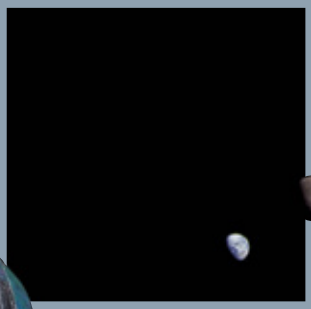
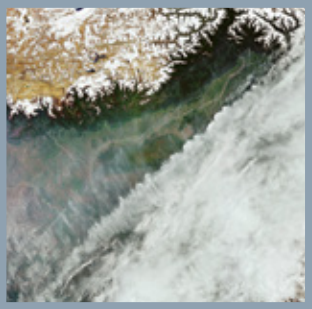
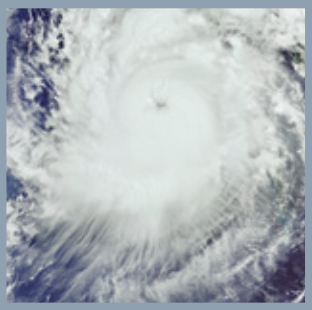
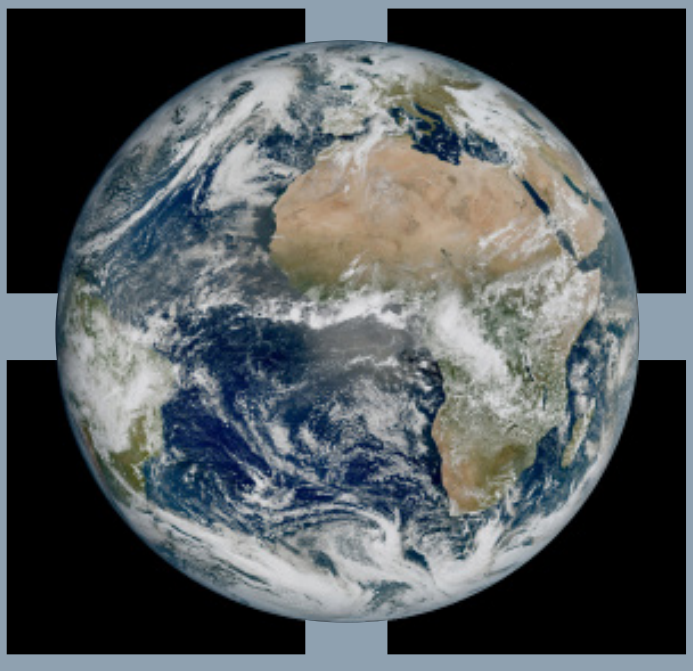
ANNUAL REPORT 2023









ANNUAL REPORT 2023 covers a year of ESA activities, images and events, from 1 November 2022 to 31 October 2023.

Scan for more ESA publications

CONTENTS

02 Foreword

04 ESA's organisational change: shaping excellence

06 The new political heart of ESA

08 We are the European Space Agency

10 Inside ESA

12 Highlights: November 2022 to January 2023

24 The backbone of all space activities

30 Highlights: February to April 2023

42 ESA's icy moons mission

48 Highlights: May to July 2023

60 The quest for a sustainable use of space

66 Highlights: August to October 2023

78 Pioneering secure communication and beyond

84 Annual Report

162 Image credits

ESA Director General Josef Aschbacher at the new ESA Headquarters in Paris, France, in May 2023.

→ THE EUROPEAN SPACE AGENCY

The year 2023 was marked by numerous achievements for the European Space Agency. ESA carried out its activities with remarkable competence, commitment and efficiency – throughout its wide range of programmes and projects.

The list of Agency successes in 2023 is long but I would like to mention just a few that generated a particularly high degree of visibility:

- April saw the launch of JUICE, a mission targeting Jupiter, its icy moons and the oceans below their surface. It will bring insights into our Solar System and its origins, down to the question of whether the icy moons could be habitable for simple forms of life.
- In July Euclid was launched on a mission to explore the composition and evolution of the dark Universe, observing billions of galaxies out to 10 billion light years.
- ESA astronaut Andreas Mogensen began his Huginn mission in August, becoming the first European pilot of Crew Dragon and also serving as Commander of the International Space Station.
- In parallel, the next generation of space explorers has now arrived. Basic training for ESA's new astronaut class began in April, ensuring a sufficient supply of spacefarers for the future.

The year culminated with the Space Summit in Seville where decisions were taken that will harness space for a greener future, result in decisive steps in exploration, and ensure autonomous access to space while preparing a paradigm shift towards a more competitive next generation of launchers. The Summit made clear the strong political support that exists for ESA and its activities.

In all of this, ESA's Agenda 2025 remains the Agency's strategic compass. In line with its priorities, links between ESA and the European Union and other stakeholders have been strengthened, while work has begun on the ESA Transformation, aiming to make the Agency more modern, more efficient and more agile.

The 2023 ESA Annual Report gives many more details about the Agency's unique accomplishments, while demonstrating that investments in ESA yield substantial societal returns. ESA remains a pivotal entity within the European space community. Its activities not only contribute to the strategic capabilities of Europe in space but also enhance the overall welfare of its citizens by bringing the vast potential of space closer to Earth.

Josef Aschbacher
ESA Director General
@AschbacherJosef

“As a priority of Agenda 2025, ESA must start its own internal transformation to become faster, more efficient, more dynamic. I want everyone in the agency to not only feel informed about this transformation, but to take ownership of it. To be a part of the process.”

Josef Aschbacher
ESA Director General

Snapshots from ESA's Transformation Town Hall at the European Space Research and Technology Centre (ESTEC), in February. Attendees included DG Josef Aschbacher, ESA directors, and many employees.

esa AMBITION

TRAN

ESA'S ORGANISATIONAL CHANGE: SHAPING EXCELLENCE

ESA's Transformation is one of the five priorities outlined in Agenda 2025. Boosting ESA's effectiveness and competitiveness in a rapidly changing world is essential if ESA is to remain a modern and attractive workplace that guarantees world-class excellence.

Space activities worldwide are witnessing a rapid revolution thanks to new players, game-changing technologies and increased competition. To meet our ambitions for a green, digital, safe and inclusive Europe, ESA needs to step up its game in space. ESA must become faster, more responsive and more dynamic to implement this vision, and must do this in a way that includes all sectors of society and respects the resources of our planet.

An internal transformation covering all sectors of ESA started in 2023 and will implement concrete changes in the way ESA operates internally and engages with its broader environment from 2024.

S F O R M A T I O N

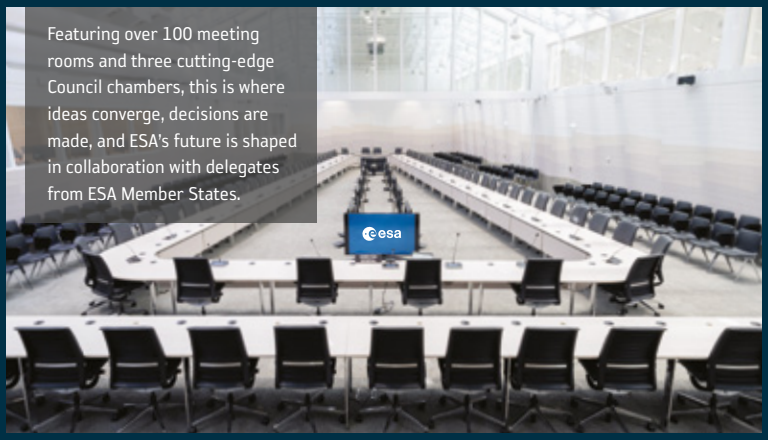
THE NEW POLITICAL HEART OF ESA

In May 2023, ESA officially inaugurated its newly renovated headquarters in the heart of Paris. More than a building, this space stands as a testament to the profound transformation reshaping the very essence of how ESA operates.

Nestled on rue Mario Nikis in the 15th arrondissement, the historic building has been ESA's home since 1976. In 2018, a remarkable five-year transformation commenced.

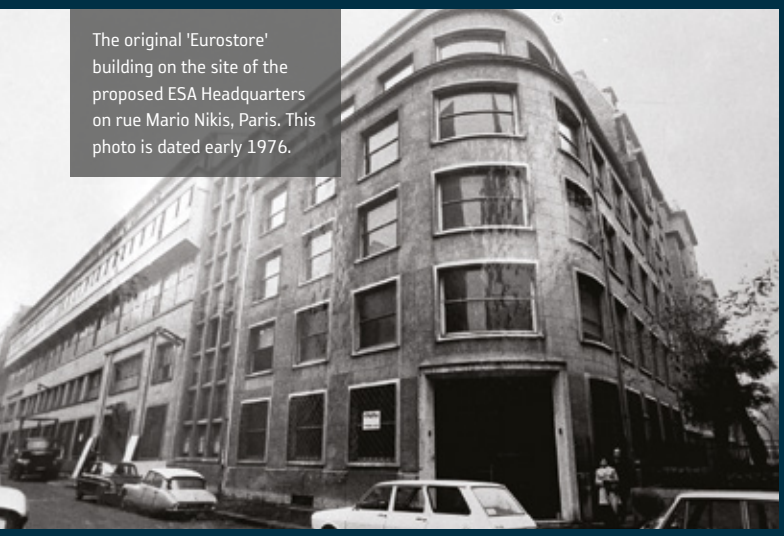
This revamped headquarters isn't just about bricks and mortar; it signifies a paradigm shift. Beyond its imposing facade lies a space meticulously crafted with the latest in design, technology, environmental sustainability, and innovative work environments. Within these walls, ESA's workforce finds itself in a dynamic ecosystem, fostering collaboration through shared areas and open spaces, all aimed at shaping the future of the European space sector.

The building's structure mirrors ESA's intimate connection with astronomy. This celestial spirit permeates the portion now open to the public – the Astrolabe visitor centre and the ESA Space Shop. Here, ESA's mission extends beyond the political and scientific realm; it becomes about sharing the marvels of space with the public, inviting everyone to partake in the grand adventure ESA represents. Welcome to a new era, where the wonders of space are not just explored but experienced.



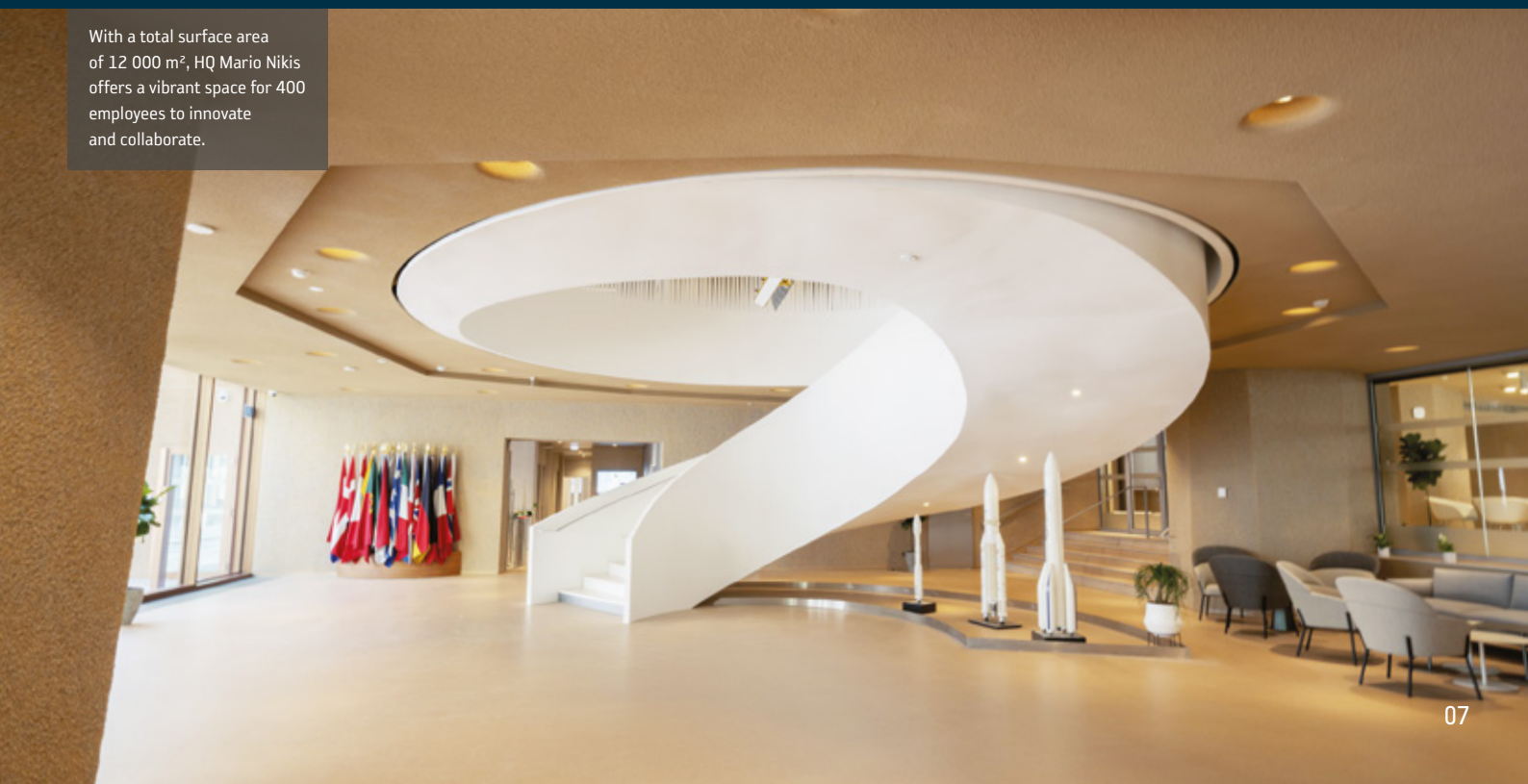
Featuring over 100 meeting rooms and three cutting-edge Council chambers, this is where ideas converge, decisions are made, and ESA's future is shaped in collaboration with delegates from ESA Member States.

Open to everyone, the Astrolabe visitor centre and the ESA Space Shop offer an immersive experience of the wonders of European space activities.



The original 'Eurostore' building on the site of the proposed ESA Headquarters on rue Mario Nikis, Paris. This photo is dated early 1976.

Welcome to the new ESA HQ!



With a total surface area of 12 000 m², HQ Mario Nikis offers a vibrant space for 400 employees to innovate and collaborate.

WE ARE THE EUROPEAN SPACE AGENCY

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

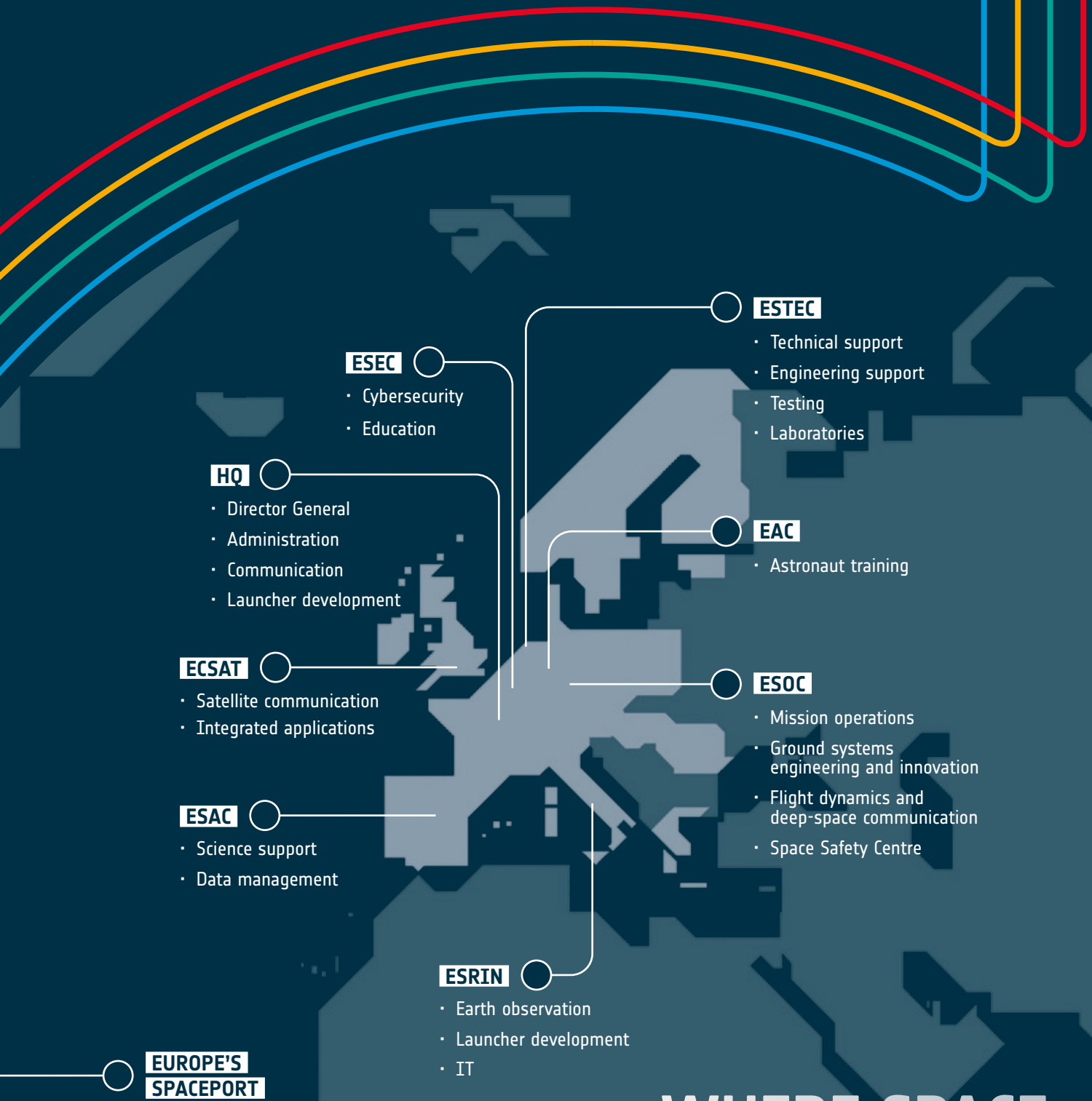
The European Centre for Space Applications and Telecommunications in Harwell, UK, focuses on telecommunications and business applications, as well as climate change, technology and science.

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.

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.



ESTEC
- Technical support
- Engineering support
- Testing
- Laboratories

ESEC
- Cybersecurity
- Education

HQ
- Director General
- Administration
- Communication
- Launcher development

EAC
- Astronaut training

ECSAT
- Satellite communication
- Integrated applications

ESOC
- Mission operations
- Ground systems engineering and innovation
- Flight dynamics and deep-space communication
- Space Safety Centre

ESAC
- Science support
- Data management

ESRIN
- Earth observation
- Launcher development
- IT

EUROPE'S SPACEPORT

WHERE SPACE TAKES PLACE

INSIDE ESA

Four pillars. 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.

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.

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.

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.

CIC

COMMERCIALISATION, INDUSTRY & COMPETITIVENESS

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.

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.

