industry capabilities in this key domain. The first two prototypes were developed to assist in the automation of routine tasks.

9 Next-generation Spacecraft Monitoring and Control

Together with European national space agencies and partners from the European space industry, ESOC has designed and developed a set of next-generation Monitoring and Control Systems, including the monitoring and control of spacecraft and ground stations (EGOS-CC), and is progressing towards deployment. A key milestone for EGOS-CC was achieved when it successfully interacted with the Swarm satellites during a routine ground station pass.

10 Essential support to upcoming missions continued full-steam

In view of upcoming launches, preparation of the ground systems is continuing to tight deadlines, with several launches upcoming in 2023 and 2024, starting with Juice. For example, the joint ESA/JAXA partnership, EarthCARE, successfully completed its penultimate system validation test, achieving an important milestone in preparing for ESOC operations.

11 ESA ground stations support first commercial Moon landing

Japan's ispace successfully launched its HAKUTO-R Mission1 on 12 December, making it the first mission by a private company to land on the lunar surface. The all-important acquisition of signal took place over Estrack's New Norcia ground station in Australia.

12 Cyber Security Operations Centre

In 2022, the Directorate of Operations invested significantly in cyber security in partnership with the ESA Security Office. Work has begun on the deployment of a Cyber Security Operations Centre (C-SOC) node at ESOC which will enable reliable detection and mitigation of cyber-related incidents in mission operations. Furthermore, the Directorate of Operations has begun a full cyber security certification, demonstrating cyber awareness to customers and partners, and ensuring compliance with increasingly stringent security needs.

focus on

ESA'S NEXT-GENERATION MISSION CONTROL SYSTEM

From satellites monitoring Earth's landmasses, oceans and climate to space telescopes peering back in time to answer fundamental questions about our Universe, every spacecraft mission relies on sophisticated software systems to process commands, send back and store data, perform automated tasks and much more.

As the number of missions flown from ESOC keeps growing, the reusability of its software across missions is increasing in importance. ESA's adaptation of the new system is the first generic infrastructure tool designed for multiple missions rather than a bespoke mission control system designed for each mission, as is the most common model worldwide.

Additionally, this modernised system enhances security and updatability by embracing current technologies for software maintenance.

A powerful European toolbox

Together with European national space agencies and partners from the European space industry, ESA led the design and development of a set of common software tools and associated infrastructure that could be used across Europe to support the integration, validation, modernisation, monitoring and control of new spacecraft and ground stations.

The result of this ambitious initiative is the European Ground Systems Common Core (EGS-CC), a collection of generic, customisable and compatible tools that will be made freely available to entities in ESA Member States.

Widespread adoption of EGS-CC will improve the flow of information between different companies and space agencies involved in different stages of a mission (notably design, assembly and in-flight operations), help the European space sector adopt new technologies more quickly, and ensure the continent's place at the competitive forefront of space exploration.

The adaptation and extension of EGS-CC at ESA to enable future generations of mission operations is coordinated and implemented under the "EGOS-CC" umbrella.

Shadow operations shed light

While EGOS-CC was tested and validated extensively during development, nothing trumps validation in a real-life setting. EGOS-CC talked to space once before in 2021, when OPS-SAT, ESA's flying laboratory, was used as a communication testing partner for EGOS-CC. Flying operational spacecraft is a risk-averse undertaking, even if technical pioneering is at its core. Shadow operations make it possible to validate extensively new technologies in a production environment before the actual rollout.

Although shadow operations are not a new concept, the virtualisation of infrastructure technologies significantly lowers the effort required and makes it a particularly effective tool for complex new system rollouts like EGOS-CC.

The concept has now been used on ESA's Swarm mission. While the current control system is still used operationally to fly the three-satellite Swarm constellation, EGOS-CC has been deployed in parallel to shadow the mission. The satellites send their data once, as always, but this is now routed to both control systems in parallel. Without interfering with the actual operational activities, EGOS-CC's functions and outcomes are checked against the results of the parallel system. Any issues detected, from the user interface to the data systems themselves, can then be ironed out and addressed.

As a result of the joint effort with European industry, the next milestone has been accomplished, and EGOS-CC has now gone a step further. For the first milestone, successful data contact was established between EGOS-CC and the spacecraft via ESA's Estrack ground station in Kiruna, Sweden. Recently, EGOS-CC accomplished its first commanding milestone when it successfully interacted with the Swarm spacecraft during a routine pass, performing a health check and executing further regular commands.

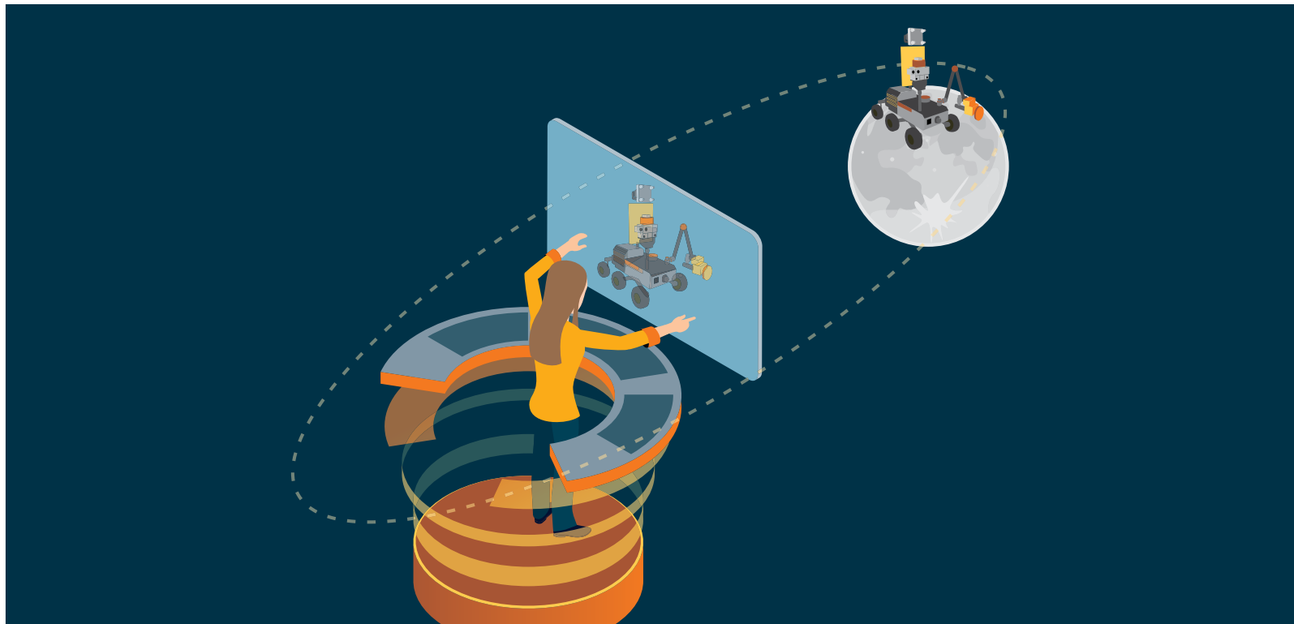
What's next for EGOS-CC?

Speaking after the first successful commanding pass with EGOS-CC, Rolf Densing, ESA Director of Operations said "Our achievement today is the result of a successful collaboration with European industry towards the next generation of space systems monitoring and control. ESOC is delivering on our Agenda 2025 commitment to introduce the European Common Core Mission Operations Software as a new standard for use by the private and public sector in Europe."

Further testing and validation efforts remain to be completed, but the first operational rollout is coming closer. If all continues to go well, the Swarm mission will be the first to migrate entirely to EGOS-CC by the end of 2023.

A full migration of all missions from SCOS-2000 to EGOS-CC is planned, which means it must be backwards compatible to ensure that the new system can work and interact seamlessly with all hardware and connected systems in use by active missions.
From 2025 onwards, all new missions will rely entirely on the resource-efficient and cost-effective EGOS-CC system, completing the switch. The new standard will also be available for the private and public sector in Europe.

Responding to ESA's Agenda 2025, ESOC continues to play its part: "ESA will continue to master the most complex space operations with efficiency gains by systematically introducing ever more automation and AI and be at the forefront of multi-mission operation systems." EGOS-CC is an important foundation block as part of this commitment.



TECHNICAL AND QUALITY MANAGEMENT

As a research and development agency, ESA does not do routine. The missions it flies are ground-breaking by definition, pushing forward the technical state of the art. This is where the Agency's Directorate of Technology, Engineering and Quality comes in. Working more than a decade into the future, its specialist teams prepare for missions to come, working to engineer solutions using technologies that do not even exist… until Directorate engineers and their counterparts in European industry invent them. The Directorate is based at ESA's largest establishment, ESTEC, the European Space Technology and Research Centre, home to a suite of technical labs and the ESTEC Test Centre for satellite testing.

These key resources remained operational through the two-year COVID-19 pandemic, while the rest of the Agency shifted to remote working. 22 June 2022 marked the day that the whole of ESTEC officially reopened, as a celebratory ESA Teams Day welcomed everyone back to the establishment. As a highlight of the day, around a thousand ESTEC personnel formed the word "ESA" on the site's rugby field, to be captured from around 700 km up in space by the Pleiades Neo Earth-observing satellite.

The establishment expanded this year, with the inauguration of a new cleanroom to serve the ESTEC Test Centre while construction began on two new buildings: the International Meeting Facility (IMF) conference centre and Hertz-2 – an enlarged radio frequency test chamber for entire large satellites.

Satellites under test at the Test Centre included EarthCARE, "Structural and Thermal Models" of the ESA-China Solar wind Magnetosphere Ionosphere Link Explorer (SMILE) satellite and the payload module of the exoplanet-detecting PLATO mission, as well as the last out of 34 Galileo First Generation satellites.