CSC

CONNECTIVITY & SECURE COMMUNICATIONS

Satellite communication underpins everyday life, enabling faster connectivity, as well as more efficient transport, healthcare, safety and security measures, environmental services and much more. This directorate 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.

NASA
esa

ESA's European Service Module powered NASA's first Orion spacecraft to the Moon and back. The ESM provided propulsion, temperature control, fuel, water, and air. The mission was uncrewed, testing spacecraft performance and operations in preparation for sending astronauts to the Moon. This image was taken on day 13 of the 25-day mission, at nearly maximum distance from Earth.

SELECTED HIGHLIGHTS

November 2022 to January 2023

The year concluded with a crucial inaugural step in the mission to return humans to the Moon.

The year 2022 bid farewell with the completion of the Artemis I mission, and a stellar performance by ESA's European Service Module (ESM). NASA's Orion spacecraft splashed down in the Pacific Ocean on 11 December, after travelling around the Moon and farther than any spacecraft designed to carry humans. The next ESMs are already in production.

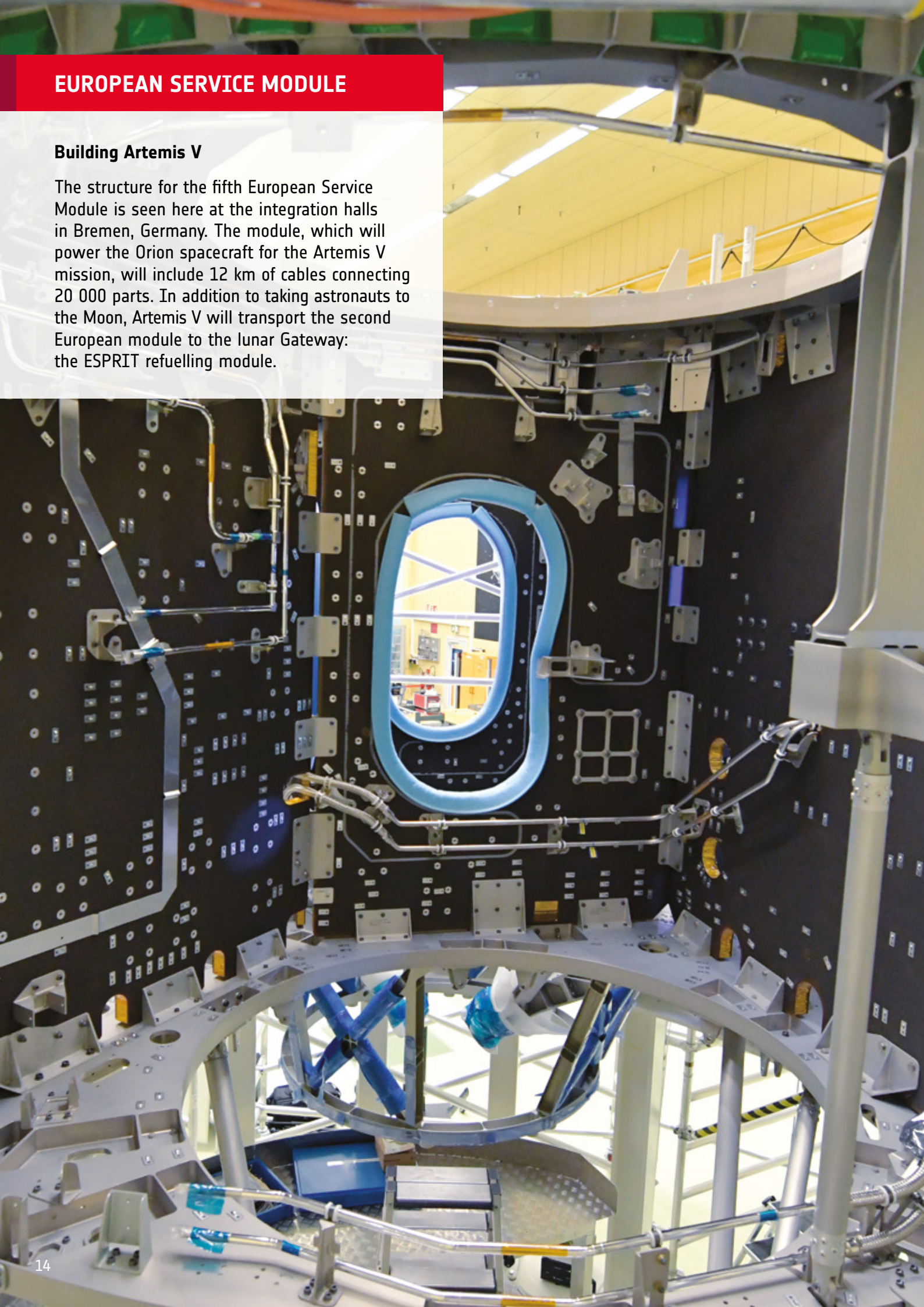
Shortly after, another important mission commenced, with the first Meteosat Third Generation Imager (MTG-I1) satellite lifting off on an Ariane 5 rocket from Europe's Spaceport in French Guiana. Once fully operational, this advanced weather satellite will revolutionise weather forecasting, providing cutting-edge observations of Earth's atmosphere and real-time monitoring of lightning events.

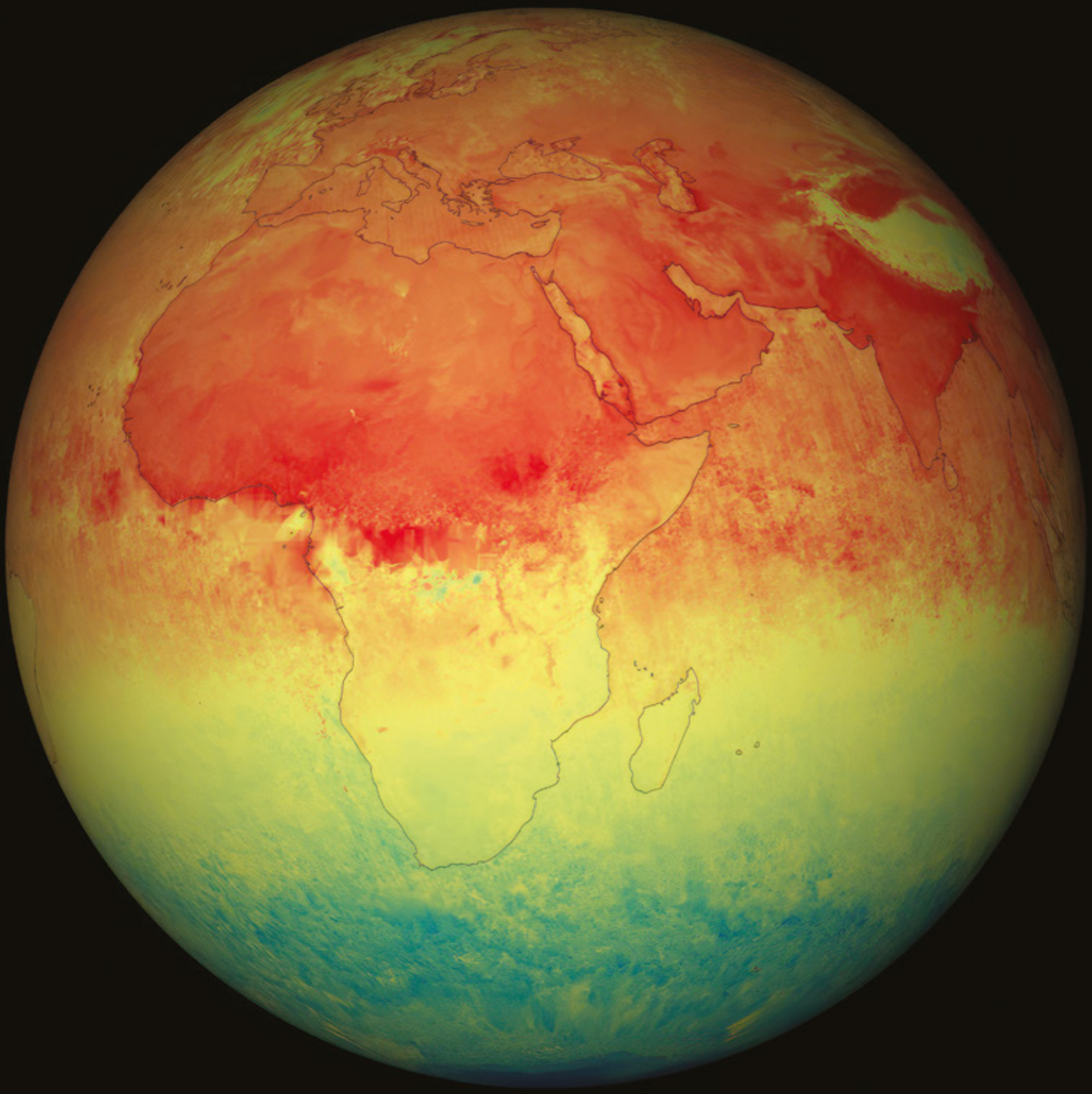
The onset of 2023 presented an exciting opportunity for the ESA/NASA Solar Orbiter spacecraft. On 3 January, the inner planet Mercury passed through the spacecraft's field of view, creating a striking transit event where Mercury appeared as a perfectly black circle moving across the face of the Sun.

EUROPEAN SERVICE MODULE

Building Artemis V

The structure for the fifth European Service Module is seen here at the integration halls in Bremen, Germany. The module, which will power the Orion spacecraft for the Artemis V mission, will include 12 km of cables connecting 20 000 parts. In addition to taking astronauts to the Moon, Artemis V will transport the second European module to the lunar Gateway: the ESPRIT refuelling module.





‘MARS’ FOR METHANE

UN announces global emissions initiative

Methane is a powerful greenhouse gas and the second biggest driver of global warming. At COP27, the United Nations announced a new satellite-based system to detect methane emissions, the Methane Alert and Response System (MARS) initiative. Copernicus Sentinel-5P will be crucial in implementing this ambitious initiative. This Sentinel-5P image shows global methane concentration in Earth's atmosphere in 2020.

FIRST MTG LAUNCH

Keeping an eye out for lightning

The first of six Meteosat Third Generation weather satellites is placed within Ariane 5's fairing for protection during launch. From 36 000 km above the equator, it will observe Earth's atmosphere in improved detail. Its novel Lightning Imager will monitor lightning events, even in daylight, allowing severe storms to be detected early and warnings issued.

WEBB VIEWS CREATION

Composite image reveals exquisite new detail

The Pillars of Creation in the Eagle Nebula blaze in this composite from two of Webb's cameras. Mid-infrared shows the pillars' layers of dust, while near-infrared reveals thousands of new stars (in orange). Gas and dust form knots in the pillars, collapsing under their own gravity to eventually form new stars.

Sailing into the sunset

This metallic sail was unfurled in late 2022 by the ION Satellite Carrier, a satellite platform operated by D-ORBIT and used to deliver miniature CubeSats into their individual orbits. Seen by the onboard camera, the Drag Augmentation Deorbiting System Nano (ADEO-N), a 3.6 sq m aluminium-coated polyamide membrane, will increase air drag upon the satellite and speed up its atmospheric re-entry.

MERCURY TRANSIT

Solar Orbiter captures planetary pass

In January, the planet Mercury passed between ESA's Solar Orbiter spacecraft and the Sun. This resulted in a great photo opportunity and Solar Orbiter's Polarimetric and Helioseismic Imager (PHI) instrument captured the transit of Mercury's silhouette across the Sun's disc. In this image, Mercury appears as a black circle in the lower right and is distinct from the sunspots at the top of the image.

A PREDICTABLE ASTEROID

Only the sixth one we saw coming

Small asteroids strike Earth every couple of weeks, and our ability to predict them is increasing. Asteroid 2022 WJ1 was first spotted by the Catalina Sky Survey. Within minutes, ESA's monitoring software reported a 20% chance of impact, and within half an hour the precise impact was detailed. The fireball appeared at exactly the predicted time and location.

ATOM-SCALE SCAN

Studying materials for space

X-ray photoelectron spectroscopy studies materials right down to their atomic scale. This image shows internal research fellow Johanna Wessing at ESA's Materials and Electrical Components Laboratory at ESA ESTEC in the Netherlands. She is studying the topmost skin of a candidate material for space. This powerful technique enables the analysis of surface structures and composition to a depth of just a few dozen individual atoms.

HERA'S TINY RADAR

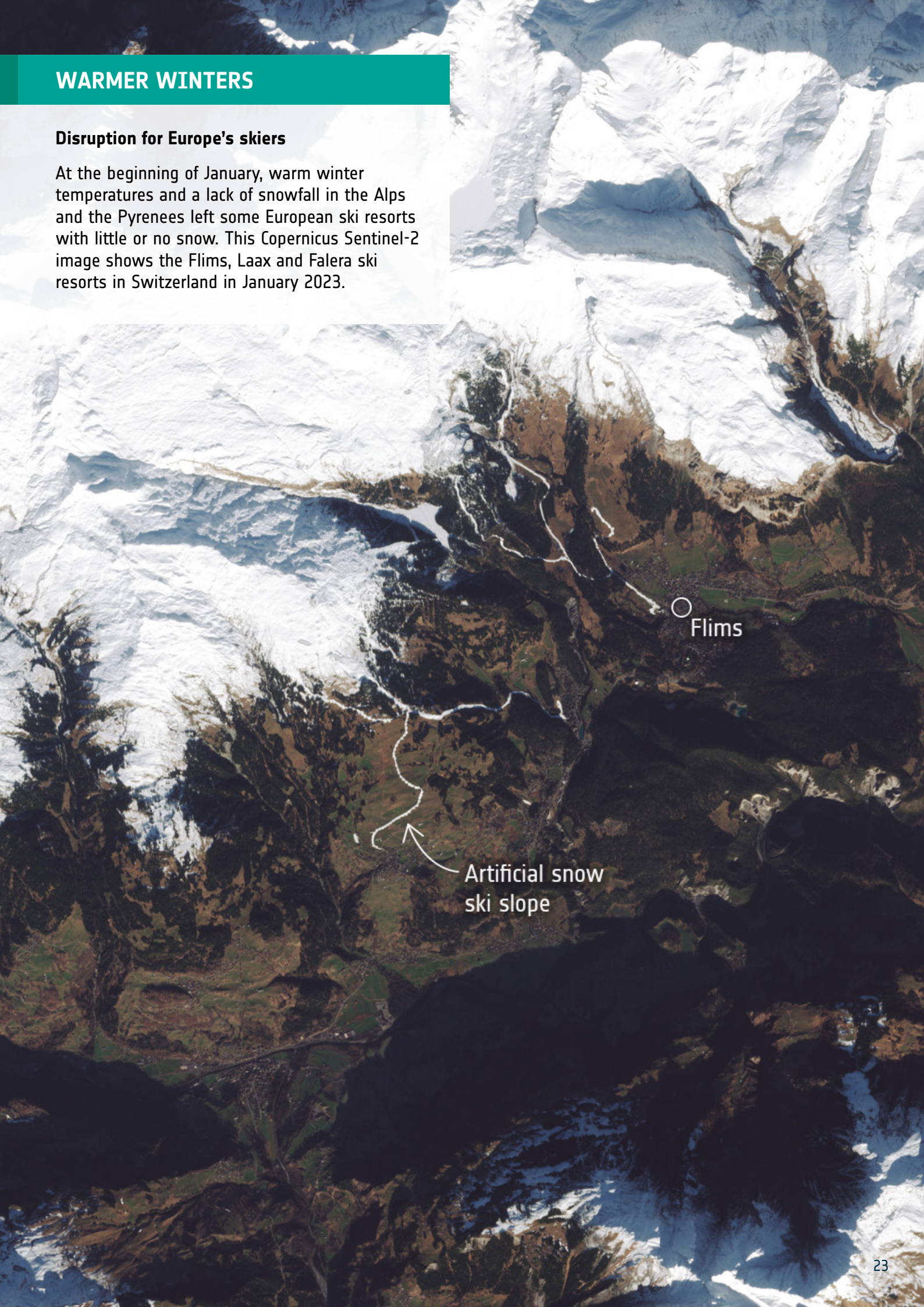
Mini-radar destined for Dimorphos

This 10-cm radar instrument will make history on board Hera's Juventas CubeSat as the smallest such instrument in space and the very first radar to probe inside an asteroid. The asteroid in question is Dimorphos, the destination of ESA's Hera spacecraft, which will carry the Juventas CubeSat. Hera will fly to Dimorphos to survey the aftermath of NASA's DART impact.

WARMER WINTERS

Disruption for Europe's skiers

At the beginning of January, warm winter temperatures and a lack of snowfall in the Alps and the Pyrenees left some European ski resorts with little or no snow. This Copernicus Sentinel-2 image shows the Flims, Laax and Falera ski resorts in Switzerland in January 2023.



THE BACKBONE OF ALL SPACE ACTIVITIES

ESA's tracking station network is evolving and adapting to the revolution in space activities.

The rapid growth of space activities would not be possible without the constant evolution of ground stations. Without them, there is no way of controlling a satellite or retrieving data from it. ESA's tracking station network – Estrack – demonstrates remarkable adaptability to meet the ever-evolving demands of modern space missions and the emergence of new commercial space ventures. Both are a source of inspiration but they also pose specific challenges for the network.

Estrack is a global system of ground stations providing links between spacecraft and the European Space Operations Centre (ESOC), located in Darmstadt, Germany. The core Estrack network is composed of seven sites, three of which are equipped with deep space antennas that play a vital role in interplanetary missions. These antennas, distinguished by their 35 m-diameter dish structures, are strategically positioned at approximately 120 degrees apart in longitude: in Spain, Australia and Argentina. This placement enables them to ensure uninterrupted coverage as the Earth rotates.

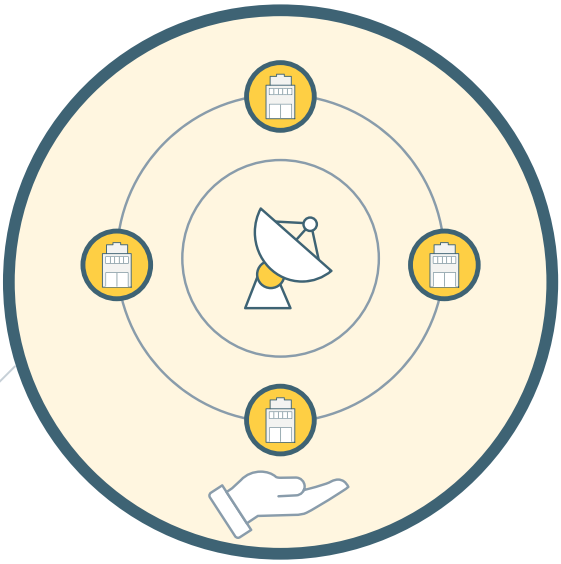
The key task of all ground stations is to communicate with spacecraft, transmitting commands and receiving scientific data and spacecraft status information, during both critical and routine mission phases. They need to do this even for spacecraft hundreds of millions of kilometres away from us. These ground stations possess the remarkable capability to track spacecraft in nearly any location, be it in Earth orbit, observing the Sun, positioned at scientifically crucial Sun-Earth Lagrange points, or journeying into the outer Solar System past the gas giants Jupiter (for the Juice mission) and Saturn (Cassini-Huygens).