IMF ground-breaking by ESA Director of Technology, Engineering and Quality Torben Henriksen

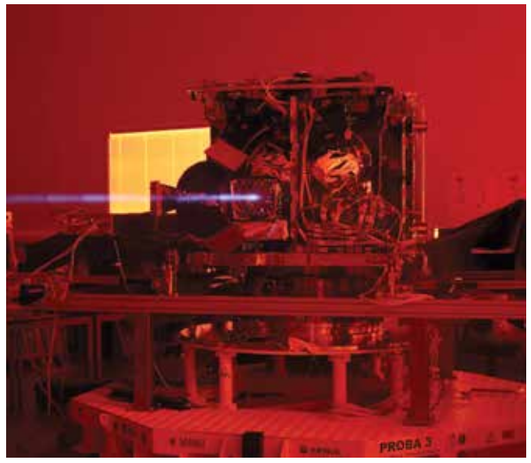
Work begins on Hertz-2

ESA's Interact rover on Mount Etna

Meanwhile, the everyday technical work of the Directorate continued apace. Highlights included the participation of the Automation and Robotics Section in a multi-agency, multi-rover field test on the volcanic slopes of Sicily's Mount Etna, led by the German Space Agency, the DLR. The Section contributed the four-wheeled, two-armed Interact rover, which was controlled by ESA astronaut Thomas Reiter from 23 km away, with time delay built in as if he were up in orbit. Success in interacting with the other robots present and performing a geological survey marked the conclusion of the multi-year Analog-1 project, investigating the feasibility of long-distance, high-fidelity robotic control incorporating haptic force feedback.

Completion of the IMPERIAL 3D printer by a Europe-wide consortium – coordinated by the Directorate's Materials' Physics and Chemistry Section – produced a printer capable of working in weightlessness and able to print high-performance polymer parts of unlimited size along one dimension, opening the way to future in-space manufacturing.

Preparation for ESA's Proba-3 double-satellite formation flying mission saw precision laser-based testing of the optical metrology system that will maintain the satellites' relative positions down to a matter of millimetres. Furthermore, as part of the Directorate's In-Orbit Demonstration Programme, an innovative trio of CubeSats completed their missions successfully – SunStorm for solar observations, RadCube for radiation and magnetosphere monitoring and SIMBA for deriving Earth's energy budget – while others were prepared for launch in 2023.



Proba-3 metrology testing

ESTEC's crucial role as the technical hub of the European space sector was underlined in September, when more than 800 companies gathered there from across the continent for the two-day European Space Days, intended to act as a catalyst for new partnerships within the sector.

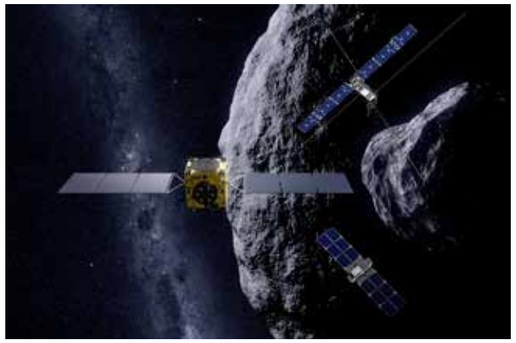
In advance of November's ESA Council meeting at ministerial level (CM22), the Directorate had published an updated version of its Technology Strategy, setting out its plan for technology development in response to the Director General's Agenda 2025, which itself underlined innovation as a crucial element in ESA's future.

CM22 itself resulted in strong support for the Directorate's R&D programmes, including new components added to the General Support Technology Programme. Electrical, electronic and electromechanical (EEE) Space Component Sovereignty for Europe is working with industry, ESA Member States and European organisations such as the European Commission and European Defence Agency to safeguard the supply of EEE components, compensating for current volatility in the global microprocessor market.

ENDURE, which stands for for "EuropeaN Devices Using Radioisotope Energy", will deliver an end-to-end European capability for radioisotope heat and power systems by the end of this decade, while the SOLARIS programme will undertake studies and technology developments, in partnership with European industry, to mature the technical feasibility and assess the benefits, implementation options, commercial opportunities and risks of space-based solar power.

Hera asteroid mission coming together

One of the major space highlights of 2022 was NASA's DART mission's intentional collision with the Dimorphos moonlet, successfully deflecting its orbit around its parent Didymos asteroid. Next comes ESA's follow-up Hera mission: due to



ESA's Hera mission seen with its CubeSats in orbit around its target asteroid

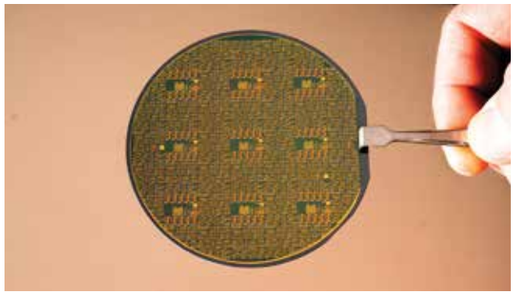
be launched in October 2024, Hera will perform a close-up survey of the DART impact site and the mass and make-up of Dimorphos, while also deploying Europe's first deep-space CubeSats for additional observations.

ESA's Directorate of Technology, Engineering and Quality is overseeing Hera's implementation. 2022 saw the mission's payload module take shape at OHB in Germany while its propulsion module was equipped at Avio in Italy. Simultaneously, numerous Hera subsystems underwent test campaigns – including its On-Board Computer and High-Gain Antenna being tested at ESTEC. The overall mission passed its System Critical Design Review at the end of 2022, at the same time as Hera received funding for its launcher and operations.

Securing components at the heart of Europe's space missions

This wafer of gallium nitride – a material more typically found at the heart of Blu-Ray players – has been etched with hundreds of space-quality microwave integrated circuits.

Unrestricted access to state-of-the-art space qualified electrical, electronic and electromechanical (EEE) parts is a cornerstone of Europe's competitiveness and non-dependence across the space sector. Accordingly, in November, ESA's Council meeting at ministerial level supported the creation of the EEE Space Component Sovereignty for Europe initiative. Managed



Wafer of Gallium Nitride – a material typically found at the heart of Blu-Ray players.

as an additional component of the Agency's General Support Technology Programme, this initiative aims to establish long-term, sustainable and uninterrupted access to state-of-the-art EEE space component technologies for ESA programmes. The initiative has a targeted budget of €155m over five years.

Expanding the envelope of radio frequency testing

The largest antenna ever tested in ESA's Hertz radio frequency test chamber was this 5m diameter transponder antenna, which will operate on the ground to help calibrate the Biomass mission, which will chart all the forests on Earth.

Radio eye on tree-counting Biomass

Shut off from all external influences, the metal-walled "Hybrid European Radio Frequency and Antenna Test Zone" chamber is shut off from all external influences. Its internal walls are studded with radio-absorbing "anechoic" foam pyramids, allowing radio frequency testing without any distorting reflections. Its name starts with "hybrid" because the chamber can assess radio signals from antennas both in localised "near-field" terms or else on a "far-field" basis, as if the signal has crossed thousands of kilometres of space. With antennas growing in size and performance, in 2022 ground was broken on a larger-scale "Hertz-2" chamber, equipped to test the coming generation of missions.

Testing materials for Venus aerobraking

Candidate materials for ESA's next mission to Venus, EnVision, were subjected to harsh conditions equivalent to "aerobraking" through the planet's atmosphere. Before beginning its scientific observations, the van-sized spacecraft will gradually lower its orbit with thousands of passages through the planet's atmosphere for up to two years, enduring intense sunlight and a harsh chemical environment. ESA's Materials and Electrical Components Laboratory took up the challenge of simulating this process, making use of a unique European facility able to reproduce corrosive "atomic oxygen" in orbital conditions.

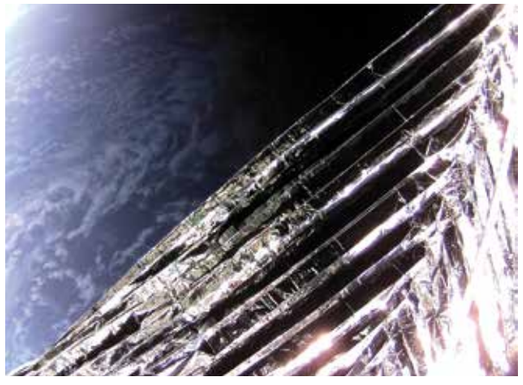
ESA's world-beating suite of technical labs declared themselves open for business this year, with the https://technology.esa.int/ website, encouraging wider commercial use of their facilities in between serving the needs of current and future European space missions.

Expansion of the ESTEC Test Centre

ESA's biggest and most complex Earth Explorer mission yet was tested for space at ESA's ESTEC Test Centre, the largest satellite test facility in Europe. The Earth Cloud Aerosol and Radiation Explorer, EarthCARE, is equipped with two main instruments, a lidar plus radar – along with a smaller radiometer and cloud imager – which are powered in turn by a mammoth 11m-long solar wing.

During 2022, the ESTEC Test Centre also said goodbye to its single biggest customer, as the last Galileo Full Operational Capability satellite left the site. All 34 Galileo FOC satellites underwent testing here over the last decade on the way to becoming Europe's single largest satellite constellation, along with the very first Galileo In-Orbit Validation satellite. The ESTEC Test Centre also expanded this year, with the formal opening of a new 350 sq. m environmentally controlled cleanroom beside it. This new FV cleanroom is being used for satellite storage, to increase the overall capacity of the site, and also hosts the Test Centre's microvibration test facilities.

Setting sail for safer skies



The unfurled ADEO-N sail on a satellite to hasten its fall back to Earth

In December, a satellite unfurled a sail like a ship of old – although its purpose was not to start a journey but hasten the satellite's fall back to Earth. By increasing its overall surface area, the 3.6-sq-m sail on Italy's ION satellite deployer will increase air drag from the scanty atoms found at the top of the atmosphere to speed up atmospheric re-entry. This "terminator sail", a large aluminium-coated polyamide membrane attached to four carbon-fibre reinforced booms, deployed autonomously from a 10cm box. The plan is to contribute to ESA's Zero Debris initiative – as the Director General says: "If you bring a spacecraft to orbit you have to remove it."

This Drag Augmentation Deorbiting System (ADEO) was developed by HTS in Germany through an ESA General Support Technology Programme project. Previous versions haven already been deployed but this in-flight test represented the final technological proof-of-concept for the ADEO family.

ESA opens up

The 11th annual ESA Open Days at ESTEC took place on 1–2 October, attracting more than 4,500 visitors. On Saturday 1 October, an ESA Open Day took place for people with disabilities, allowing them to explore the Agency's largest establishment at their own pace in a quiet environment. It was followed by a general ESA Open Day the following day, which included talks by ESA astronauts Matthias Maurer and André Kuipers, presentations by ESA directorates, access to ESTEC facilities such as the new Test Centre cleanroom, the Large Diameter Centrifuge and the Concurrent Design Facility, as well as a gathering of Dutch space companies and research institutes in the NL Space Tent.

Space to learn

CubeSat teams attend lectures at the ESTEC High Bay

Student teams from 12 European universities took part in the first Fly Your Satellite! Design Booster Training Week that took place at ESTEC's Erasmus centre in November.

Run as part of the Directorate of Technology, Engineering and Quality, ESA's Education Programme is recognised in the ESA Convention as a mandatory activity, using the fascination and the incredible body of knowledge generated by Europe's unique space programme for the benefit of the younger generation and for the growth of society at large. The Programme targets a wide range of age groups – starting from early primary school up to PhD level. It does so through a vast portfolio of activities differentiated by age, and grouped around two main pillars.

Last year the ESA STEM Education and Outreach programme inspired and supported almost 700,000 primary and secondary school teachers – training more than 50,000 of them – and reached more than 2.3 million school pupils. Boosting university students' ambitions, skills and competences through the transfer of expertise directly from space professionals is the mission of the ESA Academy Programme. In 2022, around 6,000 students benefitted from this training, which provides participants with a valuable qualification.

RESOURCES MANAGEMENT, CORPORATE ACTIVITIES AND EXTERNAL RELATIONS

- Human Resources, Facility Management and Digital Transformation: page 126

HUMAN RESOURCES, FACILITY MANAGEMENT AND DIGITAL TRANSFORMATION

HUMAN RESOURCES

2022 saw an unpreceded number of recruitments take place, with 262 new hires in total. This trend (after 188 new staff were recruited in 2021) will most probably continue in the years to come, in order to adjust staffing to the requirements of the new programmes adopted at CM22 and to cope with the retirement wave, which translates into an average of 100 yearly departures.

A new Policy on Reporting Unwanted Conduct and Investigating Harassment at ESA was agreed with the Staff Association and is due to be published in early 2023. The main change introduced is the reporting mechanism, a whistleblowing system having been established to allow any individual witnessing occurrences of unwanted conduct to report the matter to the Administration, even anonymously. The investigation process was also revised with a view to increasing the protection of all parties involved, with the aim of strengthening trust in the system.

The reform of family leave arrangements, which replaces the former provisions on maternity/paternity leave by the new concepts of bonding and pregnancy leave, as well as the changes enhancing the working conditions of YGTs (Young Graduate Trainees) and IRFs (Internal Research Fellows), is due to enter into force on 1 February 2023. The reform will enable the Agency to have a more gender-neutral framework that better takes into account modern family arrangements, including cases of adoption, in accordance with diversity and inclusion principles. As for YGTs and IRFs, the changes to be introduced are aimed at maintaining the attractiveness of these programmes for new generations of graduated scientists and postdoctoral fellows by bringing some of their entitlement leave closer to that of other staff members.

DIVERSITY AND INCLUSIVENESS

In 2022, ESA reinforced its efforts to attract and retain a diverse pool of talent and enhance inclusion.The Agency has, for example, introduced "8 Steps Forward to 2025", a list of concrete actions and measurable targets addressing the axis of diversity and inclusion related to gender, generation, disabilities, and identity.

In the past few years, the proportion of recruitments of female staff has systematically outnumbered the share of female applications, leading to a steady increase in the percentage of women in the workforce, to reach a current rate of 29%. The share of women in top management positions has also increased significantly, topping 18% in June 2022.

Since 2019, ESA has been offering internships and Young Graduate Traineeships specifically targeting people with disabilities. Additional initiatives were taken in 2022, such as the adoption of assistive digital technologies and the improvement of the accessibility of ESA buildings. ESA is the first space agency to have run a Parastronaut Feasibility Project, leading to the selection in 2022 of a candidate astronaut with a physical disability.

Several initiatives have been organised by the Agency to further promote STEM studies and space careers, especially among young women. As part of the joint celebration with EIROforum organisations of the International Day of Women and Girls in Science on 11 February, thousands of European children took part in a drawing challenge on "Women in Science". In July, ESA assumed the rotating Presidency of the EIROforum Ad-Hoc Working Group on Diversity and Inclusion.

SITES AND FACILITY MANAGEMENT

The main challenges in 2022 for the Estates and Facilities Management (EFM) Department stemmed from the overlapping phases associated with the tail-end of the COVID-19 pandemic, the Russian invasion of Ukraine and the last year of ESA's 3-yearly investment cycle.

The ending of the pandemic meant that ESA had to manage the realities of new patterns of on-site attendance and respond to the wide range of requirements and responses at an organisational and individual level. A major trend to emerge was the use of enhanced methods of managing data, precipitated in part by the onset of the pandemic and the resulting opportunities and challenges described upwards and managed downwards.

The Russian invasion of Ukraine in February saw the Department playing its lead role in crisis management and having to contend with the immediate consequences within the core EFM domain. This role was effectively performed with rapid sense-making of the situation and transfer of ongoing coordination of the wide impact to the key duty-holders in the Director General's Services and programme directorates. In turn, practical responses had to be found to massive rises in energy and component prices. These were unprecedented and the responses included extensive interaction with delegate bodies and concentration on key business continuity requirements.

The end of the investment cycle required immense efforts from ESA's construction managers at all sites, not least because of the price effects adumbrated above, but also because of the huge, practical impact of the pandemic in the first eighteen months of the period. In the end, on-budget and on-time delivery was achieved.

Finally, the highest profile construction activity — the ESA Headquarters Renovation Project — continued nominally and the building was returned from the developer with a one-week delay to the timeline identified four years earlier, (a two-week margin had been allowed within the overall schedule). The building then entered the ESA-managed fit-out phase within budget and with the construction company working hard to remedy the long list of minor snags identified on handover.

DIGITAL AGENDA AND INFORMATION TECHNOLOGY

In response to Agenda 2025 Action T1, Implementing Guidelines for a new Data Management and Governance Concept were established and agreed with all directorates in the second half of the year. The new concept puts in place a new Data Access Policy answering to the availability of new tools to consume and visualise data from corporate and programmatic data sources.

To increase the Agency's data management capabilities, a new target data architecture has been defined.

In response to Agenda 2025 Action T2, an Agency Dashboard for the Executive Board was implemented and made available in August as an operational product. In its current version, the Dashboard provides Agency-wide views on finance, procurement, workforce and geo-return metrics, with the ability to drill down at directorate level. It is in regular use by the Executive Board to assess the Agency's performance and to set target KPIs. A second, improved version was made available in December.

In 2022, preparation for the Space High Performance Computer matured. Together with all directorates, a coherent user requirements document was established, mapping more than 60 use cases across the Agency. The technical target architecture for the Space HPC was drafted and is due, from early 2023, to begin validation with industry through a Request for Information (RFI) mechanism.

The IT Department enabled a smooth transition to the "new normal" way of working, combining on-site presence with teleworking. An integrated standard videoconferencing system was deployed in 34% of all meeting rooms and 92% of all users migrated to esa365. Four directorates decided to go full mobile and abandon fixed phones.

The use of common shared IT services increased in 2022, 30% more for computing (esacloud) and 38% for the shared software development platform, while further growth is expected in 2023 based on new use cases from ESA directorates. All planned network bandwidth upgrades were completed, made possible by the new network contract.

Numerous releases of digital solutions addressing processes, competences and tools took place. These have improved internal capabilities (human resources, procurement and

finance and facility management), while also easing internal decision-making (Data Lake and Executive Board (EB) Dashboard). They also support external stakeholders, with tools for Agenda 2025 and the CM22 facilitation solution for programme subscriptions and the recent delivery of the Dynamic Purchasing System in relation to Copernicus Contributing Missions.

The IT Department is proactively sustaining ESA's enhanced cyber security posture by supporting the future operations of the Cyber Security Operation Centre (C-SOC), the tender for which took place in 2022.

The ITT for the new Corporate Applications Service Provision (CASP) contract was issued and will be awarded in 2023.

COMMERCIALISATION, INDUSTRY AND PROCUREMENT

Commercialisation

It was very apparent from the outcome of CM22 that ESA Member States have endorsed and embraced the commercialisation priority set out in Agenda 2025, by deciding to proceed with more than €1.3bn of programmes with a commercialisation focus. The ScaleUp programme, which will provide a coherent framework and catalyst for ESA's commercialisation offer, was oversubscribed by 18% with €118m. ScaleUp has an end-to-end business approach as well as being domain-agnostic. It will work closely with all ESA programmes and technical and operations directorates to provide support and services to all.

In order to support Commercialisation activities, a new website — the ESA Commercialisation Gateway — has been published as a single entry point to facilitate the access for stakeholders to programmes and services provided by ESA, in support of the development of a commercial space ecosystem. The Gateway provides access to a Commercial Space Hub for market intelligence purposes to gather market trends studies performed by the Gateway. The Gateway also manages a Market Intelligence tool used to collect the latest market trends which are condensed in mini-reports and recurring space market digests that are shared with the European space community through Gateway social media. The Gateway continues to support outreach and engagement actions with new stakeholders through its presence in space and non-space events including Paris Space Week, VIVATECH, SLUSH, Czech Space Week and the Living Planet Symposium, among others.

In September, the SME Office organised the 10th ESA Industry Space Days at ESTEC with record attendance of 1,700 visitors participating in business-to-business meetings, the industry exhibition, and conference talks focussing on CM22 programme proposals and opportunities. Throughout the year, the SME Office organised 23 training sessions via its online Learning Hub platform. More than 600 individual participants from 410 companies signed up for the webinars and on-site courses. Furthermore, in December, the first release of the esa-match evolution project – ESA's industry matchmaking tool — went live, providing new functionalities and improved features for industry, as well as ESA users. The platform supports the visibility of entities registered with ESA, facilitates partnering and cooperation between companies, and brings together (potentially unknown) products, services or technologies and (latent) needs.

Five more ESA Business Incubation Centres (BICs) have joined the ESA BIC network, increasing the total to 29 core ESA BICs, providing incubation at 90 different locations in our Member States. In terms of start-up companies, more than 200 joined our entrepreneurial community, which means that over 1,200 start-up companies have benefitted from ESA's business incubation in the past decade.