Inaugurated in March 2003, the New Norcia Deep Space Station is ESA's first tracking station dedicated to communications with deep space missions. The key component of the ground station is its massive antenna, which weighs more than 600 tonnes and is over 40 metres high. The 35 m dish is counterbalanced by 540 tonnes of ballast to maintain the highly accurate pointing of its beam.

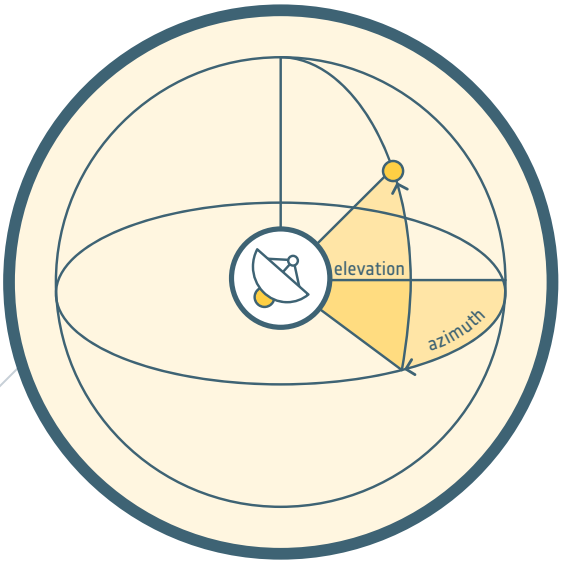
Perpetual enhancement

The Estrack network has been continuously evolving since its establishment in 1975. It undergoes regular upgrades, leveraging available technologies in collaboration with European industry. These advancements have reached an impressive milestone, where Estrack's remote operations are centralised at ESOC. "Fulfilling the requirements of all missions, those operations are efficiently managed by a team of two people during routine phases, relying on a high degree of automation," says Guillermo Lorenzo Ten, Head of the Estrack Stations & Infrastructure Section. The network also shares its capacities with other space agencies (NASA, JAXA, CNES, DLR, etc.), who in return provide tracking services to ESA missions under a number of resource-sharing agreements.

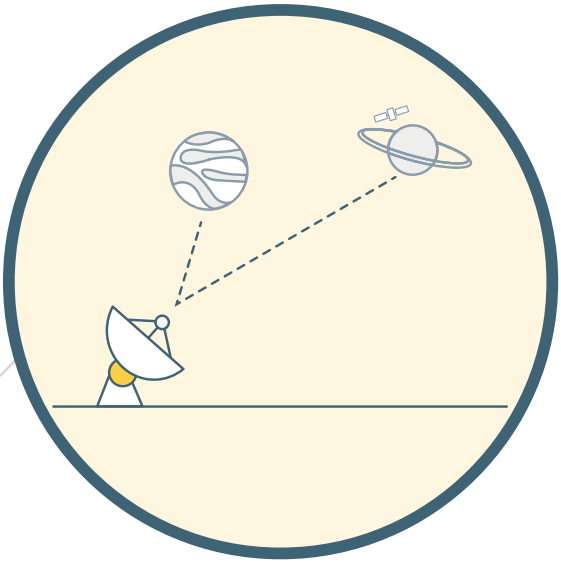
These developments are crucial as the number of supported missions continues to increase. As Guillermo highlights, "Estrack now routinely supports approximately 30 missions, providing around 5500 tracking hours per month with a remarkable 99.7% high availability." This figure of 30 missions should be compared to the approximately 16 missions supported in 2015 and the projected 37 missions planned for the beginning of the next decade. In addition to the growing number of missions, there is also a demand for advanced communication capabilities, including new frequency bands and enhanced performances. This is especially the case for ESA's new generation of science and exploration missions such as the recently launched Juice (Jupiter Icy Moons Explorer) and Euclid.



ESA stations play a vital role in supporting not only the Agency's missions but also those of other space agencies like NASA, JAXA, ISRO, and private space companies.



ESA stations enable highly precise pointing in both elevation (rotation up and down) and azimuth (rotation left and right).



ESA's deep-space stations are among the world's most advanced for interplanetary communication, capable of capturing signals from as far away as Mars, at a distance of 225 million km, or even Saturn, which is a staggering 1400 million km away.

Most Estrack stations operate as 'giant robots' remotely controlled from ESA'S ESOC mission control centre in Germany.

Furthermore, there is a pressing desire for enhanced performance, particularly in terms of increased data throughput, as it holds immense scientific value and fulfils our yearning for ever more detailed imagery. A prime example of this was the recent mosaic created with the help of ESA's Mars Express spacecraft, which unveiled the Red Planet's colour and composition in breathtaking detail.

ESA's network is facing congestion – a problem also faced by NASA's ground stations. This is not only due to the increasing number of new missions in the space industry globally but also because of the presence of what are referred to as legacy missions, such as Aeolus (the satellite to acquire profiles of Earth's wind outlived its predicted lifetime of three years by over 18 months).

According to Lucy Santana, who oversees ESA's ground facility services for deep space missions, these missions that significantly surpass their originally planned operational duration are obviously an opportunity, but at the same time they pose a challenge for network workload planning.

The recent upgrades, which incorporated higher frequency bands or cooled the 'antenna feed' to just 10 degrees above the lowest temperature possible in the Universe, have notably enhanced the data download capacity, by up to 80%. However, there are inherent limitations to the extent of improvements that can be squeezed out of pre-existing dishes. Consequently, ESA not only prioritises upgrades and collaboration agreements but also allocates resources to the development of Estrack's own strategic components.

In fact, a new deep space antenna – Estrack's fourth – is already under construction at Australia's New Norcia site. Guillermo explains, "The infrastructure works have been completed, and we are currently finalising the foundations and installing the antenna tower. Our objective is to achieve operational deployment by the end of 2025."

There is a concern that, even with these enhancements, the network may still not fully meet the growing demands. Guillermo cautions, "Based on our projections using the current mission model, we anticipate that the capacity requirements will surpass our current network capabilities by approximately 60% around 2029." To address this challenge, a project for the construction of another deep space antenna, this time in South America at the already existing Malargüe site, is currently under study. The decision to proceed with the construction will ultimately rest with ESA's Council of Ministers in 2025.

A different way of working

"That was definitely a first," reflects Gerhard Billig, a ground operations engineer at ESOC and service manager for Estrack's support for the inaugural mission of the HAKUTO-R lunar exploration program by ispace,

THE CORE ESTRACK NETWORK COMPRISES SEVEN STATIONS IN SEVEN COUNTRIES

a commercial Moon landing service provider. "Our Estrack station network was the optimal choice for such a mission, and we signed a commercial contract as the exclusive provider of the crucial communication link between Earth and the spacecraft."

This achievement is noteworthy as it marks a momentous occasion for two reasons: it was the first time ESA offered sole ground station support for a commercial space mission, and was also intended to be the first commercial lunar landing in history.

The mission was launched into a low-energy transfer orbit by a SpaceX Falcon 9 in December 2022. The connection between the spacecraft and the prime mission control centre in Tokyo was assured by ESA's deep space antennas and two smaller ones located in Kourou, French Guiana, and New Norcia, Australia. The Goonhilly Earth Station Ltd in the UK, the world's only commercial deep space ground station, was also involved as part of the 'Estrack extended network'.

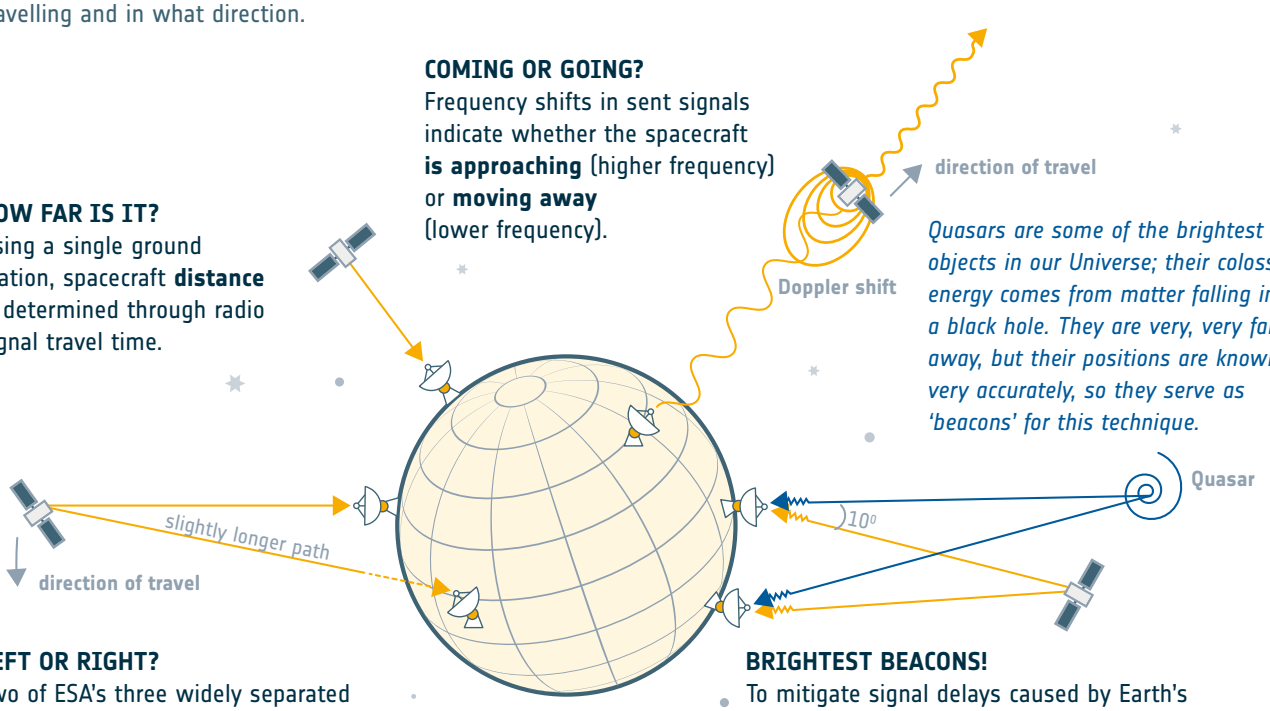
The Estrack and Goonhilly stations followed the lander as it ventured out into deep space (as far as 1.5 million km from Earth) and back again on a sweeping trajectory designed to reduce the amount of fuel the spacecraft needed to carry. After having reached lunar orbit, the satellite began the descent sequence at the end of April 2023, but failed to land safely on the Moon.

HOW NOT TO LOSE A SPACECRAFT

ESA's ultra-precise deep-space navigation technique tells us where spacecraft are to within a few hundred metres even at a distance of 100 million km. Navigating a spacecraft around our Solar System requires knowing how far away it is, how fast it is travelling and in what direction.

HOW FAR IS IT?
Using a single ground station, spacecraft **distance** is determined through radio signal travel time.

COMING OR GOING?
Frequency shifts in sent signals indicate whether the spacecraft **is approaching** (higher frequency) or **moving away** (lower frequency).



Quasars are some of the brightest objects in our Universe; their colossal energy comes from matter falling into a black hole. They are very, very far away, but their positions are known very accurately, so they serve as 'beacons' for this technique.

LEFT OR RIGHT?
Two of ESA's three widely separated deep-space ground stations capture signals to determine spacecraft movement left or right.

BRIGHTEST BEACONS!
To mitigate signal delays caused by Earth's atmosphere and ground station electronics, signals from a nearby **quasar** are used to subtract its known location from spacecraft measurements.

Nevertheless, ispace is already planning new attempts in 2024, relying again on the support of Estrack, which, along with the NASA network, is the only one able to offer quasi 24-hour coverage for such a mission.

For ESA's ground station teams, this mission has provided valuable experience. "What was different working with that kind of young commercial company is that things went fast with them," says Gerhard. "They have proven to be very agile in terms of their ability to adapt their plan and setup."

The company made a significant decision to alter the satellite's trajectory, prompted by a weight issue, opting for a trajectory that would take it much farther from Earth, and take much longer. This presented a considerable challenge for Estrack, as it necessitated rapid adaptation to a nearly complete redefinition of the mission within a limited timeframe. As one result, Estrack was reaching out to the Goonhilly station to request additional support in order to meet the demands of the revised mission parameters.

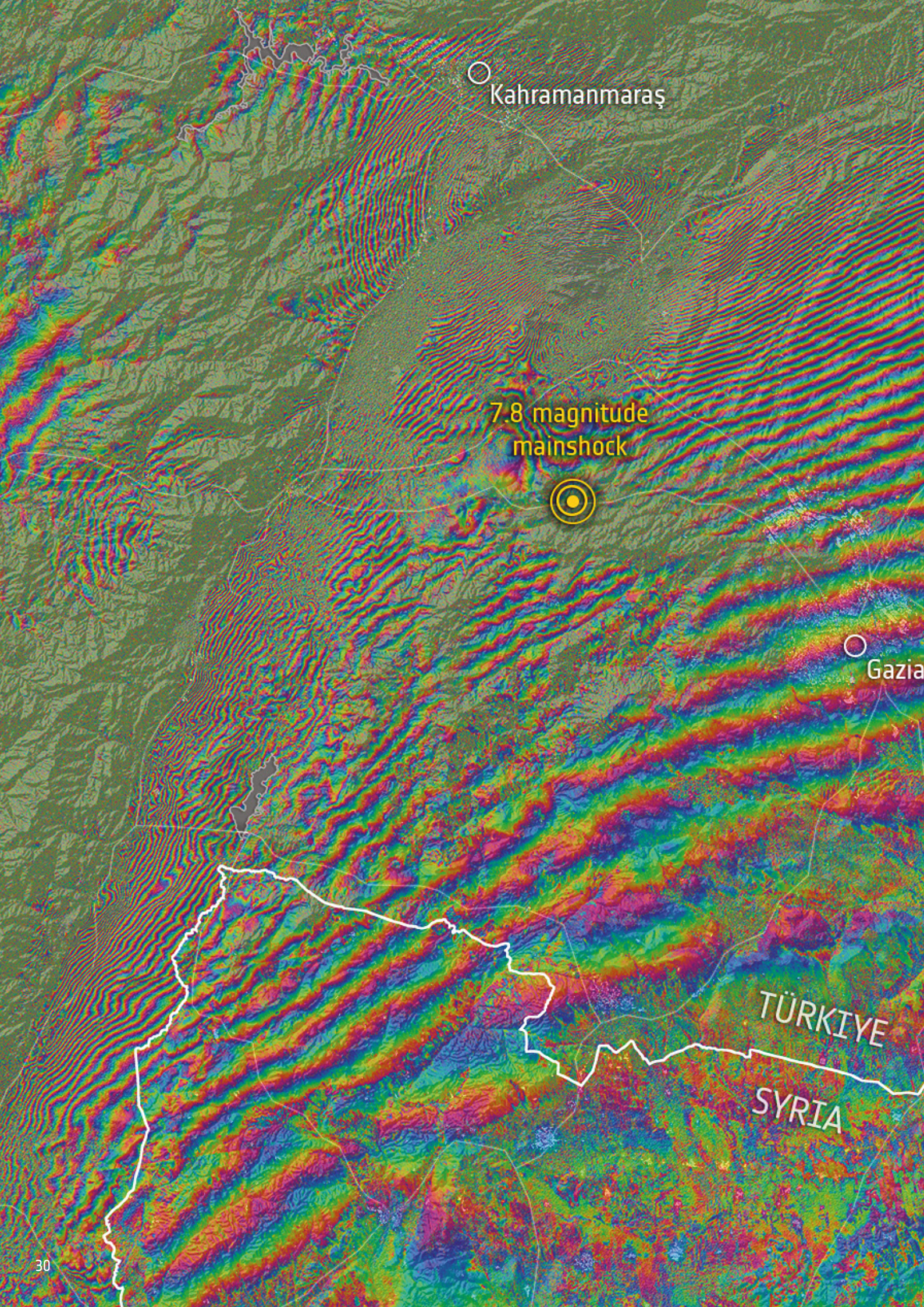
A rewarding challenge

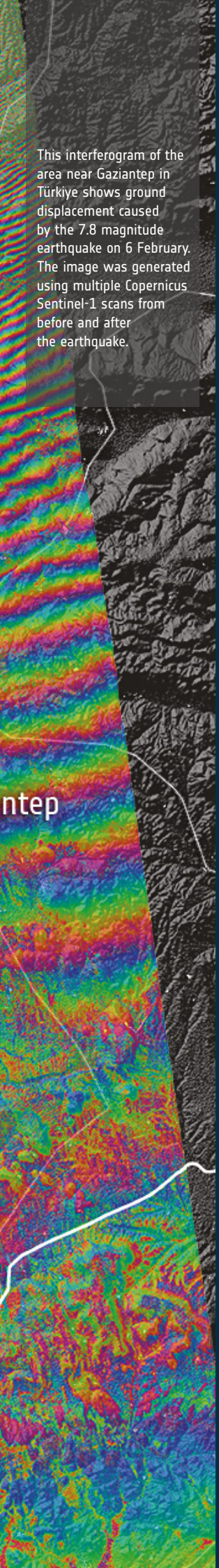
The primary focus of the network remains dedicated to providing connections with satellites for ESA missions. Assistance for third parties is granted on a case-by-case basis, typically for specific mission phases. The support extended by Estrack to companies such as ispace is accommodated within the network's available spare time, making it akin to an additional bonus or a "cherry on the cake," as Gerhard notes. This collaboration exemplifies ESA's active involvement in emerging commercial space activities, highlighting its willingness to engage and contribute to the evolving landscape of the space industry.

The support to international and commercial partners follows well-established standards in terms of communication and interfaces. Nonetheless, Estrack's teams occasionally face the need to think outside the box. Companies like ispace, for instance, have demonstrated an ability to "push procedures to the limit, even in the way they operate a satellite," remarks Lucy. It is sometimes "a different working culture, which pushes us to find creative solutions."

Consequently, Guillermo acknowledges that collaborating with such entities offers a uniquely enriching experience. It presents valuable cross-fertilisation opportunities, allowing for mutual learning and insights into diverse operational and spacecraft engineering practices. For Gerhard, "We do not work with an external entity to make a profit, because we are just covering our cost at the end. We do it because this kind of activity keeps the European space industry at the forefront of space exploration and, in the case of the HAKUTO-R mission-1, provides valuable experience that will benefit upcoming ESA and partner missions destined for the Moon."

ESA's mission control at ESOC in Darmstadt, Germany, is home to the engineering teams that control spacecraft in orbit, manage the tracking station network, and design and build the systems on the ground that support missions in space.


Kahramanmaraş
7.8 magnitude
mainshock
Gazia
TÜRKIYE
SYRIA



This interferogram of the area near Gaziantep in Türkiye shows ground displacement caused by the 7.8 magnitude earthquake on 6 February. The image was generated using multiple Copernicus Sentinel-1 scans from before and after the earthquake.

SELECTED HIGHLIGHTS

February to April 2023

Juice embarked on an eight-year mission to explore Jupiter and its three ocean-bearing moons: Ganymede, Callisto, and Europa.