The Technology Transfer Brokers network has grown from seven to ten Brokers with activities in ten Member States. Six contracts for technology transfer Feasibility and Design activities were placed to de-risk the technology transfer process. ESA also offered expertise and facilitated networking to industry.

At the end of 2022, the ESA patents portfolio contained 116 inventions protected by 578 patents around the world. As a reminder, ESA's patents portfolio is freely available to industry in the Member States for space applications (www.esa.int/ip).

The ESA Investor Network was also created to partner with and support venture capital funds. By the end of 2022, the network had 19 members (and 13 collaboration agreements under signature), with a portfolio of over 50 space companies. Five Capacity Building Workshops were organised for fund managers with over 200 participants in cooperation with the European Union Agency for the Space Programme (EUSPA), the European Commission, and the European Investment Fund.

PROCUREMENT, FINANCIAL OPERATION AND LEGAL AFFAIRS

Commercialisation, Procurement and Industrial Policy, Audit

In addition to supporting the management of the programmes and Legal Services Department in preparing for CM22, the Procurement Department placed more than 1,500 contracts (and 3,000 purchase orders) with a value of over €2.2bn. In a ministerial Council year, financial commitments are naturally lower than in the two years following (€10.5bn after Space 19+). 98% of the contracts were below €10m while €1bn was placed on about twenty large projects. Worth mentioning in particular are the large contracts for Eagle-1 (first PPP with the involvement of the EU), FORUM, Galileo 2nd Generation, Comet Interceptor, Hera, Luna and the procurement actions for IRIDE (€1bn of Italian National Recovery Fund delegated to ESA).Together with the Industrial Audit services, a new profit policy has been put in place as well as a coordinated position for handling the impact of inflation on industrial contracts, leading to particularly difficult negotiations during 2022. The Industrial Audit Plan was successfully completed, including audits related to the Soyuz launch cancellation performed

jointly with European Commission auditors under ESA lead, as well as those related to the Ariane 6 Transition Phase.

An Implementing Instruction for Call for Proposals has been put in place, as a first step towards harmonising "close to market" activities.

FINANCE, PLANNING AND CONTROL

The Finance Department actively supported the preparation of CM22 with financial and sustainability analyses for the ESA Executive Board, programme boards and Council Working Group, as well as Member State consultations concerning budget affordability and subscription simulations.

Financial Accounting and Operations

With its 2022 accounts, ESA aims to repeat its 2021 achievement, which marked 10 years of unqualified financial statements and, for the first time, zero audit recommendations, thus fostering continued stakeholder confidence in ESA's financial management.

Using highly digitalised processes, ESA completed over 36,000 payment transactions, incorporating special measures for industry through the COVID-19 and Ukraine crises, with an average time-to-payment of 13.5 calendar days versus ESA's 30-day contractual terms. Digitalisation continued in invoice processing and travel expense management.

Treasury management performed extremely well, despite high volatility, and launched a treasury management system implementation.

Financial Highlights

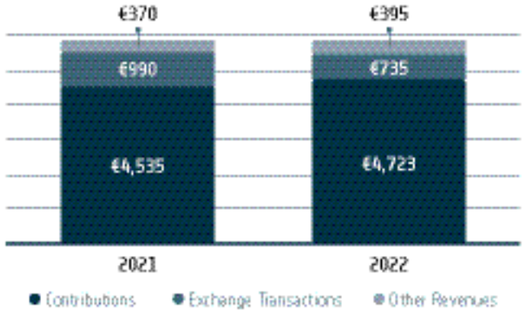
2022's Financial Highlights are based on the unaudited 2022 ESA Financial Statements. The ESA Financial Statements 2022 will be audited by the Audit Commission of the European Space Agency in accordance with the International Standards on Auditing (ISA).

The audited ESA Financial Statements and the Independent Auditor's report will be submitted to Council in accordance with the ESA Financial Regulations and approved at the Council meeting on 28 June 2023.

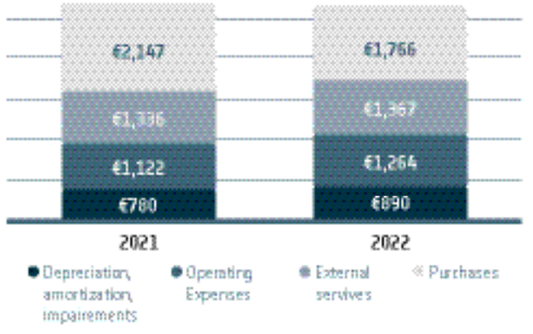
The Financial Highlights presented herewith consist of the following two components:

- Financial Position (ESA consolidated) and
- Financial Performance (ESA consolidated).

REVENUES COMPARISON 2021 & 2022 (M€)

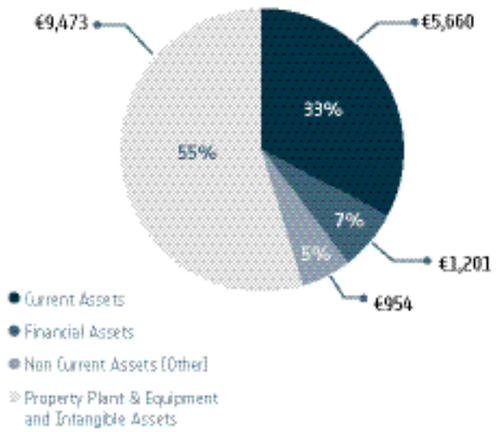


EXPENSES COMPARISON 2021 & 2022 (M€)

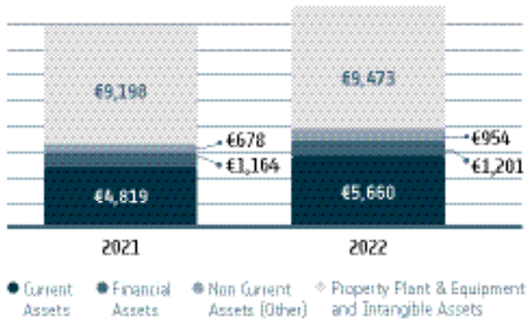


FINANCIAL POSITION 2021/2022 (M€)

ASSETS CATEGORIES 2022 (M€)

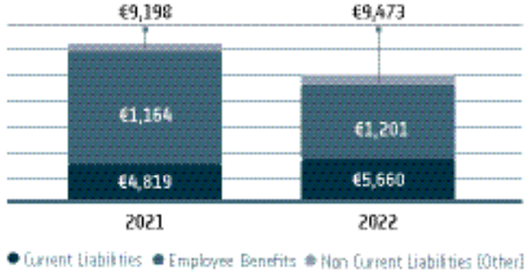


ASSETS COMPARISON 2021 & 2022 (M€)



LIABILITIES CATEGORIES 2022

LIABILITIES COMPARISON 2021 & 2022



Corporate Planning, Budgeting and Controlling

The outcome of CM22 was integrated into 2023 budgets, the Long-Term Plan and multi-year Agency financial plans, and strategies developed to deal with inflationary pressures. 2023 cost plans were endorsed by programme boards and Council adopted the 2023 budgets (€7.1bn including third-party activities).

Digitalisation progressed including the successful deployment of the enhanced Digital Subscription Tool (DST) for Member States and financial KPIs for management dashboards as well as analyses for Agency planning and monitoring.

Workforce Management

Following the ambitious package approved at the 2022 Council meeting at ministerial level, the ESA Council approved in December an increase in the staff ceiling to cope with new initiatives to be implemented in addition to those already approved. Recruitment activity was intense in 2022 (up 13% over 2021) accompanied by the recruitments of 27 Junior Professionals. The Agency pursued its efforts aimed at reinforcing compliance with national labour legislation and is reviewing the overall Agency Resource Strategy that will drive the future sourcing of manpower resources.

Member States	Hors Classe	A	L	B	C	Total Staff
Austria	1	32	1	2		33
Belgium	1	111		4		116
Czech Republic		9				9
Denmark		10		1		11
Estonia		4		2		6
Finland		21		2		23
France	3	530	9	51	4	597
Germany	2	459	4	31		496
Greece		27		2		29
Hungary		9		1		10
Ireland		15		2		118
Italy	1	377	1	14		392
Lithuania		1				1
Luxembourg		5				5
Norway		25		2		27
Poland		33		1		34
Portugal		33		2		35
Romania		37		1		38
Slovenia		2		1		3
Spain	1	216		3		220
Sweden		35		2		37
Switzerland	1	24		1		26
The Netherlands		61		9		70
United Kingdom	1	260	2	18		281
Total	**11**	**2336**	**17**	**152**		**2520**
Non-Member States						
Canada		26		1		27
Total		**26**		**1**		**27**
Grand Total	**11**	**2362**	**17**	**153**	**4**	**2547**

LEGAL SERVICES

In 2022, ESA's Legal Services Department served the Council and its subordinate bodies as well as the preparation and implementation of the Agency's programmes and activities. Most notably, the Department was instrumental in the preparation and conduct of the Council meeting at ministerial level held in Paris in November, with the following resolutions being among the noteworthy outcomes:

- Resolution on ESA Accelerating the Use of Space in Europe (ESA/C-M/CCCXIII/Res.1 (Final));
- Resolution on the Level of Resources for the Agency's Mandatory Activities 2023-2027 (ESA/C-M/CCCXIII/Res.2 (Final));
- Resolution on the CSG (2023-2027) (ESA/C-M/CCCXIII/Res.3 (Final));
- Resolution on ESA programmes and activities (ESA/C-M/CCCXIII/Res.4 (Final)).

In addition, the Legal Services Department accompanied the drafting and negotiation of more than twenty international agreements, concluded with governments, international organisations and institutions of both Member States and non-Member States, thereby enabling increased international cooperation in space applications, human spaceflight and exploration, science, space transportation and many other domains. In October, ESA welcomed Slovakia as its fourth Associate Member, following the ratification and entry into force of the respective Association Agreement.

CORPORATE SOCIAL RESPONSIBILITY

2022 was a crucial year for ESA in terms of reducing its environmental footprint and increasing the contribution of its programmes and activities to sustainability. The ESA Council meeting at ministerial level (CM22) approved, on the one hand, programmes whose benefits will contribute to the sustainable development of society and, on the other hand, the ambitious ESA Green Agenda, aimed at reducing the Agency's greenhouse gas (GHG) emissions in line with the objectives of the Green Deal and the Paris Agreements.

By mid-2022 a complete evaluation of ESA GHG emissions in 2019 had been completed and now constitutes the baseline against which the Agency will measure its progress towards its mid-term (2030) and long-term (2050) targets.

After several months of preparation, CM22 was also the opportunity to gather ESA and public and private organisations from the European space sector to sign a Statement for a Responsible Space Sector, thereby demonstrating their commitment to the long-term sustainability of space projects and paving the way for the social and environmentally responsible management of all space sector activities.

As of early 2022, the signatory organisations have been working together on specific topics related to the scope of the Statement, notably common pathways towards the decarbonisation of the space sector, responsible procurement, and life-cycle assessment and eco-design applied to space products and systems.

Further information about ESA's achievements and progress towards its sustainability goals can be found in the ESA Corporate Sustainability and Responsibility Report 2020–2021 published in 2022.

COMMUNICATION

In 2022, there was a continued focus on the OneESA strategic objective, both externally and internally. OneESA places the focus on stronger cooperation with ESA Member States and their general publics as well as enhancing leadership communication with the following concrete objectives in mind:

- Establishing a stronger cooperation gateway with all ESA Member States by enabling more proactive joint communication activities, improve the sharing of multilingual content (such as webstories, videos, animations, infographics and printed brochures) and new digital tools such as the ESA Web TV channel, digital travelling exhibitions and interactive publications.
- Further reinforcing and improving Internal Communication by reaching the critical mass of resources and presence at all ESA sites and hubs, creating opportunities for ESA staff to connect.
- Expanding the marketing activities using the ESA brand in partnership with companies and media through licensing and merchandising agreements, reaching out to sectorial domains where ESA is not yet present.
- Strengthening leadership communication to support the new European space ambitions set out in Agenda 2025.

RELATIONS WITH MEMBER STATES

In 2022 the Director General regularly visited and exchanged with Member States, often taking the opportunity offered by major events. This included appointments with ministers and politicians in charge of space matters and related fields, as well as with delegations. The preparation of CM22 in November was a particular focus of this interaction, for example in the form of Council Working Group meetings. Moreover, the Director General addressed parliaments, industry, academic institutions, associations, and the media whenever possible. In parallel, the Executive remained in continuous and close touch with relevant national counterparts.

Signature of the Association Agreement by the Slovak State Secretary for Science, Research and Higher Education, Mr Ľudovít Paulis at ESTEC, on 14 June 2022

EXTERNAL RELATIONS

Relations with European Union Institutions

In 2022, relations between the European Union (EU) and ESA were reinforced and major milestones were achieved. On 16 February, EU and ESA Member States met at ministerial level in Toulouse for a European Space Summit. The Summit was in two parts: a formal ESA Council meeting at ministerial level and an informal EU Competitiveness Council meeting on space. The French Presidency of the European Space Agency and of the European Union chaired the meetings, reflecting the close and growing cooperation between the EU and ESA. Member States agreed to work over the coming months on tangible proposals to improve space traffic management. The objective is twofold: to increase Europe's operational capacities and to put forward common rules at EU level that will subsequently be advocated for at international level. Ministers also reaffirmed their strong political support for the Accelerators and Inspirators identified by ESA to address challenges — from the climate-change-induced crisis and consequences thereof to threats to crucial European infrastructure in space and on Earth. They also confirmed their ambitious plans to work closely together to "accelerate" Europe as a world leader in space. During CM22, ESA Member States also reaffirmed the need to define the future direction of ESA space exploration policy. The proposal to create an independent expert group tasked with advising on possible options in terms of human and robotic space exploration and human spaceflight was hailed. It was decided that a follow-up Space Summit should be held in 2023.

International Relations

Cooperation with EU member states that are not members of ESA continued through Association (with Slovenia, Latvia, Lithuania, and Slovakia, the latter joining on 13 October), reinforced cooperation (new European Cooperating State agreements were concluded with Cyprus and Bulgaria, on 19 November 2021 and 15 February 2022, respectively), and

general cooperation (ESA is finalising the negotiations on the next steps in its relations with Croatia and Malta). Associate Members subscribed to optional programmes at CM22 in accordance with their priorities and capabilities, including a significant enlarged participation of Slovenia.

The mutually beneficial cooperation with Canada was successfully pursued through multiple activities. At CM22, Canada joined the Space Safety optional programme for the first time.

The most visible achievement of ESA-NASA cooperation in 2022 was the inaugural flight of the Space Launch System which successfully deployed the Orion capsule and its European Service Module during the Artemis 1 mission. The decision to extend ESA ISS operations until 2030 was takenat CM22. ESA astronauts Mathias Maurer and Samantha Cristoforetti successfully concluded a one-and-a-half-year period of continuous European presence on board the ISS.

Several agreements between ESA and NASA were formalised including a Memorandum of Understanding (MoU) on the Lunar Pathfinder mission, a Framework Agreement for a Strategic Partnership in Earth System Science and an MoU on the cooperation on Science and Sample Management of the Mars Sample Return Campaign. ESA and NASA highlighted their mutual interest in potential future lunar and Mars cooperation in a series of non-binding joint statements.

The NASA-ESA-CSA James Webb Space Telescope delivered breakthrough scientific returns.

The Russian invasion of Ukraine had multiple consequences. Soyuz launch operations from Europe's Spaceport in French Guiana (the CSG) were unilaterally halted by the Russian space agency Roscosmos. The ESA Council discontinued the cooperation with Roscosmos on lunar robotics exploration and terminated cooperation on the ExoMars Rover and Surface Platform mission.

ESA-China relations continued to progress, regretfully without opportunities for face-to-face meetings. Cooperation progressed on the SMILE mission (Solar wind Magnetosphere Ionosphere Link Explorer), which aims to build a more complete understanding of the Sun-Earth connection by measuring the solar wind and its dynamic interaction with the magnetosphere. Cooperation also progressed on the Einstein Probe, a mission dedicated to time-domain high-energy astrophysics, the primary goals of which are to discover high-energy transients and monitor variable objects. ESA and China are planning, in 2023, to hold the mid-term review of the fifth edition of the Dragon programme, which focuses on the exploitation of Copernicus Sentinels, Chinese, ESA and ESA Third-Party mission Earth observation data for geo-science and applications development. There are 55 joint Chinese and European teams addressing science and application development in ten topics relating to Earth system science.

Signature of a new PECS Charter by Bulgarian Deputy Minister of Innovation and Growth, Ms Karina Angelieva at ESTEC, on 14 June.

Signature of a Joint Statement on Lunar cooperation activities with NASA administrator Bill Nelson in Paris, on 19 September 2022.

The Director General and the President of the Japanese Aerospace Exploration Agency (JAXA) met twice to take stock of current ESA-JAXA cooperative activities. Both agencies were focused on the implementation of the many joint projects reinforcing bilateral relations.

The cooperation agreement with the Indian Space Research Organisation (ISRO) was extended by a further period of five years. The Director General and the Chairman of ISRO acknowledged in September the tight bilateral cooperation on a ground station network and ground operations.

The Director General met the Head of the Australian Space Agency to further discuss possible joint space application activities. He also met with the new Head of the New Zealand Space Agency, with whom he agreed to establish a regular dialogue on space debris.

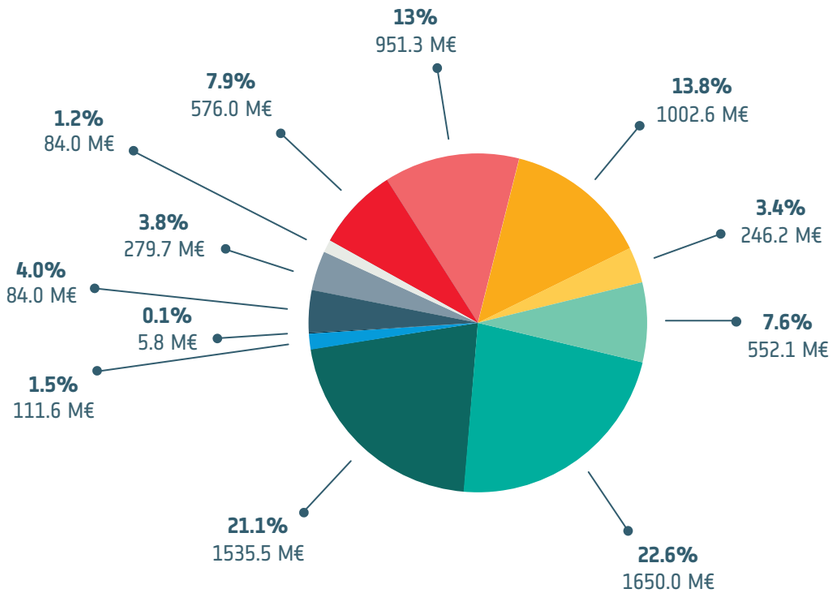
ESA celebrated the tenth anniversary of the Deep Space Antenna located in Malargüe, Argentina on 5–11 December.

School visit to DS-3, Malargüe, Argentina, December 2022.

Income

ESA Mandatory Activities (including the General Budget and Scientific Programme) and activities associated with the General Budget are financed by Member and Participating States' contributions. ESA Optional Programmes are financed by Member and Participating States' contributions, and for some programmes, also by other entities, including the European Union and EUMETSAT. For Optional Programmes, Participating States declare a voluntary subscription on a multi-annual basis. Third Party Programmes, managed by ESA, are fully financed by third parties.