On 6 February, a devastating 7.8-magnitude earthquake struck southern and central Türkiye and northern and western Syria, causing widespread destruction, and claiming tens of thousands of lives. In response, the International Charter 'Space and Major Disasters' was activated, utilising satellite imagery from Copernicus Sentinel-1 and Sentinel-2 missions to support local rescue operations.

In early April, ESA welcomed its newest astronaut candidates to the European Astronaut Centre in Cologne, Germany, where they commenced their intensive 12-month basic training. Chosen from a competitive pool of 22 500 applicants across ESA Member States in November 2022, this group of five candidates is part of the 17-member astronaut class of 2022.

During the same month, awe-inspiring images were received, including a ground-breaking, detailed view of Earth from the first Meteosat Third Generation Imager (MTG-I1), promising a revolution in weather forecasting. Additionally, the 33rd launch anniversary of the NASA/ESA Hubble Space Telescope was celebrated with a vibrant image of a nebula.

Lastly, on 14 April, humanity's next bold mission to the outer Solar System, ESA's Juice mission (JUpiter ICy moons Explorer), embarked on its eight-year journey to Jupiter.

BACK TO SCHOOL

ESA astronaut candidates start basic training

ESA's newly selected astronaut candidates of the class of 2022 arrived at the European Astronaut Centre in Cologne, Germany, on 3 April to begin their 12-month basic training. Clockwise from the back row: Pablo Álvarez Fernández, Sophie Adenot, Marco Sieber, Raphaël Liégeois, Rosemary Coogan and the Australian Space Agency astronaut candidate Katherine Bennell-Pegg.

A REVOLUTION IN WEATHER FORECASTING

ESA's satellite provides spectacular images

This first image from Europe's latest weather satellite, the Meteosat Third Generation Imager, reveals a level of detail about the weather over Europe and Africa not previously possible from 36 000 km above Earth. When fully operational, the system will provide critical data for short-term and early detection of potential extreme weather events over the next 20 years.

HAPPY BIRTHDAY, HUBBLE

A colourful image of newly forming stars

On 24 April, astronomers celebrated the NASA/ESA Hubble Space Telescope's 33rd launch anniversary with an ethereal photo of a nearby star-forming region, NGC 1333. The nebula is in the Perseus molecular cloud and is approximately 960 light-years away. Hubble's colourful view unveils glowing gases and pitch-black dust blown around by several hundred newly forming stars embedded within the dark cloud.

TESTING 'ZERO GRAVITY'

John McFall's first parabolic flight

John McFall, the first-ever member of the ESA astronaut reserve with a disability, is seen here floating on board a parabolic flight in April. John was selected to take part in a feasibility project to improve our understanding of, and to help overcome, the barriers that space flight presents for astronauts with a physical disability.

ESA'S TECHNICAL HEART EXPANDS

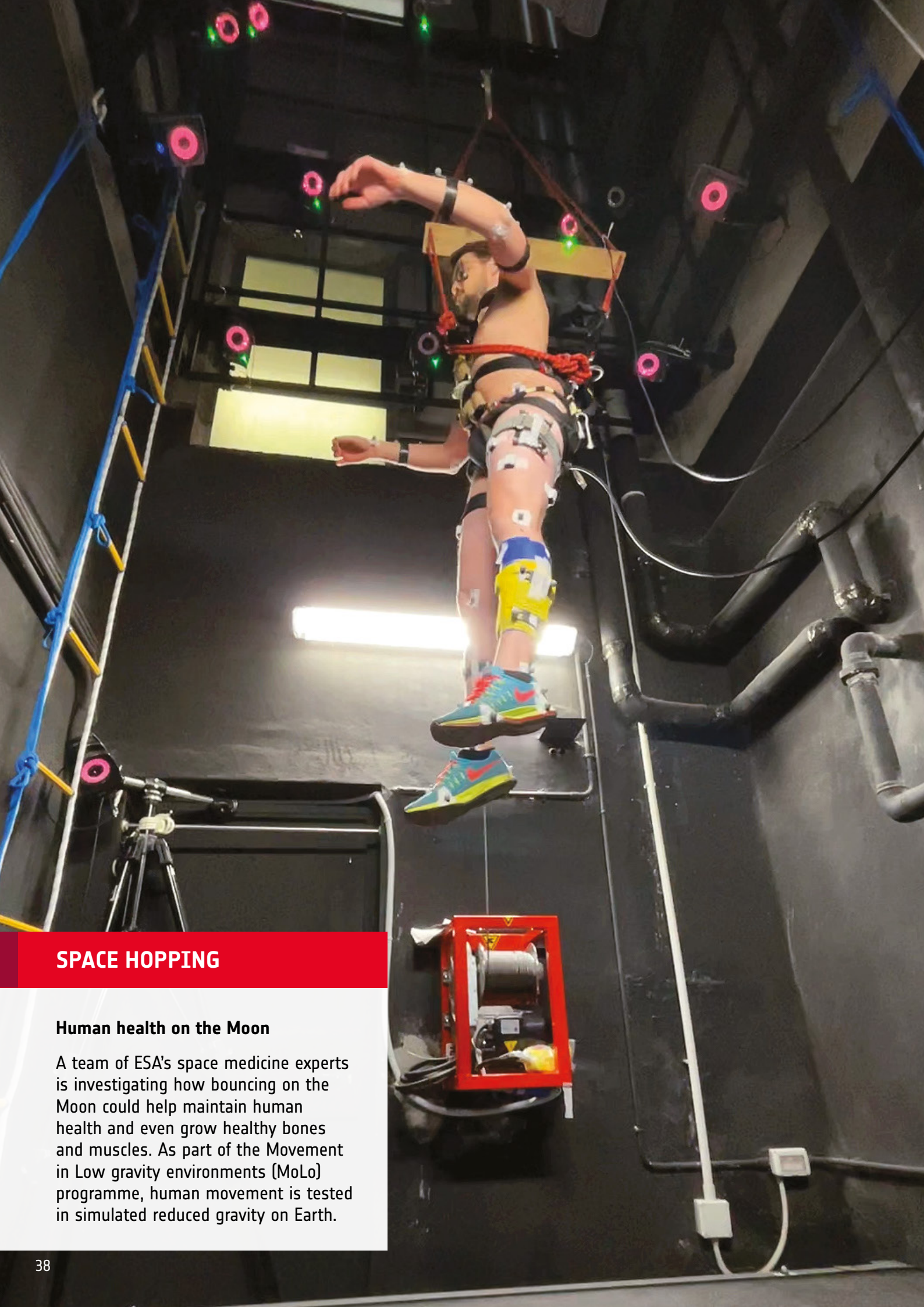
Two simultaneous construction projects

Orange cranes highlight the two current construction projects at ESA-ESTEC, in the Netherlands. On the dune side, the new Hertz 2.0 radio frequency test facility is taking shape, intended to accommodate the largest future space antennas and satellites. At the lower left, we see the site of the International Meeting Facility, which will become a focal point for the entire establishment.

PRACTICE MAKES PERFECT

An ESA astronaut prepares for the next mission

Here we can see ESA astronaut Andreas Mogensen at the European Astronaut Centre training for his Huginn mission to the International Space Station. He is examining ESA's Advanced Closed Loop System, which filters the air on the Space Station for CO_2, and through further processing, creates clean oxygen for the astronauts to breathe and water to be reused in the life-support system.



SPACE HOPPING

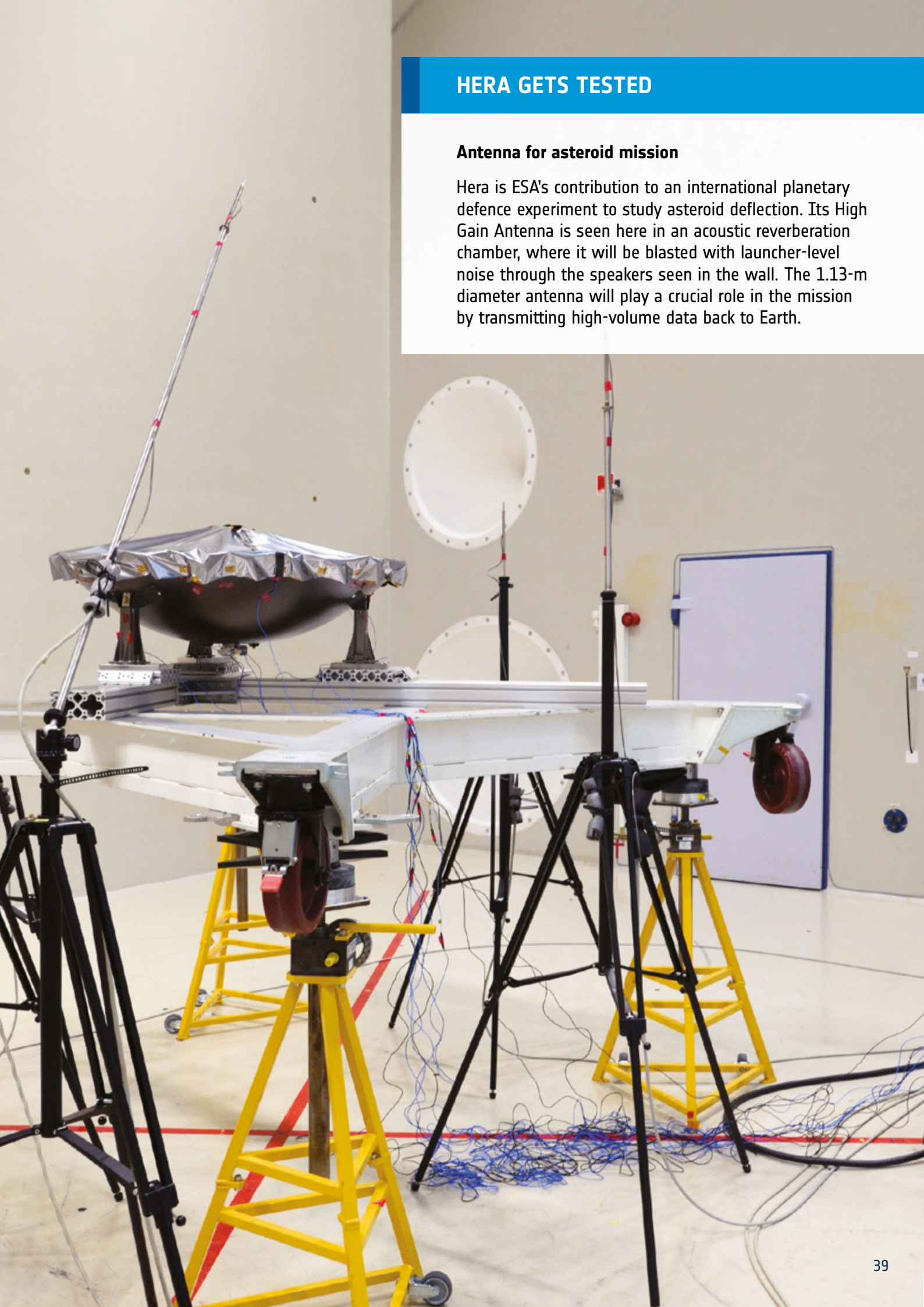
Human health on the Moon

A team of ESA's space medicine experts is investigating how bouncing on the Moon could help maintain human health and even grow healthy bones and muscles. As part of the Movement in Low gravity environments (MoLo) programme, human movement is tested in simulated reduced gravity on Earth.

HERA GETS TESTED

Antenna for asteroid mission

Hera is ESA's contribution to an international planetary defence experiment to study asteroid deflection. Its High Gain Antenna is seen here in an acoustic reverberation chamber, where it will be blasted with launcher-level noise through the speakers seen in the wall. The 1.13-m diameter antenna will play a crucial role in the mission by transmitting high-volume data back to Earth.



WORLD CEREAL

New ESA contribution to global food security

On 20 April, ESA launched WorldCereal – the world's first dynamic system capable of providing seasonally updated crop information to help monitor agricultural production across the globe. An example of the high precision of the system is this Copernicus Sentinel-2 image that shows the Al Wahat al Dakhla Desert centre-pivot irrigation systems, where equipment rotates around a central pivot and crops are watered with sprinklers.

JUPITER MISSION LEAVES EARTH

Ariane 5 lifts Juice into orbit

ESA's latest interplanetary mission, Juice (Jupiter Icy Moons Explorer), began its journey to Jupiter, where it will study in detail the gas giant planet's three large ocean-bearing moons: Ganymede, Callisto and Europa. The estimated date of arrival is July 2031 with the aid of momentum and direction gained from four gravity-assist flybys of the Earth-Moon system, Venus and, twice, Earth.

ESA'S ICY MOONS MISSION

How is this mission to Jupiter bringing together world-class capabilities from across ESA?

With its launch in April 2023, ESA's Jupiter Icy Moons Explorer (Juice) mission took one big step towards its destination. Ahead lies a journey to Jupiter that will take eight years, followed by four years exploring the Jovian system, during which the mission's 10 science instruments will study Jupiter and its moons.

The science instruments were developed by institutions from all over Europe, together with contributions from the US, Japanese and Israeli space agencies. Collaboration and planning have been key to coordinating the 80 companies and more than 2000 people involved in the mission's development. As ESA's Director General, Josef Aschbacher, described it during the launch broadcast on 14 April: "It is really a mission of major magnitude."

Juice was placed inside the nose cone, or fairing, of an Ariane 5 launcher on 1 April. Shortly after launch on 14 April, the fairing opened and Juice separated from the rocket.

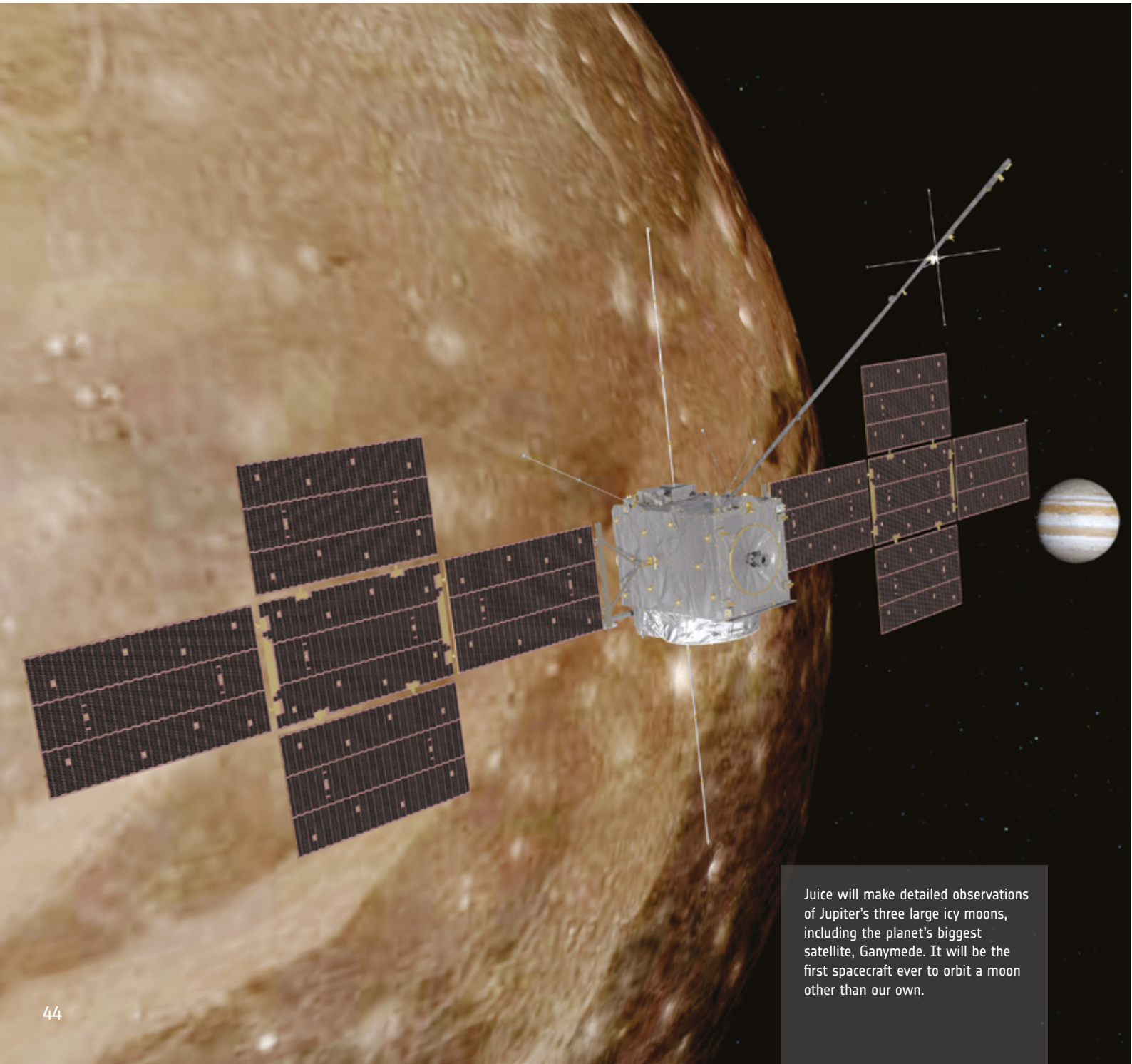
Juicy science

Juice will study Jupiter's atmosphere and environment, including its magnetic field, and will look in depth at three of the gas planet's moons – Ganymede, Callisto and Europa – which are thought to hold liquid water beneath their icy crusts.

Ganymede, the only moon in the Solar System to generate its own magnetic field, will be one of the main scientific focuses. Olivier Witasse, ESA project scientist for the mission, says: "For me the main question I would like to see answered by Juice is the story of the liquid ocean on Ganymede. This is quite fascinating. We should be able to understand its location, depth beneath the surface, quantity of water and composition."

Juice's radar sounder instrument (RIME) will probe the subsurface of the icy moons to a depth of 9 km, giving us data about their inner layers. And the spacecraft's cameras will take images of Ganymede and Callisto at a resolution of less than 10 m per pixel. These will be the highest-resolution images ever taken of those objects. "In the end we will have a detailed map of Ganymede, including its thin atmosphere and magnetic field. It will be like discovering and exploring an entirely new world," says Olivier.

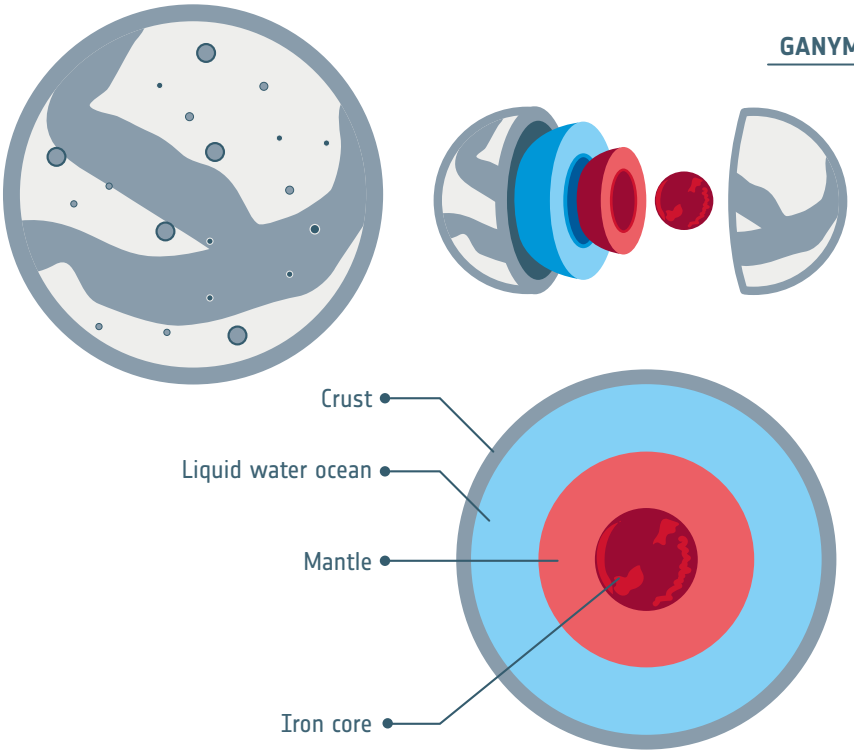
The data sent back to Earth by the Juice spacecraft will enable scientists to gain a better understanding of the conditions necessary to host life and the formation of planetary systems, including our own Solar System (two of the core themes of ESA's Cosmic Vision programme).



Juice will make detailed observations of Jupiter's three large icy moons, including the planet's biggest satellite, Ganymede. It will be the first spacecraft ever to orbit a moon other than our own.

UNDERSTANDING GANYMEDE

Juice will explore Jupiter's large icy moons. Ganymede is the prime target. As well as its magnetic field and complex core, Juice will investigate the underground ocean. The presence of liquid water is a vital indicator of habitability.



GANYMEDE:

- Juice flybys: **12**
- Juice's closest approach: **200 km**
- The only moon in our Solar System known **to generate its own magnetic field**
- Thought to hold **six times more water than Earth**
- Has an icy crust thought to be **150 km** thick and an underground saltwater ocean, **100 km** deep
- Diameter is **5260 km** (less than half the size of Earth but bigger than Mercury)

A long journey

Before reaching its destination in the outer Solar System and beginning its scientific investigation, Juice will have travelled 6 billion km. Its trajectory to and around Jupiter is incredibly complex and influences all aspects of the mission, including the science, communications with mission control and ground stations, as well as fuel usage.

To travel this kind of mind-boggling distance using fuel alone would involve an inordinate quantity of fuel, as much as 370 000 kg, according to ESA's Arnaud Boutonnet, a mission analyst who worked on designing Juice's innovative trajectory. In fact, Juice will only carry 3650 kg of fuel.

He explains that the four gravity assists on the way to Jupiter will help the spacecraft to gain momentum while saving fuel. One of the most complex manoeuvres during this initial part of the trajectory is the lunar-Earth gravity assist, which will take place in August 2024. "An exceptional degree of navigational accuracy is required for this double flyby because, with just one day between the flyby of the Moon and then Earth, there is no time to correct any navigational errors," says Arnaud.

The real complexity, however, comes when Juice arrives at Jupiter. On 17 July 2031 (the team can pinpoint the moment down to the second), the flight trajectory team will be holding their collective breath as Juice performs a flyby of Ganymede, before entering, less than half a day later, into orbit around Jupiter. The sequence is automated and, again, there is no time to correct possible errors. Arnaud says: "If this sequence doesn't work correctly, the spacecraft will travel away from Jupiter into deep space and the mission will be over."

Once in orbit around the gas giant, Juice will complete 35 unprecedented flybys of Jupiter's icy moons, comparable to a gymnast performing an Olympic routine on horizontal bars (if the bars themselves are also constantly in motion). At such a distance from Earth, it is possible for the spacecraft's position to be out by many tens of kilometres. To reduce this error risk, which could cause collision or excessive fuel consumption, the team introduced optical measurements to improve positional accuracy.

The trajectory also had to avoid exposing the spacecraft to excessive radiation, while keeping Juice in direct sunlight most of the time. Any more than five hours in a solar eclipse and the batteries would stop providing power and the spacecraft would be dead. Arnaud says: "The trajectory design team had to design an innovative orbit to avoid the long eclipses, which will occur during the Jupiter spring equinox in March 2033. We started to design with a white sheet of paper and had to research

and invent our methods – and we are now converting our research into reality."

ESA's trajectory design team for Juice collaborated closely with Yves Langevin from Juice's science working team, as well as with colleagues at NASA working on the US space agency's spacecraft also destined for Jupiter, the Europa Clipper mission, which is planned to launch in 2024.

Preparing for launch

While the trajectory design for Juice began more than a decade before launch and logistics were planned as soon as the Ariane 5 flight was secured, ground preparations at the launch site could only begin with the arrival of the Juice team at Europe's Spaceport in French Guiana, just 10 weeks before liftoff. During the launch campaign, Manuela Baroni was the ESA launcher interface engineer, who supported the assembly, integration, and testing (AIT) of the spacecraft. Her role included overseeing the preparation of the spacecraft, including technical checks, fuelling and ensuring magnetic cleanliness, before the final encapsulation inside the Ariane 5 rocket ready for launch.

Collaboration across ESA was extremely important at this point. Manuela explains: "The preparation of the final chronology is done in very tight coordination with our colleagues at ESOC – in particular with the mission director, and with flight dynamics and flight analysis colleagues." The team also collaborated closely with industrial partners, including Arianespace and Airbus, with whom they shared long hours in the control rooms.

In parallel, the team considered how to recycle equipment after launch, with a strong push to repurpose industrial components. Manuela says: "If we can reuse the leftover hardware, such as a spacecraft container or ground support equipment, this can amount to several million euros saved for future projects, for laboratories or R&D activities. This benefits the agency and the taxpayer, as well as the environment."

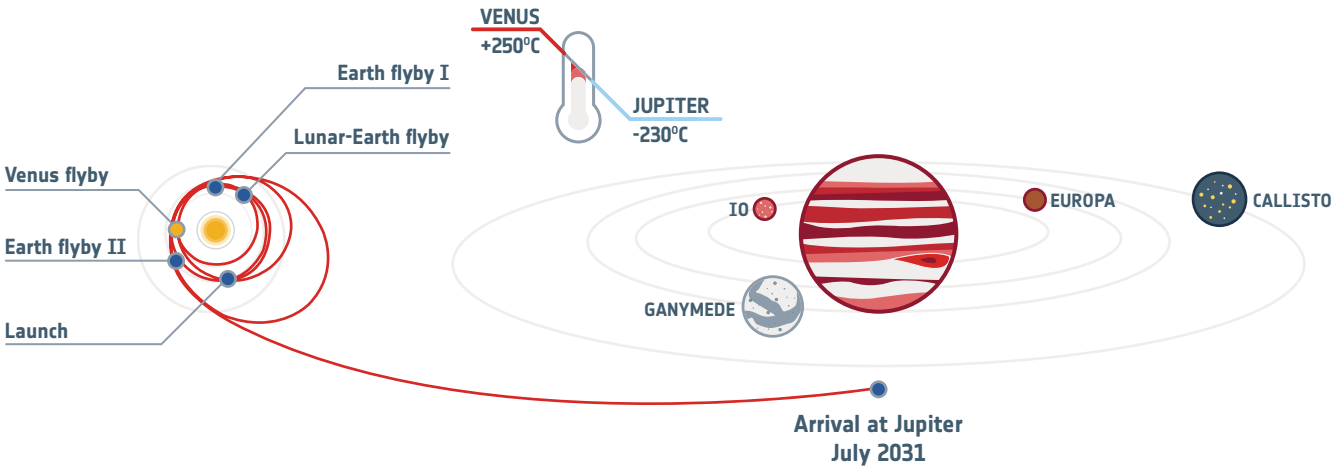
Juice generated a huge amount of media interest before launch, so communication was also an important part of Manuela's job. "I was involved in presentations to external parties, media interviews and social media. For me it was also important to give a female face to this campaign, to show the work done by women in STEM," she says.

Simulations at mission control

While the launch campaign was in full flow in Kourou, the spacecraft operations teams at ESOC, in Darmstadt, Germany, were also focused on preparation, including simulations for the mission's launch and early orbit

JUICE'S JOURNEY TO JUPITER

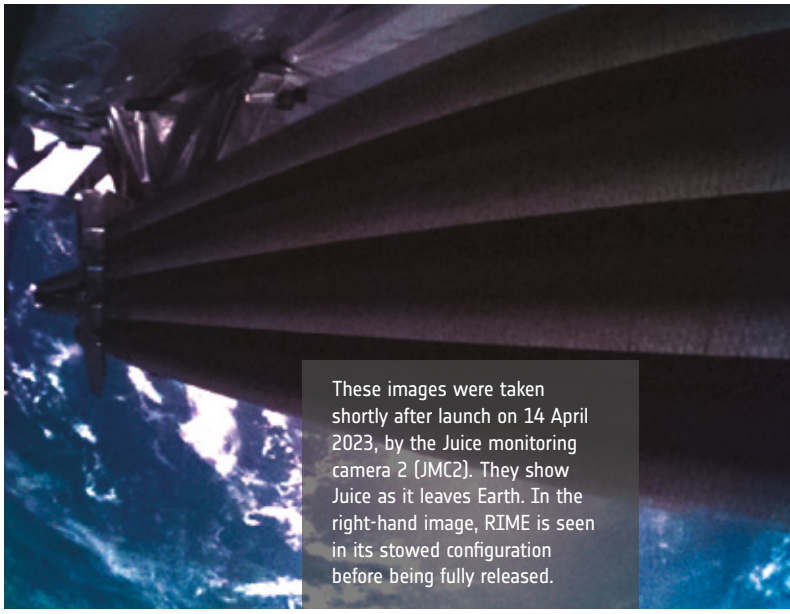
Juice is due to arrive at the Jupiter system by July 2031. It will already have travelled 6 billion km before even starting its complex tour and study of Jupiter and its moons.



Journey to Jupiter: **6 billion km**

- Journey around the Jupiter planet-moon system: **1 billion km**
- Jupiter has 95 moons but Juice will focus on four of them: **Ganymede, Callisto, Europa and Io**
- **35 flybys** of Ganymede, Callisto and Europa

This is the team at ESA's mission control that will fly Juice to Jupiter with four planetary flybys of Earth and Venus. The mission's tour of the icy, complex Jovian system includes 35 lunar flybys.



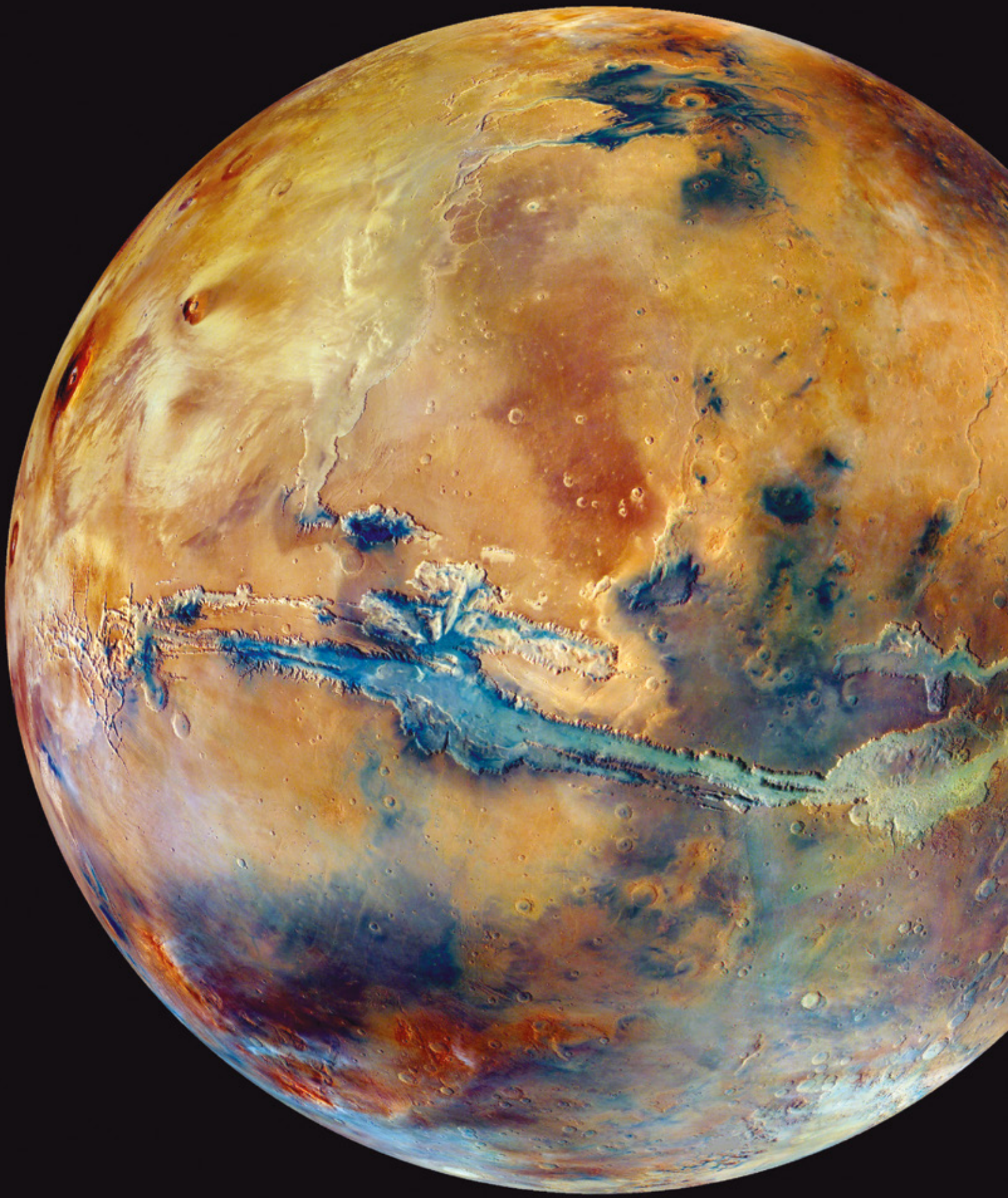
These images were taken shortly after launch on 14 April 2023, by the Juice monitoring camera 2 (JMC2). They show Juice as it leaves Earth. In the right-hand image, RIME is seen in its stowed configuration before being fully released.

phase (LEOP). Spacecraft operations engineer Angela Dietz, who led one of the launch teams, says: "The simulations help us to work as a team and to learn to react to contingencies. We test the flight procedures, data systems, ground systems and interfaces. The spacecraft and all its instruments are controlled by commands, which have to be tested and validated."

As Juice gets further away from Earth, these commands, sent by radio signal, will take longer to reach the spacecraft and eventually it will take up to 53 minutes to send a command through ESA's Estrack deep-space antennas. Angela says: "That's when you lose the interactivity with the spacecraft and everything has to be pre-programmed. If there's a problem, you can't intervene quickly, so we ensure the spacecraft has a high level of autonomy to troubleshoot its own issues."

Juice is go!

As soon as Juice lifted off from Kourou, the flight operations team began to put their meticulously planned operations into practice. But even the best-laid plans can go awry and, in this case, a tiny pin – just 3.7 mm long – failed to release one of the antenna booms that holds the RIME radar instrument. Without a fully extended boom, the radar experiment would be far less effective. After several weeks and attempts to dislodge the stubborn pin, it was eventually agreed to try knocking it loose by activating one of RIME's other booms. With Juice travelling at orbital speed at a distance of more than 8.7 million km away from Earth, the tiny metal pin moved just enough to release the boom. With RIME and the other nine instruments on board all fully deployed and commissioned, Juice was ready to make its eight-year journey to Jupiter.



To mark 20 years of ESA's first mission to the Red Planet (Mars Express), the High Resolution Stereo Camera (HRSC) team has produced a new global mosaic, which reveals a far richer colour view of Mars than has been seen before. Darker grey-toned areas of Mars represent grey-black basaltic sands of volcanic origin; lighter patches show clay and sulphate minerals; and the large scar across the planet's face is the colossal Valles Marineris canyon system.

SELECTED HIGHLIGHTS

May to July 2023

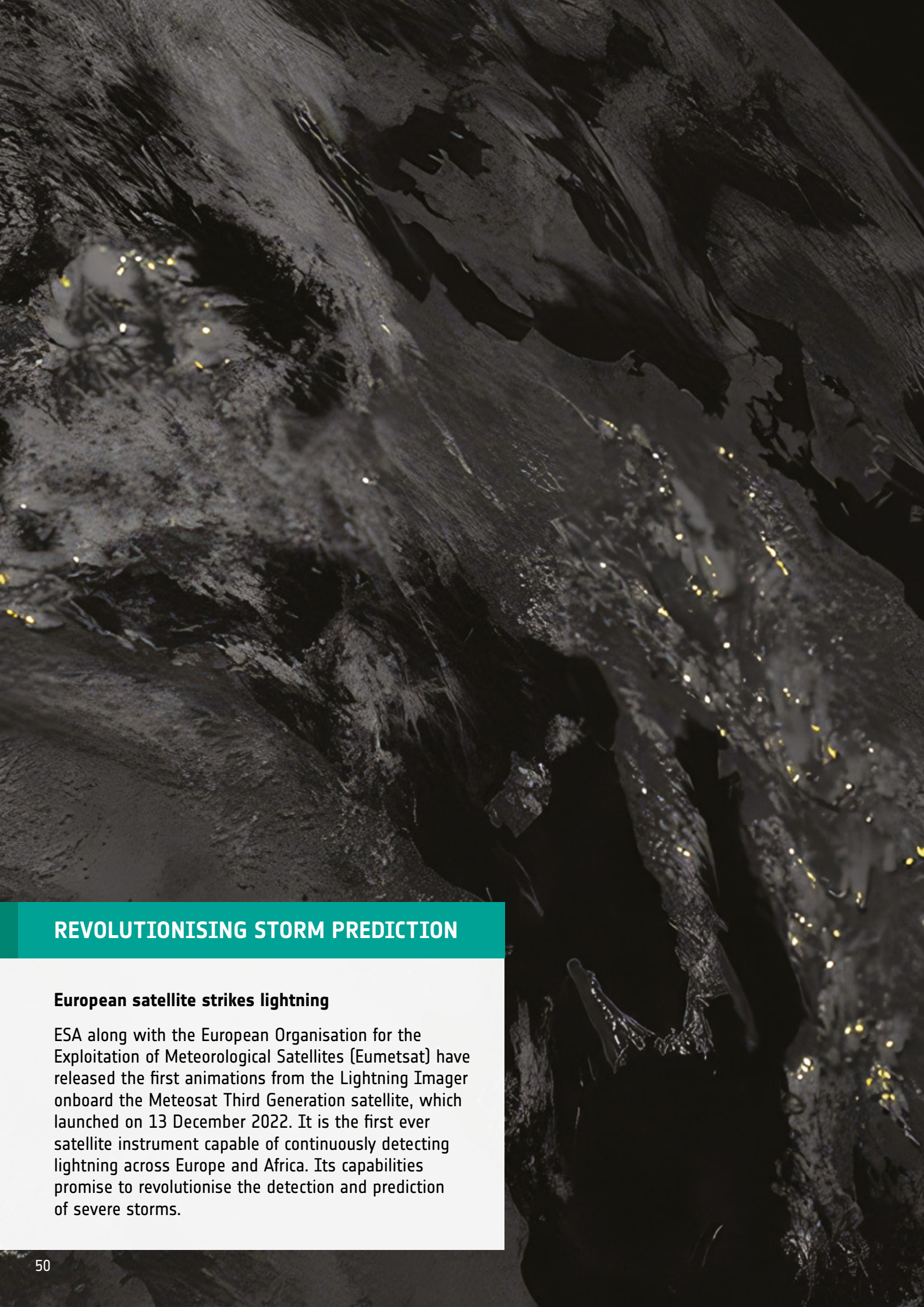
The launch of ESA's latest astrophysics mission, Euclid, provides a new tool to delve into the cosmic mysteries of dark energy and dark matter.