ESA 2022 BUDGET BY DOMAIN

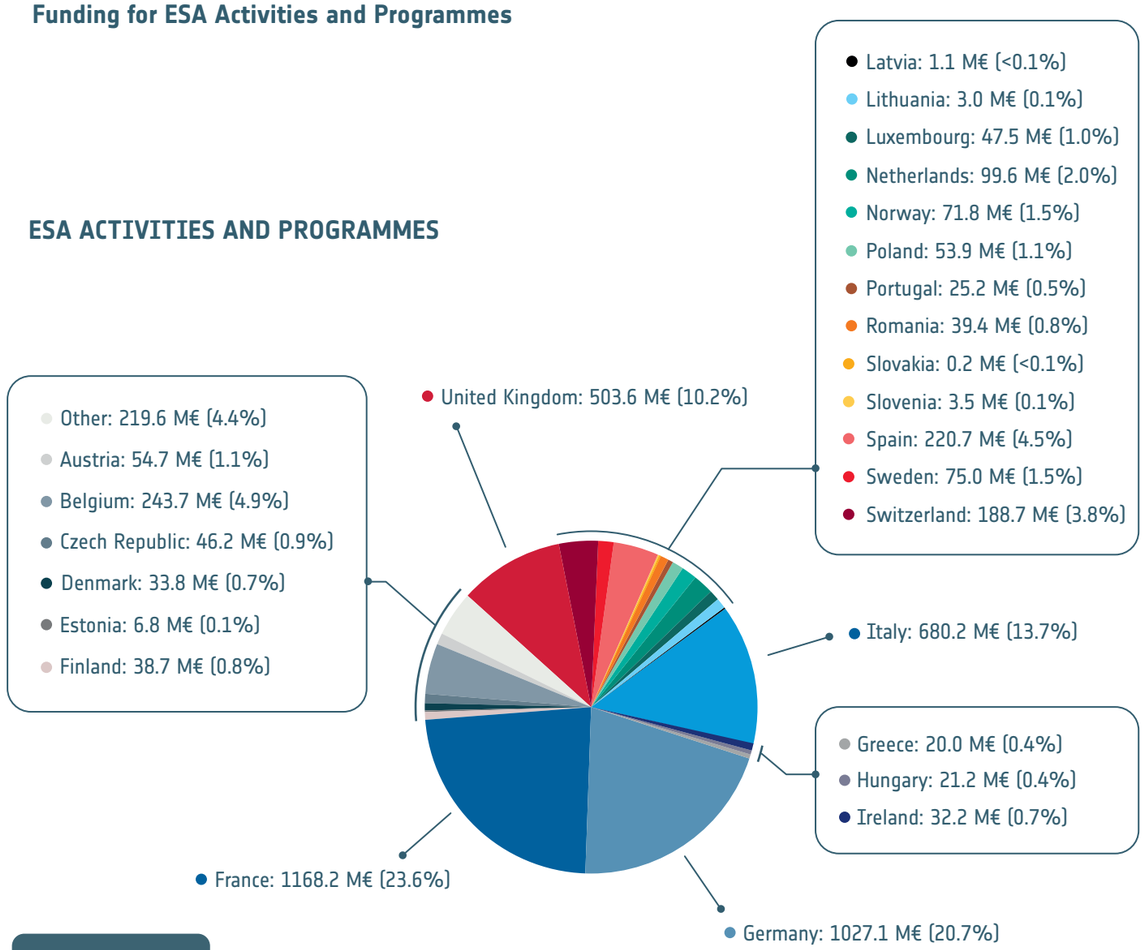


- Scientific Programme
- Human and Robotic Exploration
- Space Transportation
- Technology Support
- Telecom & Integrated Applications
- Earth Observation
- Navigation
- Space Safety
- European Cooperating States Agreements
- Basic Activities
- Associated with General Budget
- Prodex

TOTAL 7.3 B €

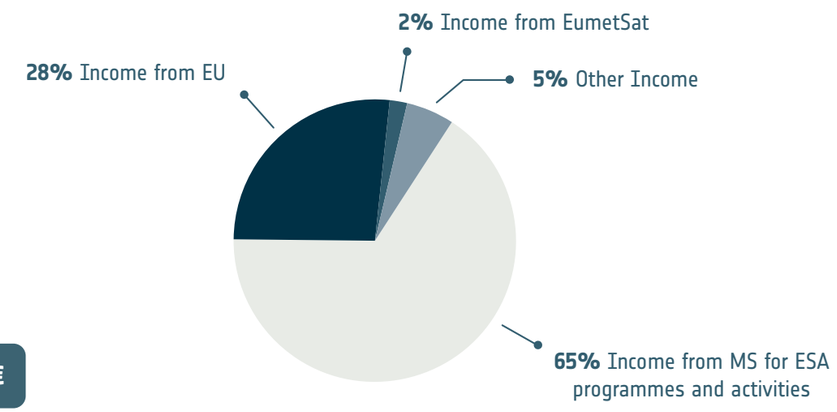
Funding for ESA Activities and Programmes

ESA ACTIVITIES AND PROGRAMMES



TOTAL 5.0 B €

BUDGET 2022 BY FUNDING SOURCE



TOTAL 7.3 B €

Cost

ESA's total cost in 2022 amounted to €7,367M, of which €5,023M related to ESA programmes and activities and €2,344M to Third Party activities.

Mandatory Activities represented 11% (€800M), 55% was accounted for by Optional Programmes (€4,094M), 2% by activities associated to the General Budget (€130M), 32% by programmes financed by Third Parties (€2,344M).

The majority of cost accrued in 2022 by domain is provided below.

Basic Activities: Discovery, Preparation & Technology Development (37%), Mission Operations Infrastructure (13%), Sites & Common IT Investment (13%) and Engineering Labs & Test Centres (13%)

Scientific Programme: Missions in implementation (53%) Missions in operation (23%), Mission Preparation (17%)

Space Transportation: LEAP Ariane 5 Supplementary (22%), Ariane 6 Development (14%), Ariane 6 & P120C Transition (12%) and Space Rider Step 2.2 (5%)

Earth Observation: Copernicus Space Component (33%), EOEP Period 5 (12%), Future EO (11%), MetOp Second Generation Development (11%)

Human and Robotic Exploration: Mars Sample Return (20%), Orion-ESM Batch A (16%), Gateway (15%) and Orion-ESM Flight Models 1 to 3 (9%)

Telecom and Integrated Applications: Core Competitiveness (41%), PARTNER (29%) and IAP/BASS (17%)

Technology Support: General Studies Technology Programme R&D (89%) and Proba-3 (11%)

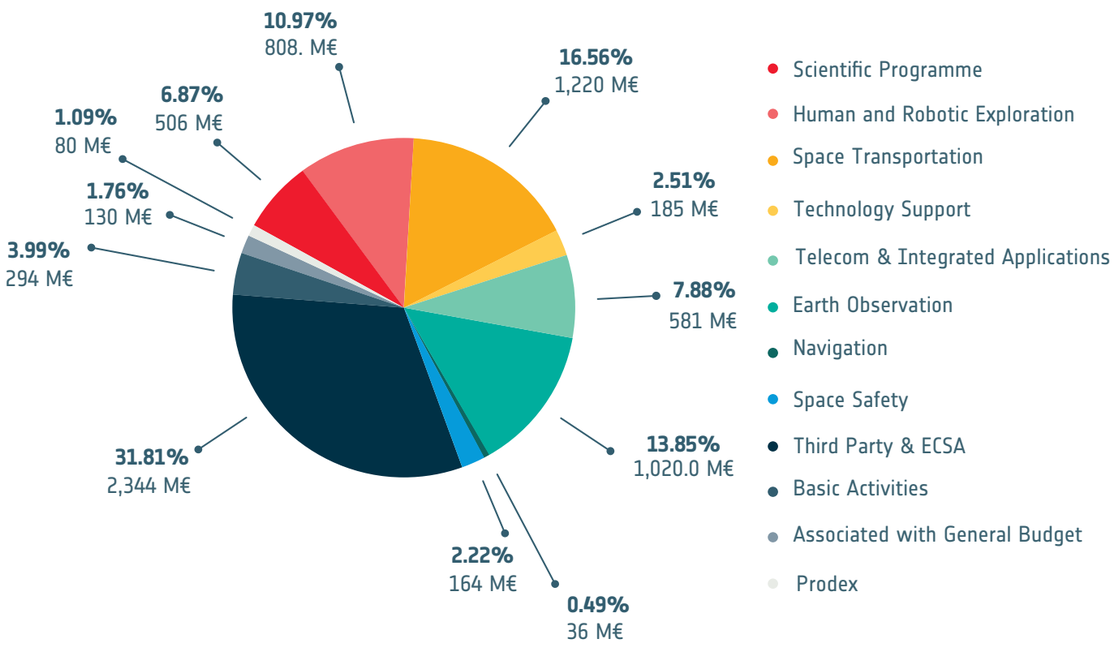
Space Safety: HERA Mission (57%) and Core activities (25%)

Navigation: NAVISP (99%)

Third party: EU programmes, Galileo FOC DC - GSA – EUSPA (53%) in Navigation and Copernicus MFF (26%) in Earth Observation

Associated to General Budget: CSG 2020-2024 (86%)

COST (€MILLION)



Notes to the Financial Statements

As required by the ESA Financial Regulations, the Agency's annual Financial Statements are prepared in accordance with International Public Sector Accounting Standards (IPSAS) since 2010.

The Financial Information presented herewith was extracted from the audited ESA Financial Statements for the financial year 2022. This Financial Information consists of the following extracted components:

- Statement of Financial Position;
- Statement of Financial Performance;
- Statement of Changes in Net Assets/Equity;
- Statement of Cash Flows.

In 2022 special attention was paid to the consolidation of earlier achievements. The following actions were undertaken and will continue to be pursued in the coming years:

- continued optimisation of the interim and year-end closure process and further automation of the production of the Financial Statements;
- successful implementation of an Optical Character Recognition tool, based on Artificial Intelligence and machine learning, to semi automate the registration of low value invoices;
- further roll-out of a procedure for manual journal entry testing within Income Management;
- continuation of the accounting risk assessment review of significant purchase contracts;
- successful implementation of the new strategy for the physical inspection of assets;
- further automation of the process for collecting accruals.

The Net Surplus of 2022 amounts to 452.3 M€, after capitalisation of Assets Under Construction and work-in progress, as compared to a Net Surplus of 586.4 M€ in 2021.

The decrease of the 2022 result by 134.1 M€ compared to 2021 is mainly due to the slight decrease of operating revenue by 42.0 M€ and decreased operating expenses by 87.0 M€.

The 2022 net surplus breaks down into:

- 800.4 M€ net surplus for ESA activities and programmes (788.0 M€ net surplus in 2021)
- 359.9 M€ net deficit for Pensions (213.1 M€ net deficit in 2021)
- 11.8 M€ net surplus for Social Security (11.5 M€ net surplus in 2021)

The Financial Information presented hereinafter, was extracted from the ESA Financial Statements 2022.