June ushered in scorching temperatures and sparking the warmest summer on record by a large margin. The Copernicus Sentinel-3 mission's radiometer provided crucial data, showing once again how measurements of the temperature of Earth's surface taken from space are essential to track the impact of climate change.

In mid-June, ESA formally handed over the European Service Module-2 to NASA. Integrated with the Orion crew capsule, it's set for liftoff to the Moon in 2024. During the Artemis II mission, the ESM-2 will have a crucial role, providing water and air to the four astronauts, in addition to supplying electricity, propulsion, and temperature control for the spacecraft.

ESA's Euclid mission lifted off on a SpaceX Falcon 9 on 1 July and started its month-long journey to Sun-Earth Lagrange point L2, located 1.5 million km from Earth. By observing billions of galaxies out to 10 billion light-years, it will create the most extensive 3D map of the Universe, with the third dimension representing time.

This period concluded with two remarkable events. ESA demonstrated its commitment to sustainable spaceflight and responsible operations with the first-of-its-kind assisted reentry of a satellite. Additionally, we bid farewell to Ariane 5, which, after 117 flights, has rightfully earned its retirement.



REVOLUTIONISING STORM PREDICTION

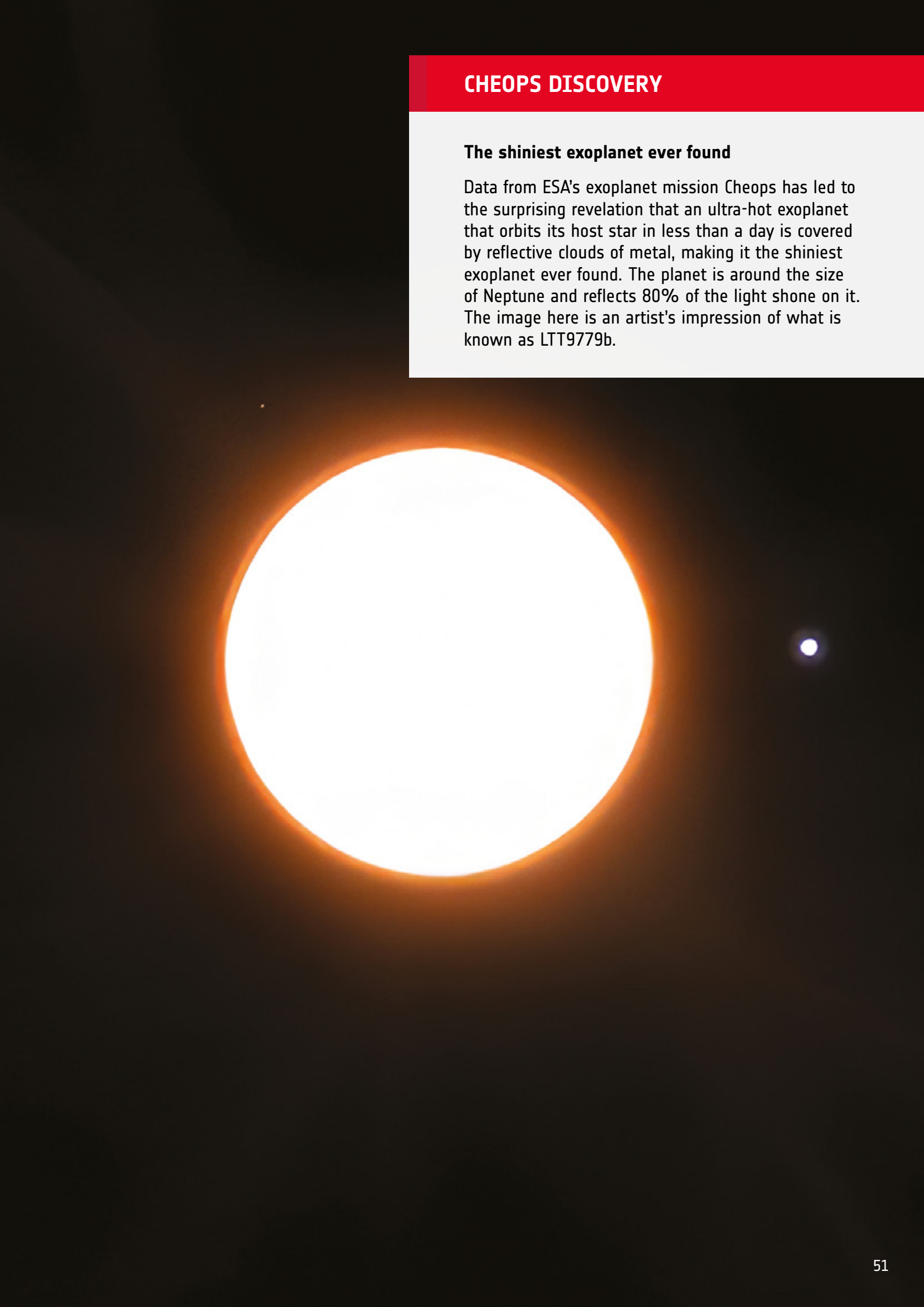
European satellite strikes lightning

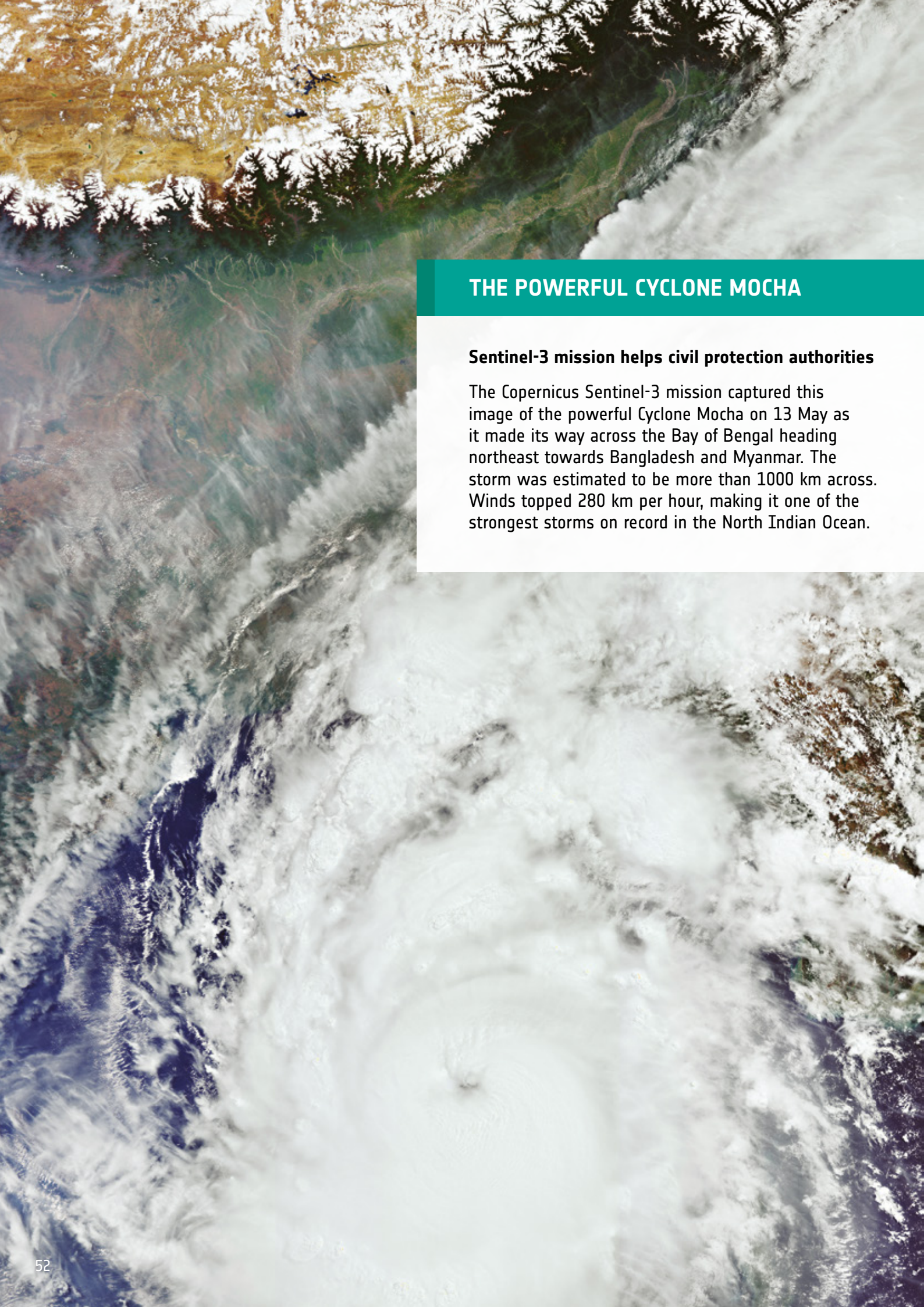
ESA along with the European Organisation for the Exploitation of Meteorological Satellites (Eumetsat) have released the first animations from the Lightning Imager onboard the Meteosat Third Generation satellite, which launched on 13 December 2022. It is the first ever satellite instrument capable of continuously detecting lightning across Europe and Africa. Its capabilities promise to revolutionise the detection and prediction of severe storms.

CHEOPS DISCOVERY

The shiniest exoplanet ever found

Data from ESA's exoplanet mission Cheops has led to the surprising revelation that an ultra-hot exoplanet that orbits its host star in less than a day is covered by reflective clouds of metal, making it the shiniest exoplanet ever found. The planet is around the size of Neptune and reflects 80% of the light shone on it. The image here is an artist's impression of what is known as LTT9779b.





THE POWERFUL CYCLONE MOCHA

Sentinel-3 mission helps civil protection authorities

The Copernicus Sentinel-3 mission captured this image of the powerful Cyclone Mocha on 13 May as it made its way across the Bay of Bengal heading northeast towards Bangladesh and Myanmar. The storm was estimated to be more than 1000 km across. Winds topped 280 km per hour, making it one of the strongest storms on record in the North Indian Ocean.

WATER-POWERED INNOVATION

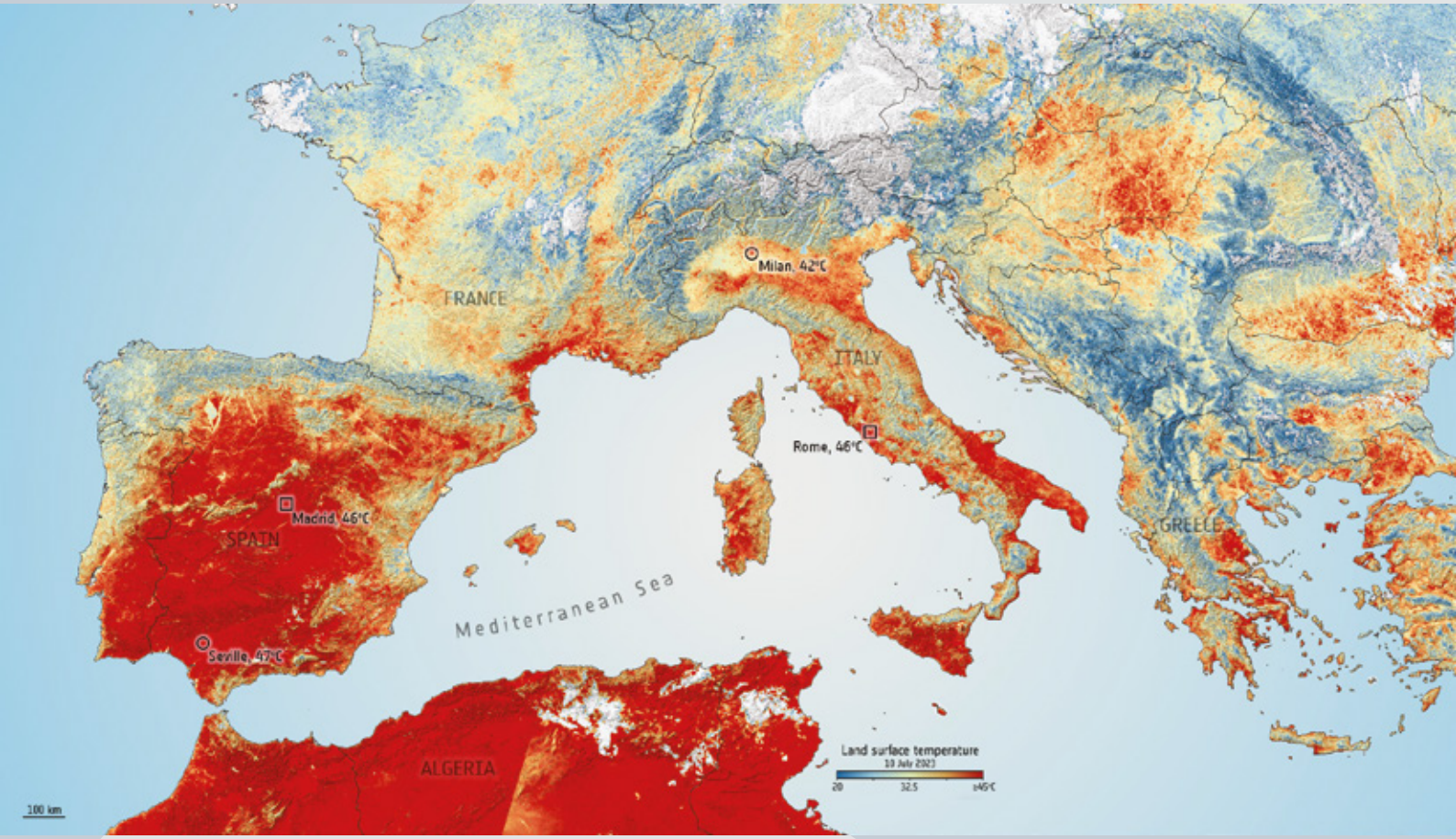
A tiny new space thruster chip

Designed to manoeuvre the smallest classes of satellites, this space thruster chip, no larger than a fingernail, relies on electrolysis for its operation. Developed in partnership with Imperial College in the UK, the Iridium Catalysed Electrolysis CubeSat Thruster (ICE-Cube Thruster) underwent rigorous testing as part of an ESA General Support Technology Programme de-risk activity. These tests aimed to validate the thruster's feasibility in a controlled laboratory environment.

READY FOR ASSEMBLY

European Service Module-2 on the move

On 22 May, the European Service Module-2 and the Orion crew module adapter for the Artemis II spacecraft were transported into the Final Assembly and System Testing (FAST) cell within NASA's Operations and Checkout Building at the Kennedy Space Center in Florida, USA. Subsequently, the spacecraft modules underwent integration with the crew module before being transferred to NASA's Exploration Ground Systems for fuelling.



THE HOTTEST SUMMER

Colouring heat records with Sentinel-3 mission

This summer set new records for high temperatures. The image above uses data from the Copernicus Sentinel-3 mission's radiometer instrument and shows the land surface temperature across Europe and parts of northern Africa on the morning of 10 July. Land surface temperatures hit 46°C in Rome, while Madrid and Seville reached 46 and 47°C, respectively.

OUT OF THE SHADOW

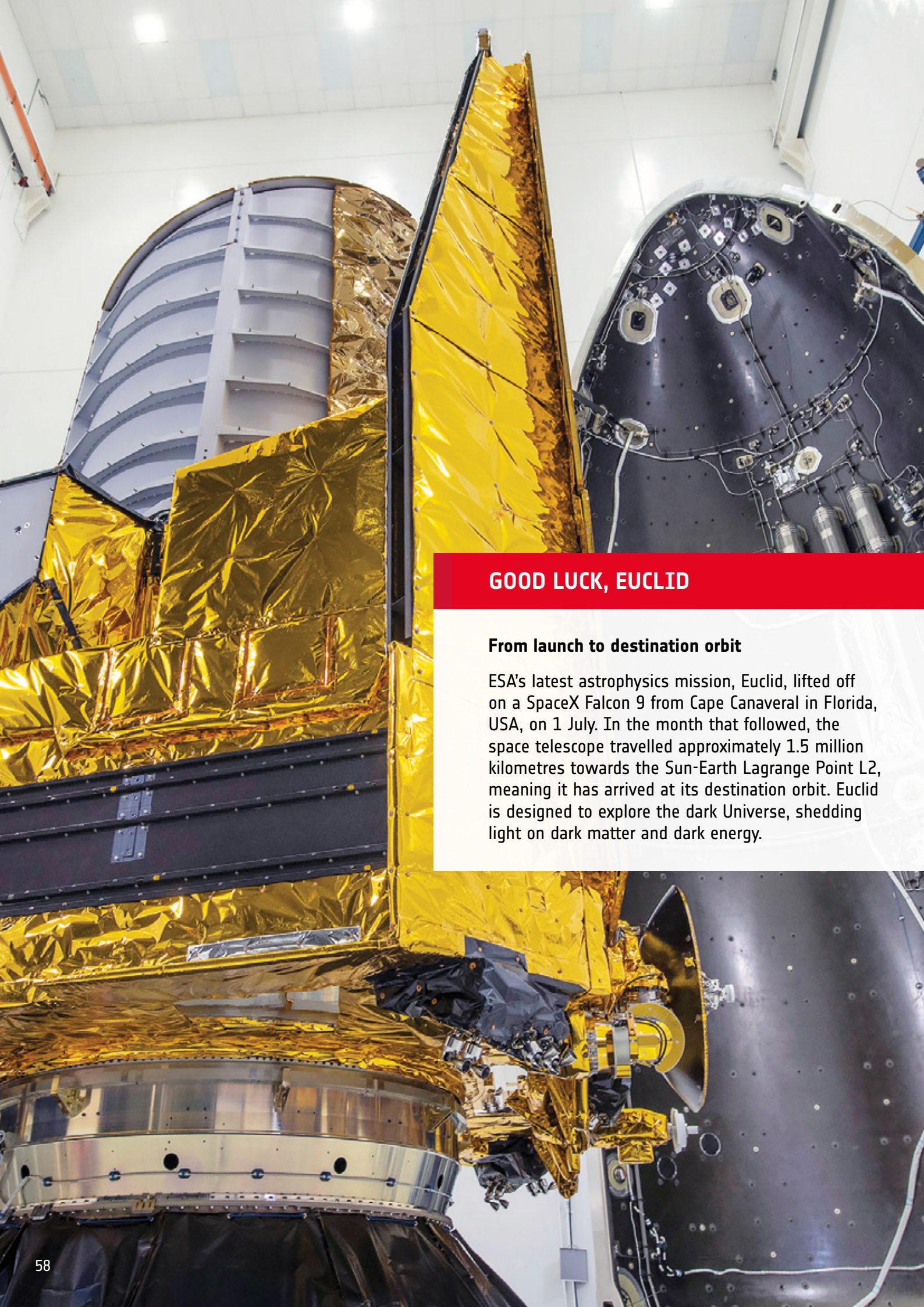
BepiColombo's third Mercury flyby

The ESA/JAXA BepiColombo mission has made its third of six gravity assist flybys at Mercury, snapping images of a newly named impact crater (Manley) as well as tectonic and volcanic curiosities as it adjusts its trajectory for entering Mercury orbit in 2025. The smallest planet in the Solar System starts appearing from the night side at the top right of this image taken on 19 June.

THE FINAL MISSION

Ariane 5 bows out in style

Europe's Ariane 5 rocket completed its final flight on 6 July, placing two communications satellites into their planned geostationary transfer orbits. The mission marked the 117th flight for Ariane 5, a series that began in 1996 and subsequently carried numerous commercial and European institutional missions into space.



GOOD LUCK, EUCLID

From launch to destination orbit

ESA's latest astrophysics mission, Euclid, lifted off on a SpaceX Falcon 9 from Cape Canaveral in Florida, USA, on 1 July. In the month that followed, the space telescope travelled approximately 1.5 million kilometres towards the Sun-Earth Lagrange Point L2, meaning it has arrived at its destination orbit. Euclid is designed to explore the dark Universe, shedding light on dark matter and dark energy.

FAREWELL AEOLUS!

A trailblazing mission comes to an end

On 30 April, Aeolus, the first mission to observe Earth's wind profiles on a global scale, concluded its nominal operations. The mission surpassed its expected three-year lifespan by over 18 months. In a remarkable achievement, ESA's spacecraft operators guided Aeolus in a first-of-its-kind assisted reentry, leading to the spacecraft's demise over Antarctica on 28 July.

THE QUEST FOR A SUSTAINABLE USE OF SPACE

By introducing a new approach to space debris and successfully executing an assisted satellite reentry, ESA aims to be a pioneer in advancing space sustainability.

Upon receiving a collision warning, ESA's teams responsible for satellites in orbit swiftly engage in analysing the potential threats. These threats might include an object as small as a few centimetres wide or another spacecraft, whose trajectory indicates a collision risk. Upon confirmation of the threat, an avoidance manoeuvre becomes imperative, as even small space junk can seriously damage satellites that provide us with essential communication, navigation, or monitoring services.

The frequency of these warnings has been steadily increasing in recent times. For 10 of the ESA satellites, they nearly quadrupled from 2020 to 2022. This trend underscores a concerning scenario around Earth that experts deem nothing short of catastrophic. If no action is taken, given the escalating pace of space activity and the proliferation of space debris (any uncontrolled human-made equipment, spacecraft, upper stage of a rocket or fragments thereof), an ominous cascade of collision incidents looms above our heads.

In light of this, ESA has embraced a new strategy for space sustainability: the Zero Debris approach. The agency's aim is to make sure that no new debris is generated in orbit by 2030, which implies implementing measures that exceed current international guidelines and recommendations. An example of ESA's commitment to establishing Europe as a pioneer in the sustainable use of space is the first-of-its-kind assisted reentry of one of its satellites.

Since the dawn of the space age, there has consistently been more space debris in orbit than operational satellites. Given the global scale of the problem posed by space debris in the near-Earth environment, only a globally supported solution can be the answer.

Aeolus: A remarkable farewell

Exceeding both scientific expectations and its planned orbital lifespan, the Aeolus mission stands as one of ESA's most successful Earth observation missions. It was the first satellite to acquire profiles of Earth's wind on a global scale. Yet, its conclusion proved to be just as innovative as its time spent in orbit. In a bold move, ESA conducted an assisted reentry of the 1360 kg satellite at the end of July 2023, a decision diverging from the mission's original design.

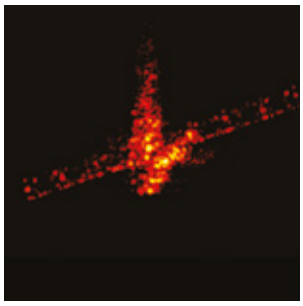
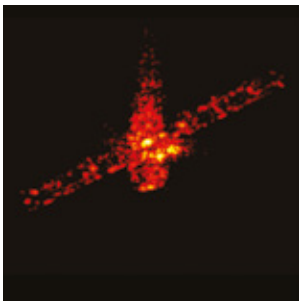
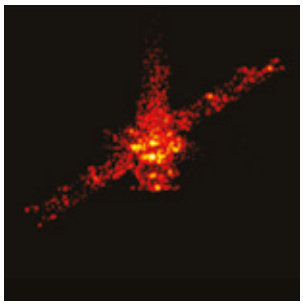
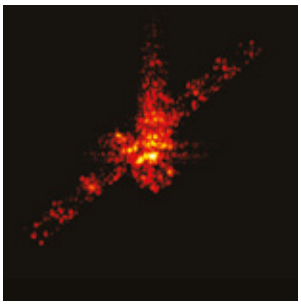
"The goal of this first-of-its-kind assisted reentry was to guide Aeolus on a final safe path, where it would disintegrate in Earth's atmosphere as far as possible from inhabited regions," says Mission Manager Tommaso Parrinello. "Although we could have opted for an uncontrolled reentry, we acknowledged a moral duty to set a precedent and demonstrate that we can go beyond mere legal requirements. We wanted to convey a significant message: at ESA, we take care of our satellites, from their launch to the mission's conclusion."

After months of detailed planning and analysis, ESA together with industrial partners designed a complex and never-before-performed set of manoeuvres to control, as much as possible, Aeolus's fall. With this objective in mind, the team of spacecraft engineers, flight dynamics experts, and space debris specialists at ESOC mission control centre in Germany meticulously pushed the satellite to its operational boundaries. During a week of intense and critical operations, they executed a sequence of intricate manoeuvres, reducing Aeolus's orbit from around 280 km to a mere 120 km, targeting its descent and eventual disintegration over uninhabited regions. Aeolus reentered over Antarctica on 28 July.

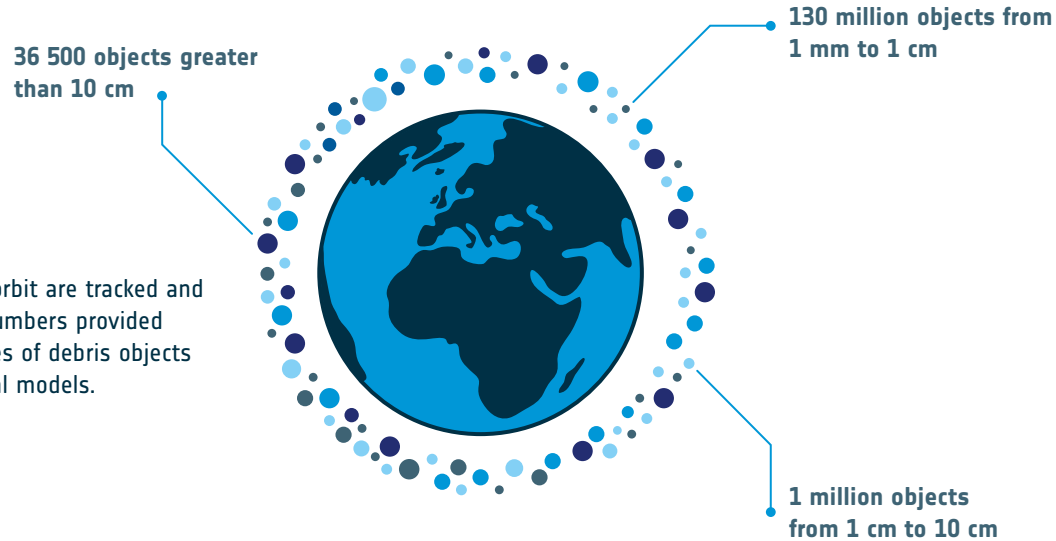
The task was monumental, as highlighted by the mission's members. For Libe Jauregui, Aeolus Flight Dynamics Manager, the descent through the atmosphere presented heightened intricacies, given that the satellite's original design did not encompass manoeuvres at such low altitudes. Likewise, assuring communication and command transmission for the "extremely significant manoeuvres" during reentry was a taxing endeavour for the ground stations, adds Giulio Baldo, Aeolus Ground Operations Manager. For the whole team, meticulous preparation and pre-execution simulations were indispensable.

Isabel Rojo Escude-Cofiner, Aeolus Flight Operations Director, says the objective was clear and straightforward: "We wanted to reduce the risk of potential fragments impacting inhabited regions. How? By attempting a set of precise manoeuvres in previously unexplored territory. The pressure and stakes were high, but our cohesive teamwork got us through."

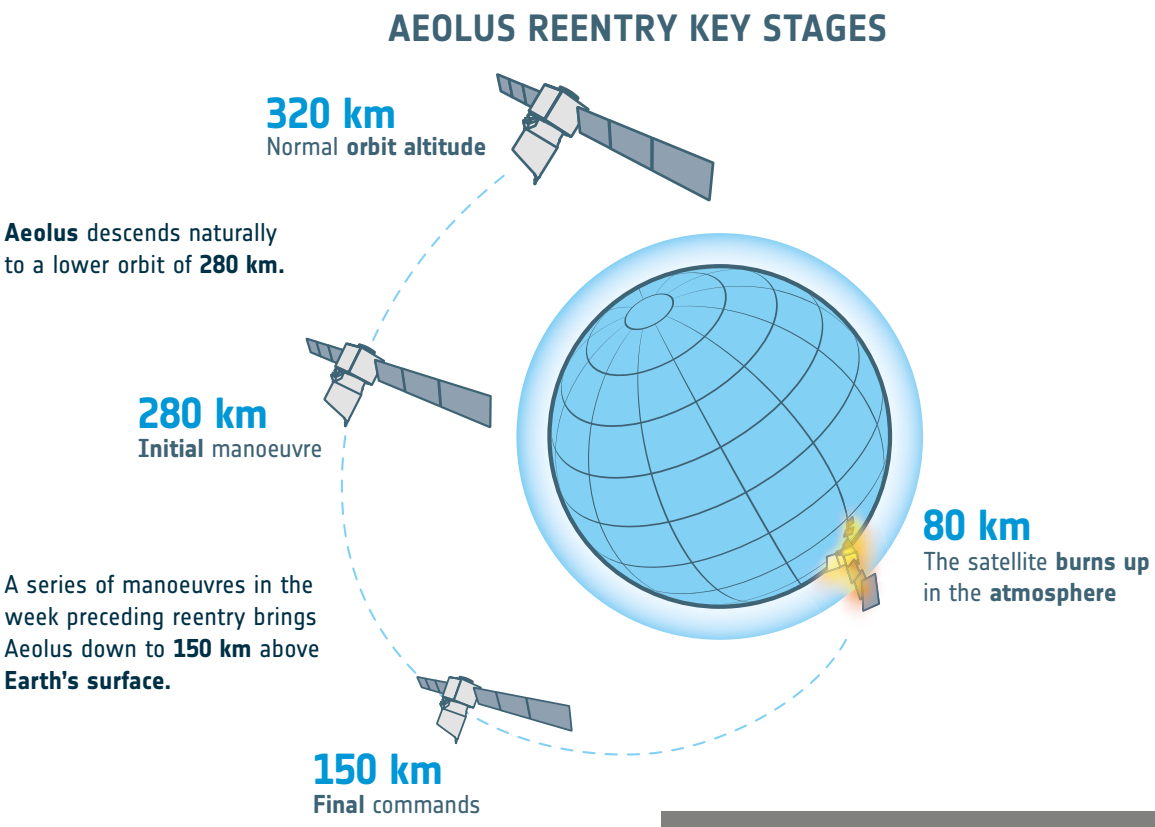
"Our endeavour with Aeolus was to set a precedent by showcasing the standards we aspire for all to embrace moving forward," concludes Libe. Tommaso adds, "Through Aeolus's end, our aim was to heighten awareness about the urgency of preserving the space environment, which is progressively becoming more polluted."

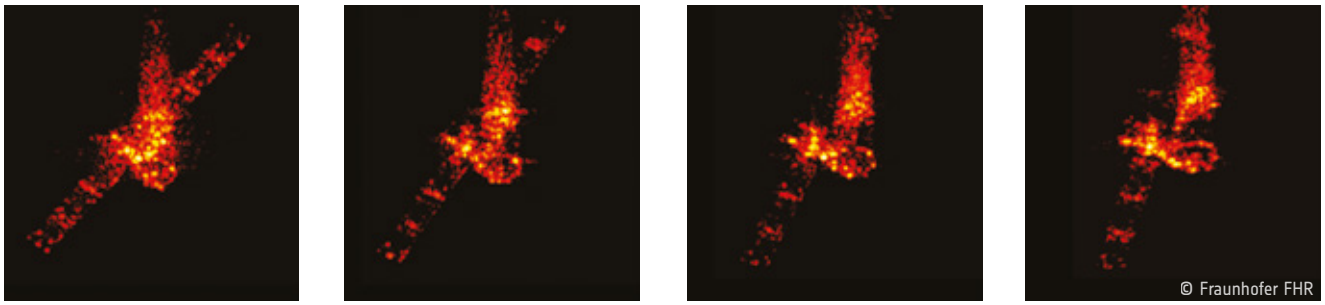
SPACE DEBRIS BY NUMBERS



Not all objects in orbit are tracked and catalogued. The numbers provided represent estimates of debris objects based on statistical models.



Aeolus was in orbit around Earth for four years, eleven months and six days. For three hours at the very end, it was space debris. Those are the last eight images ever taken of ESA's wind-profiling mission, showing it beginning to tumble as it was buffeted by Earth's atmosphere, during its very brief 'junk' phase.



Navigating the orbital minefield

Out of the roughly 15 880 satellites launched since the start of the space age in 1957, approximately 10 590 persist in orbit, with 8700 currently operational. They coexist with an estimated excess of 130 million debris fragments, ranging from 1 mm to 1 cm, as well as 1 million fragments spanning 1 cm to 10 cm, along with over 36 500 fragments surpassing 10 cm. Collectively, these elements have a mass of more than 11 000 tons.

Ranging from expired satellites to launcher upper stages and adapters or fragmented remnants, those debris, not all of which can be detected and tracked, far exceed bullet-like velocities. While a collision with an active satellite could jeopardise or even destroy the spacecraft and its vital terrestrial services, a serious impact on a crewed mission would be catastrophic. Simultaneously, each collision generates additional debris, as fragments are released upon impact.

ESA teams overseeing satellites in Earth orbits, including the three-satellite Swarm mission and the Sentinel satellite family, have observed a surge in collision alert occurrences. In 2020, 28 warnings were issued, leading to 10 necessary collision avoidance manoeuvres. In 2021, there have been 48 warnings with 7 executed manoeuvres. The subsequent year recorded 99 warnings, prompting 27 satellite trajectory adjustments to avoid a possible collision.

"Each manoeuvre involves a great deal of work," observes Libe, who works on ESA's Earth observation satellites. "We need to analyse and predict the trajectory of debris, calculating the risk of collision, planning the manoeuvre, sending commands to the satellite to change orbit and

checking to see that the results were as expected." It holds the potential "to influence the operational capabilities of the satellites, disrupt scientific measurements and entails extra fuel consumption."

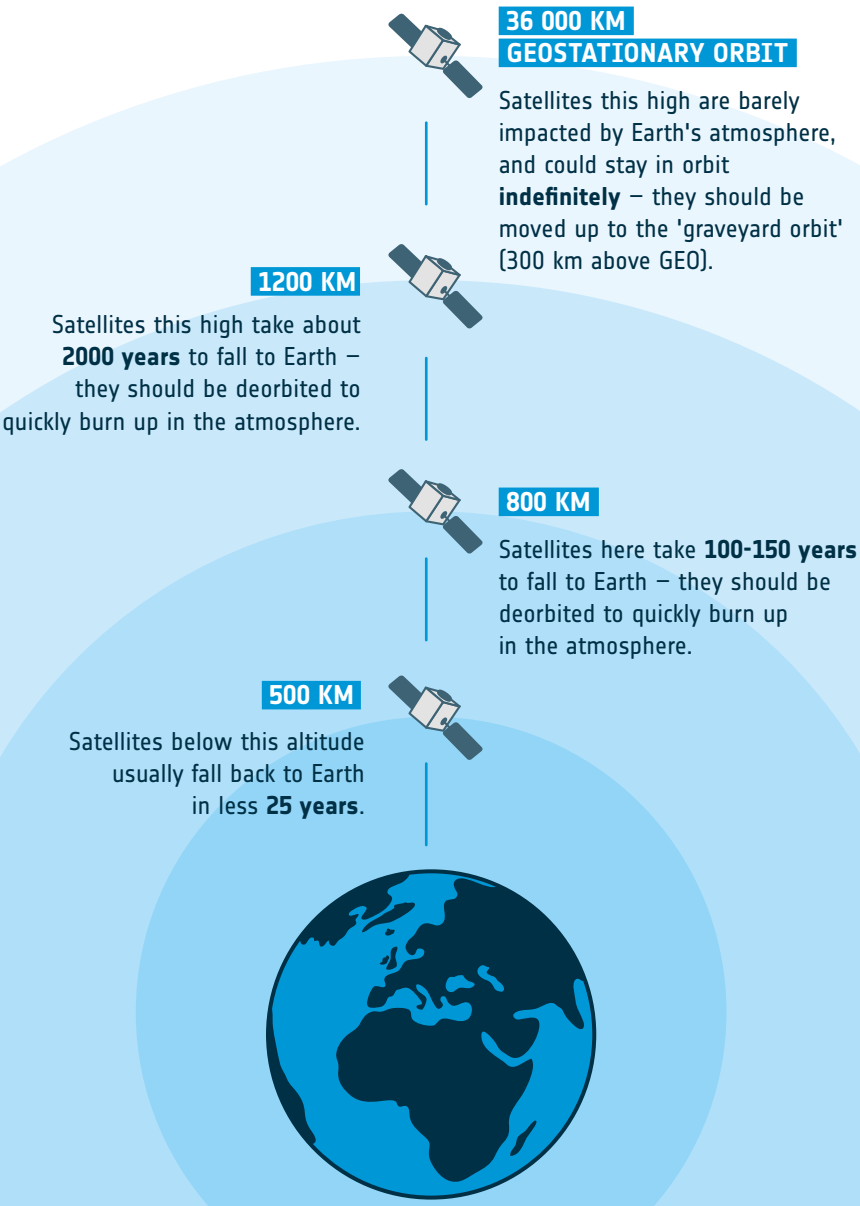
The increasing number of avoidance manoeuvres doesn't stem from a sudden debris spike, but rather from the nearly exponential rise in orbital activities, says Tim Flohrer, Head of ESA's Space Debris Office. He underscores, "We are witnessing a surge in traffic, especially in some areas, which comes from the emergence of new operators, advancements in miniaturisation, and the widespread establishment of large commercial constellations in low Earth orbits, notably below 600 km of altitude." In the previous year, over 2400 satellites were launched, a stark contrast to merely 15 years ago, when approximately 100 satellites were launched annually.