ESA Financial Statements 2022 also include a summary of significant accounting policy and Notes to the Financial Statements, and were audited by the Audit Commission of the European Space Agency. The Audit Commission conducted its audit in accordance with the International Standards on Auditing (ISA). As required by the Financial Regulations, this audit included also the aspect of regularity. In the Audit Commission's opinion, the 2022 audited Financial Statements give a true and fair view of the Financial Position of the European Space Agency as at 31 December 2022, and of its Financial Performance and its Statement Cash Flows for the 12 month period ended 31 December 2022, in accordance with International Public Sector Accounting Standards (IPSAS).

Concerning the aspect of regularity, the Audit Commission reported that nothing came to its attention, which would indicate that the transactions of ESA have not been made, in all significant respects, in accordance with the Regulations of the European Space Agency.

The audited Financial Statements and the Independent Auditor's report were submitted to the Council in accordance with the ESA Financial Regulations, which were approved by the Council Meeting on 28 June 2023.

I. STATEMENT OF FINANCIAL POSITION

	Notes	31 december 2022 million €	31 december 2021 million €
Total Assets		**17,275.5**	**15,859.4**
Current assets		**5,659.8**	**4,819.1**
Cash and cash equivalents	3.1	3,194.4	1,954.4
Recoverables from non-exchange transactions	3.2	167.5	234.5
Receivables from exchange transactions	3.3	1,656.5	2,151.8
Inventories	3.4	641.3	478.4
Non-current assets		**11,615.8**	**11,040.3**
Recoverables from non-exchange transactions	3.2	12.0	12.0
Receivables from exchange transactions	3.3	925.6	666.4
Financial assets	3.5	1,200.8	1,164.2
Property, plant and equipment	3.6	9,144.9	8,874.6
Intangible assets	3.6	332.5	323.1
Total Liabilities		**10,007.2**	**12,528.5**
Current liabilities		**3,748.1**	**3,248.6**
Payables under exchange transactions		**3,146.1**	**2,720.6**
Current payables	3.7	1,410.6	1,516.7
Pre-financing from exchange transactions	3.8	1,486.6	1,072.7
Deferred income	3.9	249.0	131.2
Contributions and other payables		**249.6**	**234.1**
Prepaid contributions and other amounts payable to Member/Participating States	3.1	182.4	201.7
Pre-financing from non-exchange transactions		3.0	2.4
Other payables	3.11	64.2	30.0
Employee benefits obligations	**3.12**	**270.7**	**232.7**
Provisions	**3.13**	**81.6**	**61.2**
Non-current liabilities		**6,259.2**	**9,279.9**
Employee benefits obligations	3.12	5,512.7	8,749.3
Other payables	3.11	392.2	229.0
Deferred income	3.9	287.8	280.7
Pre-financing from non-exchange transactions		0.2	0.0
Pre-financing from exchange transactions	3.8	66.3	20.9
Net Asset		**7,268.3**	**3,330.9**
Reserves		**10,647.3**	**6,352.4**
Amounts to be called from Member States	**3.14**	**-3,831.3**	**-3,618.3**
Net Surplus/ (Deficit) for the period	**II**	**452.3**	**586.4**
Net Assets		**7,268.3**	**3,330.9**

II. STATEMENT OF FINANCIAL PERFORMANCE

	Notes	2022 million €	2021 million €
Operating Revenues	**4.1**	**5,853.5**	**5,895.5**
Contributions from Member/Participating States		4,723.0	4,534.5
Other contributions and grants		26.2	26.6
Revenues from exchange transactions		735.3	990.9
Staff contributions		64.4	55.3
Other operating income		304.6	288.2
Operating Expenses	**4.1**	**-5,297.7**	**-5,384.7**
Purchases		-1,796.6	-2,146.8
External Servicies		-1,367.2	-1,336.0
Staff expenses		-765.2	-745.5
Other Operating expenses		-304.9	-273.6
Expenses from non-exchange transaction (*)		-193.5	-103.3
Depreciation and amortization		-698.6	-738.8
Impairment		-134.9	0.1
Write-downs inventories and fixed assets, doubtful debts, provisions for future losses		-36.8	-40.8
Net Surplus / (Deficit) from Operating activities		**555.8**	**510.8**
Financial Activities	**4.2**	**-103.5**	**75.6**
Financial revenue		26.4	99.8
Financial expenses		-129.9	-24.2
Net Surplus / (Deficit) for the period		**452.3**	**586.4**

(*) Expenses from non-exchange transactions are mainly related to the ESA/Arianespace Contract concerning the Ariane supplementary exploitation accompanying activities of the LEAP (the "LEAP Supplementary Frame Contract") (see also Note 3.11.1)

III. STATEMENT OF CHANGES IN NET ASSETS

		31 December 2021	Allocation of audited 2021 surplus/ (deficit)	2022 Net Surplus	Change in the present value of the Employee Benefit Defined Benefit Obligation	Fair Value adjustments	Transfers between reserves	Other changes	31 December 2022
		million €	million €	million €	million €	million €	million €	million €	million €
RESERVES	**A**	**4,152.3**	**1,202.2**		**1,017.8**	**-9.1**	**0.0**	**-0.4**	**6,362.8**
Member States Capital and Reserves		**-4,273.8**	**70.9**		**1,017.8**	**-9.1**	**-1.5**		**-3,195.5**
Revaluation Reserve		1,085.2	-258.5				-1.5		825.2
Currency Exchange Gains Reserve		3.1	-1.5				0.1		1.7
Sundry Reserves		0.1							0.1
Other Reserves		-5,362.1	330.9		1,017.8	-9.1			-4,022.5
Social security reserve		36.8	9.1			-0.7			45.2
Buffer Fund fair value reserve		15.2				-8.4			6.9
Reserve Barter		-405.7	321.8						-83.9
Actuarial gains and losses		-5,008.5			1,017.8				-3,990.7
Accumulated Surplus		**8,426.0**	**1,131.3**				**1.5**	**-0.4**	**9,558.3**
Accumulated Surplus ESA programmes		8,301.3	1,104.7				1.5		9,407.5
Accumulated Surplus Third Party programmes		104.2	27.9					-0.4	131.7
Accumulated Surplus PECS		20.4	-1.3						19.1
AMOUNTS TO BE CALLED FROM MEMBER STATES	**B**	**-3,375.0**	**-243.2**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**-3,618.3**
Member States pension scheme receivable		-3,375.0	-243.2						-3,618.3
Accumulated Deficit									
Net Surplus / (Deficit) for the Period	**C**	**959.0**	-959.0	586.4					586.4
TOTAL NET ASSETS	**A+B+C**	**1,736.3**	**0.0**	**586.4**	**1,017.8**	**-9.1**	**0.0**	**-0.4**	**3,330.9**

		31 December 2021	Allocation of audited 2021 surplus/ (deficit)	2022 Net Surplus	Change in the present value of the Employee Benefit Defined Benefit Obligation	Fair Value adjustments	Transfers between reserves	Other changes	31 December 2022
		million €	million €		million €	million €	million €	million €	million €
RESERVES	**A**	**6,362.8**	**799.5**		**3,537.0**	**-53.3**	**0.0**	**1.5**	**10,647.3**
Member States Capital and Reserves		**-3,195.5**	**-339.1**		**3,537.0**	**-53.3**	**15.0**	**-0.1**	**-35.9**
Revaluation Reserve		825.2	-139.6				15.0		700.6
Currency Exchange Gains Reserve		1.7	0.9						2.6
Sundry Reserves		0.1						-0.1	0.0
Other Reserves		-4,022.5	-200.4		3,537.0	-53.3			-739.2
Social security reserve		45.2	11.5			-5.2			51.5
Buffer Fund fair value reserve		6.9				-48.1			-41.2
Reserve Barter		-83.9	-211.9						-295.8
Actuarial gains and losses		-3,990.7			3,537.0				-453.8
Accumulated Surplus		**9,558.3**	**1,138.6**				**-15.0**	**1.6**	**10,683.3**
Accumulated Surplus ESA programmes		9,407.5	1,165.8				3.1	1.6	10,578.0
Accumulated Surplus Third Party programmes		131.7	-28.2				-18.1		85.3
Accumulated Surplus PECS		19.1	1.0						20.0
AMOUNTS TO BE CALLED FROM MEMBER STATES	**B**	**-3,618.3**	**-213.1**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**-3,831.3**
Member States pension scheme receivable		-3,618.3	-213.1						-3,831.3
Accumulated Deficit									
Net Surplus / (Deficit) for the Period	**C**	**586.4**	-586.4	452.3					452.3
TOTAL NET ASSETS	**A+B+C**	**3,330.9**	**0.0**	**452.3**	**3,537.0**	**-53.3**		**1.5**	**7,268.3**

IV. STATEMENT OF CASH FLOWS

	31 December 2022 million €	31 December 2021 million €
Net Cash Flows	**1,240.0**	**381.0**
Net Cash Flows from Operating Activities	**2,555.2**	**1,588.3**
Surplus/(deficit) from ordinary activities	452.3	586.4
Reclassification to investing activities	**-2.1**	**-43.0**
Non-cash movements	**968.3**	**732.0**
Depreciation and impairment	833.5	738.8
Provisions and Accruals	20.0	34.7
Write-downs / Adjustments inventories and fixed assets, provisions for future losses on inventories	16.5	-0.6
Revaluation of financial assets at fair value	98.4	-40.8
Decrease (Increase) in Deferrals/accruals of past or future operating cash receipts or payments	**1,136.7**	**312.9**
Decrease/(increase) in inventories	-163.6	-127.1
Decrease/(increase) in recoverables from Member States	66.2	23.7
Decrease/(increase) in other receivables	-62.0	214.2
Decrease/(increase) in other current assets	299.3	-935.3
Increase/(decrease) in payable to Member/Participating States	-17.8	37.3
Increase/(decrease) in pre-financing	460.1	124.5
Increase/(decrease) in other payables	216.1	618.4
Increase/(decrease) in provisions for employee benefits	338.3	357.3

	31 December 2022 million €	31 December 2021 million €
Net Cash Flows	**1,240.0**	**381.0**
Net Cash Flows from Operating Activities	2,555.2	1,588.3
Net Cash Flows from Investing Activities	**-1,315.2**	**-1,207.3**
Acquisition of fixed assets	-1,129.0	-1,076.9
Proceeds from sales of fixed assets	0.1	0.0
Purchases of financial investments (portfolio)	-384.9	-341.2
Proceeds on disposal of financial investments (portfolio)	192.2	205.2
Interests received on financial assets	6.5	5.6
Net increase/(decrease) in cash and cash equivalents	**1,240.0**	**381.0**
Cash and cash equivalents at the beginning of the year	1,954.4	1,573.4
Cash and cash equivalents at year-end	3,194.4	1,954.4

ANNEX

- Annex 1 – Advisory bodies
- Annex 2 – International Agreements signed in 2022
- Annex 2 – Patent Groups
- Annex 3 – List of events organised in 2022
- List of ESA Publications

ANNEX 1

Advisory bodies

ESA advisory groups can be divided into two categories: advisory groups to ESA delegate bodies and advisory groups to the ESA Director General.

ADVISORY GROUPS TO ESA DELEGATE BODIES

AFC Advisory Group

Pension Buffer Fund Management Board (PBF-MB)

IPC Advisory Groups

- Technology Harmonisation Advisory Group (THAG)
- Technology Advisory Working Group (TA-WG)
- Industrial Policy Evolution Working Group (IPE-WG)

JCB Advisory Groups

- 5G Advisory Committee (5JAC)
- Space Systems for Safety and Security (4S) Advisory Committee
- Optical Communication – ScyLight Advisory Committee (SCOTT)

PB-EO Advisory Group

- Data Operations Scientific and Technical Advisory Group (DOSTAG)

PB-HME Advisory Group

- Exploration and Utilisation Board (EUB)

SEC Advisory Groups

- ESA INFOSEC Panel
- ESA Industrial Security Panel

ADVISORY GROUPS TO THE ESA DIRECTOR GENERAL

Science Advisory Committees

- Space Science Advisory Committee (SSAC)
- Advisory Committee for Earth Observation (ACEO)
- GNSS Science Advisory Committee (GSAC)
- Human Spaceflight and Exploration Science Advisory Committee (HESAC)
- Space Situational Awareness Advisory Group (SSA-AG)

Science Working Groups

- Astronomy Working Group (AWG)
- Life Sciences Working Group (LSWG)
- Physical Sciences Working Group (PSWG)
- Solar System Exploration Working Group (SSEWG)

Other Advisory Groups

- Advisory Communication Committee (ACC)
- Advisory Committee on Education (EXP-ACE).

More information on the various groups can be found in the yearly Council document on the ESA Advisory Structure.

ANNEX 2

International Agreements signed in 2022

LEG/526: The Memorandum of Understanding between the National Aeronautics and Space Administration and ESA concerning the ESA Retroreflector Payload

LEG/527: The Memorandum of Understanding between the National Aeronautics and Space Administration and ESA concerning the Package for Resource Observation and In-situ Prospecting for Exploration, Characterization, and Testing (PROSPECT) Mission

LEG/532: The European Cooperating State Agreement between ESA and the Government of the Republic of Bulgaria

LEG/532, add.1: The Plan for European Cooperating State (PECS) Charter between ESA and the Government of the Republic of Bulgaria

LEG/535: The Memorandum of Understanding between ESA and JAXA concerning the EMS-L instrument and its flight on the ISRO/JAXA Joint Lunar Polar Exploration Mission (LUPEX)

LEG/536: The Implementing Arrangement between ESA and NASA concerning the Provision by ESA of Service Modules for NASA's Orion Crew Vehicle as a Contribution to the Gateway Partnership

LEG/537: The Charter Establishing a European Centre for Space Economy and Commerce

LEG/538: The Agreement between ESA and JAXA concerning network and operations cross-support

LEG/539: The Agreement between ESA and the United States National Oceanic and Atmospheric Administration, National Environmental, Satellite, Data and Information Service (NESDIS) for cooperation on space-based space weather observations

LEG/540: The Implementing Arrangement between ESA and the United States National Oceanic and Atmospheric Administration, National Environmental, Satellite, Data and Information Service (NESDIS) for cooperation on space-based space weather observations

LEG/541, add.1: The Plan for European Cooperating State (PECS) Charter between ESA and the Government of the Republic of Cyprus

LEG/542: The Multilateral Agreement concerning the PLATO mission between the Agenzia Spaziale Italiana (ASI), the Centre National d'Etudes Spatiales (CNES), the Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR), the Ministerio de Ciencia e Innovación del Reino de España (MICINN), the SRON Netherlands Institute for Space Research (SRON), the Swedish National Space Agency (SNSA), the United Kingdom Space Agency (UKSA), and ESA

LEG/543: The Multilateral Agreement concerning the Ariel mission between the Agenzia Spaziale Italiana (ASI), the Centre National d'Etudes Spatiales (CNES), the Ministerio de Ciencia e Innovación del Reino de España (MICINN), the United Kingdom Space Agency (UKSA) and the ESA

LEG/544: The Memorandum of Understanding between the National Aeronautics and Space Administration and ESA concerning Cooperation on Science and Sample Management of the Mars Sample Return Campaign

LEG/545: The Association Agreement between ESA and the Slovak Republic

LEG/546: The Memorandum of Understanding Between ESA and the European Space Policy Institute

LEG/547: The Framework Agreement between the National Aeronautics and Space Administration and ESA for a Strategic Partnership in Earth System Science

LEG/548: The Charter on the establishment of the Space for Climate Observatory

LEG/549: The Cooperation Agreement Between ESA and ASECNA on Satellite Navigation

LEG/550: The Agreement between ESA and the International Space Science Institute (ISSI)

ANNEX 2

Patent Groups

TABLE 1: LIST OF 2021 INVENTIONS THAT ESA DECIDED TO PROTECT

ESA ref	Title	Decision	Name of ESA inventors	Origin of the invention	Ownership
789	UPPER SIDE BAND SYMMETRIC SYNTONIZATION BETWEEN TWO SATELLITES	PCT patent application	M. Martin Neira	In-house work	ESA
780	Confidential- still to be protected	PCT patent application	F. Amarillo	In-house work	ESA
782	DEVELOPABLE WAVEGUIDE COUPLER FOR USE IN MICROWAVE DEVICES	PCT patent application	N. Fonseca	In-house work	ESA
783	"HEURISTIC RADIO RESOURCE MANAGEMENT FOR MASSIVE MIMO IN BROADBAND COMMUNICATION SATELLITES"	PCT patent application	PCT patent application R. de Gaudenzi & P. Angeletti	In-house work	ESA
792	TRANSMIT/ RECEIVE MULTIPLE FEED PER BEAM SINGLE REFLECTOR ANTENNA	PCT patent application	N. Fonseca	In-house work	ESA

TABLE 2: LIST OF ESA PATENTS GRANTED BY PATENT OFFICES IN 2021

ESA/PAT	Title	Country of grant
610	RECONFIGURABLE RF FRONT END CIRCUIT FOR A MULTI-BEAM ARRAY FED REFLECTOR ANTENNA SYSTEM	DE, FR, GB and CH
714	EXOTHERMIC REACTION AIDED SPACECRAFT DEMISE DURING RE-ENTRY	DE, FR, GB, AT and CH
653	HIGH VOLTAGE TOLERANT CMOS DRIVER FOR LOW-VOLTAGE BI-DIRECTIONAL COMMUNICATION BUSES	DE, FR, GB, ES and SE
735	MAGNETIC DAMPING FOR SPACECRAFT STABILISATION AFTER END OF LIFE	FR, GB, DE, PT, IT, ES, BE and US
675	INTERFERENCE-RESILIENT FLEXIBLE TECHNIQUES FOR PAYLOAD RESOURCE ALLOCATION IN BROADBAND SATELLITES	GB, LU, DE, ES, FR
654	A BUS FAILURE DETECTION, PROTECTION AND PROPAGATION PREVENTION CAN TRANSCEIVER ARCHITECTURE FOR LOW-VOLTAGE CMOS PROCESS IMPLEMENTATION	DE, NL, BE, CH, SE, ES, IT, AT, FR, and GB
541	A METHOD FOR COMPENSATING SIGNAL DISTORTION IN AN EMITTING PAYLOAD | PROCÉDÉ DE COMPENSATION DE DISTORSION DE SIGNAUX DANS UNE CHARGE UTILE ÉMETTRICE	IN
702	A DIRECTIONAL COUPLER AND METHOD OF MANUFACTURING THEREOF	US
720	COMPRESSION AND DECOMPRESSION OF FIXED LENGTH DATA STRUCTURES	US

ANNEX 3

List of events organised in 2022

MONTH	EVENT	Ambition messaging
January	Director General's annual press conference	*#AccelerateSpace*
January	World Economic Forum Davos - IFC	*#ESAAmbition*
February	Space Summit, Toulouse	*#ESAAmbition*
April	Launch Minerva mission Samantha Cristoforetti	*#ExploreFarther*
April	Return Cosmic Kiss mission, Matthias Maurer	*#ExploreFarther*
May	Gaia 3rd Data Release	*#Space4Climate*
May	Living Planet Symposium, Bonn, Germany	*#Space4Climate*
June	ILA, Berlin	*#Space4Climate*
July	Webb First results	*#ExploreFarther*
July	First Flight of Vega-C	*#Space4Economy*
July	Farnborough International Air Show	*#AccelerateSpace*
September	IAC Paris	*#AccelerateSpace*
October	Return Minerva mission Samantha Cristoforetti	*#ExploreFarther*
November	Launch of Artemis-1 with ESM-1	*#ExploreFarther*
November	ESA Council meeting at ministerial level CM22	*#ESAAmbition*
November	New European Astronauts Class Announcement	*#ESAAmbition*
December	Return of Artemis-1 with ESM-1	*#ExploreFarther*
December	Launch of the first Meteosat Third Generation satellite from Europe's Spaceport	*#Space4Climate*

LIST OF ESA PUBLICATIONS

PRINTED PUBLICATIONS
The *ESA Highlights* magazine 2022
Space Ambition book
Eleven fact sheets for CM22, with presentation folder
Update and reprint of *This is ESA* in six languages
Space Economy brochure
ESA Crew-4/Dragon VIP launch booklet
ESA Corporate Responsibility and Sustainability Report (SP-1340)
INTERACTIVE PUBLICATIONS
ESA Highlights 2022
One ESA brochure in six languages
This is ESA brochure in 23 languages
ESA Impact 2022 (produced quarterly and editions for Council)

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