Pioneering new standards

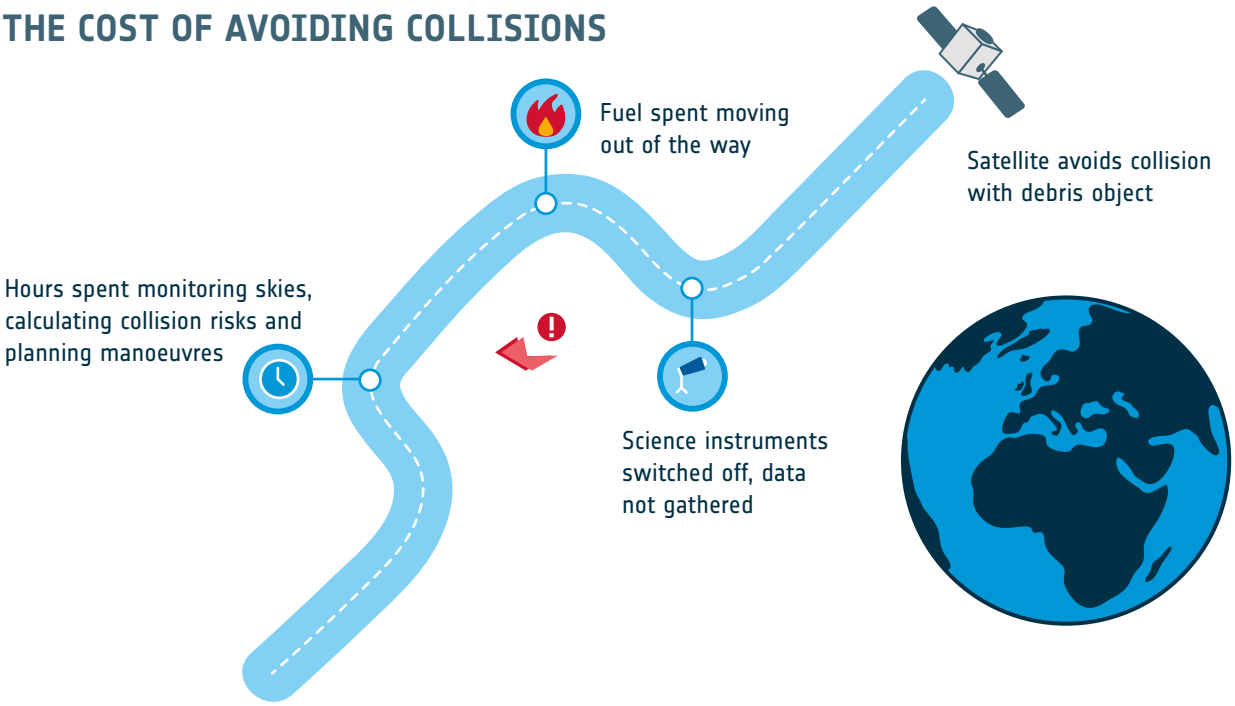
The growing consensus that stricter space debris mitigation practices need to be implemented globally is founded on many simulated scenarios of long-term evolution of the space environment conducted by ESA and other space agencies, like those presented by ESA's Space Debris Office in their most recent annual Space Environment Report (June 2023). These simulations show that even if no more rockets are launched, the amount of space debris in orbit will continue to increase due to collisions between objects already in orbit.

In the absence of universally binding regulations, and because the current regulations are not sufficient to tackle the full scale of the space debris problem, ESA has committed to develop and implement more ambitious measures for space debris mitigation and remediation

FALLING TO EARTH TAKES A LONG TIME



THE COST OF AVOIDING COLLISIONS



by 2030: the Zero Debris approach. The aim is to curtail debris generation in critical orbits.

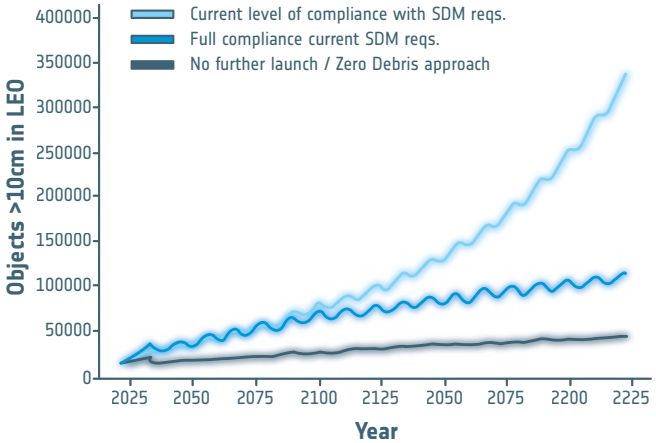
This strategy is a central component of both ESA's Agenda 2025 and the PROTECT accelerator. It encompasses key actions, including evolving Space Debris Mitigation standards and policies, enhancing spacecraft platforms, demonstrating reliable removal services, and improving space operations and traffic coordination. Its execution relies on a roadmap of pivotal technical advancements, demanding close collaboration with all stakeholders, particularly the European industry, says Luisa Innocenti, Head of ESA's Clean Space Office.

Luisa adds that the key focus is preventing future satellites from becoming debris, while simultaneously enhancing technology for actively removing large objects. "We need to drive the development of technologies that hasten reentries and ensure more efficient atmospheric decay," she says. "Currently set at a 25-year timeframe, we are actively working to shorten this window for post-mission disposal in protected regions to five years, or even shorter if the risk of collision of the satellite during the post-mission disposal phase is too high."

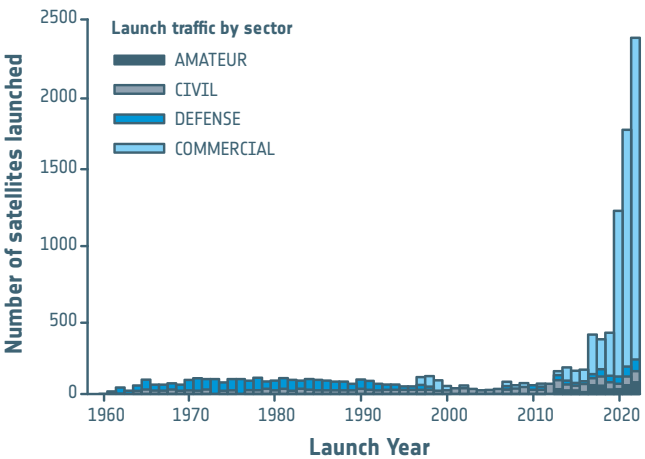
In early November, at the Space Summit 2023 in Seville, Spain, ESA unveiled the Zero Debris Charter, a pioneering initiative uniting proactive entities to set ambitious, measurable space debris mitigation and remediation targets for 2030. This collaborative effort is accomplishing two vital goals: building a diverse community of actors in Europe and beyond committed to further advancing space safety and sustainability; developing a precise and common vision of space sustainability for 2030 on which to build an ambitious European roadmap.

"The Zero Debris approach will significantly affect how we procure, build, and operate missions at ESA," says Tim. "The goal is both ambitious and crucial." He points out that "our modern society is more dependent on orbital resources than ever before, so it's imperative that we shift our perspective on the space environment." This "finite resource" might presently be endangered due to "over-exploitation," he says. "This underscores the need for all of us to embrace a new approach to all our space activities."

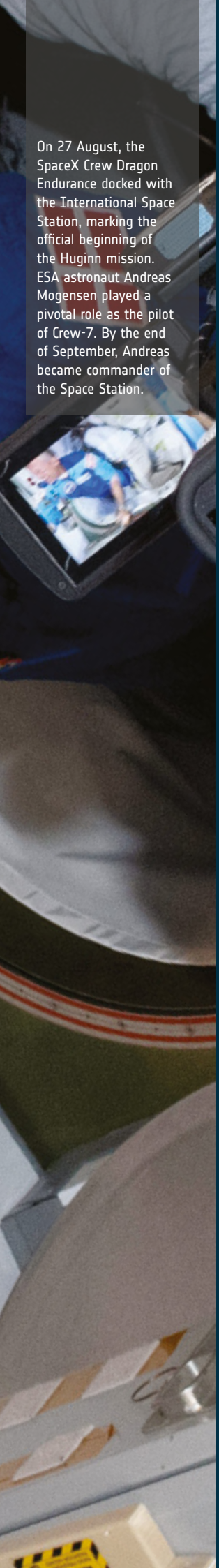
Evolution of number of objects in Low Earth Orbit over 200 years for different scenarios



Payload Launch Traffic into 200 ≤ h_p ≤ 1750 km



To CAM
OVHD FWD
IMV VALVE
esa
huginn



On 27 August, the SpaceX Crew Dragon Endurance docked with the International Space Station, marking the official beginning of the Huginn mission. ESA astronaut Andreas Mogensen played a pivotal role as the pilot of Crew-7. By the end of September, Andreas became commander of the Space Station.

SELECTED HIGHLIGHTS

August to October 2023

In September, ESA astronaut Andreas Mogensen became commander of the International Space Station, the sixth European to take on this role.

Hera is complete. ESA's asteroid mission for planetary defence was built and prepared in two halves, but in August, they were brought together to make a single spacecraft, ready for full-scale testing of its readiness for space. Hera is scheduled for launch in October 2024, to rendezvous with the Didymos and Dimorphos asteroid system about two years later.

Following the devastating earthquake that struck Morocco on 8 September, radar measurements from Europe's Copernicus Sentinel-1 satellite mission proved instrumental in assessing ground shifts resulting from the quake. These measurements not only facilitated post-disaster reconstruction planning but also advanced scientific research.

In September, notable events unfolded in the realm of launchers. Vega, in its 23rd launch, deployed two Earth observation satellites and a number of CubeSats into orbit. Meanwhile, a critical phase in Ariane 6's testing occurred with a complete launch sequence on the launch pad at Europe's spaceport in French Guiana.

Concluding this 2023 overview, a captivating image from ESA's Euclid mission was unveiled at the Space Summit 2023 in Seville, Spain. The image showed a dazzling display of the Perseus galaxy cluster adorned with thousands of faraway galaxies twinkling like holiday lights in the vast cosmic expanse.

HERA IS COMPLETE

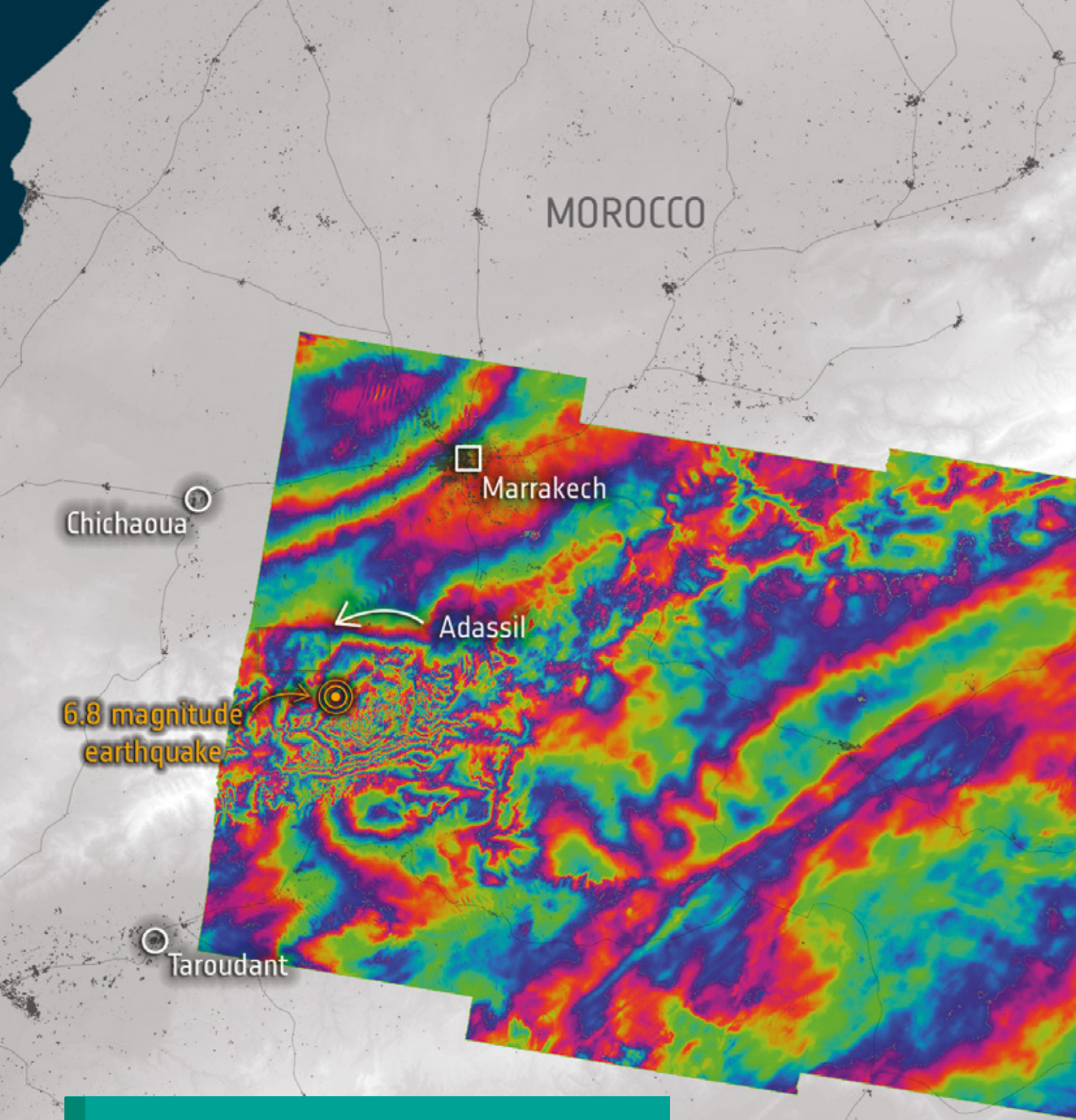
ESA's asteroid mission ready to be tested

Hera's Core Module can be thought of as the brains of the mission, hosting its onboard computer, mission systems and instruments. Enclosed in a cage, it is seen here being lowered onto the spacecraft's Propulsion Module at OHB Bremen to complete the spacecraft.

ARIANE 6 DRESS REHEARSAL

A key step in the test campaign

At Europe's Spaceport in French Guiana, on 5 September, ESA's new Ariane 6 launch vehicle was fuelled up and its core stage engine fired. With the rocket standing on its launch pad, the Vulcain 2.1 engine was ignited, fired for four seconds as planned and switched off before its liquid oxygen and liquid hydrogen fuels were drained to their separate underground tanks.



MOROCCO EARTHQUAKE FRINGES

Satellite imagery aids emergency response

Following the devastating earthquake that struck Morocco on 8 September, satellite data were made available through the International Charter 'Space and Major Disasters' to help emergency response teams on the ground. Radar measurements from Europe's Copernicus Sentinel-1 satellite mission were used to analyse how the ground shifted as a result of the quake. Sentinel-1 acquisitions from 30 August and 11 September were combined to produce this interferogram, the coloured fringe pattern shows surface displacement.

A GOLDMINE OF KNOWLEDGE

New Gaia image of Omega Centauri

ESA's Gaia mission has unveiled a wealth of new data, including this stunning view of Omega Centauri, showcasing ten times more stars within the cluster. This expanded dataset will empower researchers to study the cluster's structure, how the constituent stars are distributed, how they're moving, and more.

23RD VEGA FLIGHT

Two new satellites put in orbit

On 8 October, Vega's 23rd flight deployed two satellites and a number of CubeSats into Earth orbit. The rocket's main passengers were two Earth observation satellites: THEOS-2, offering crucial data on water resources, weather, and land use for Thailand's Ministry of Agriculture, and Triton, a Taiwan Space Agency satellite designed to collect signals that bounce off the sea surface to help scientists calculate wind patterns over our oceans.

GALILEO'S LATEST ASSET

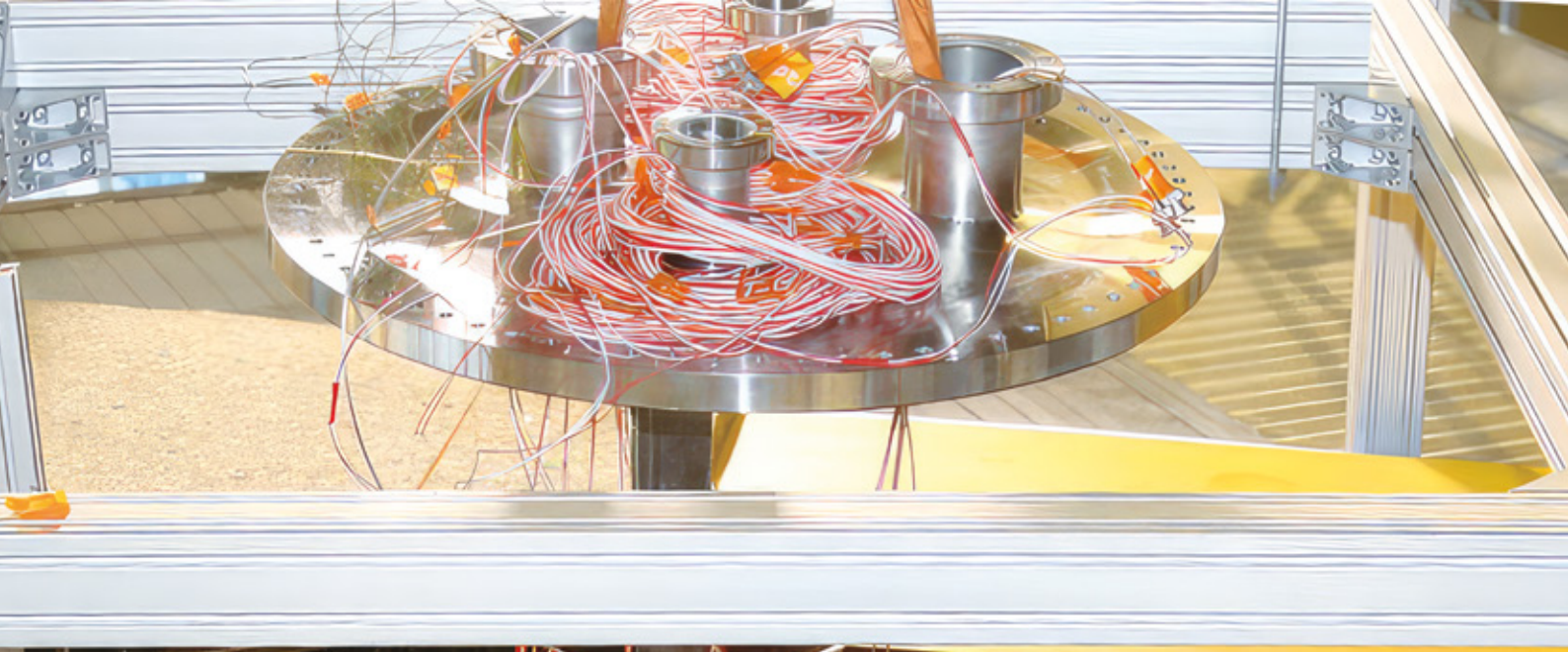
New station goes on duty

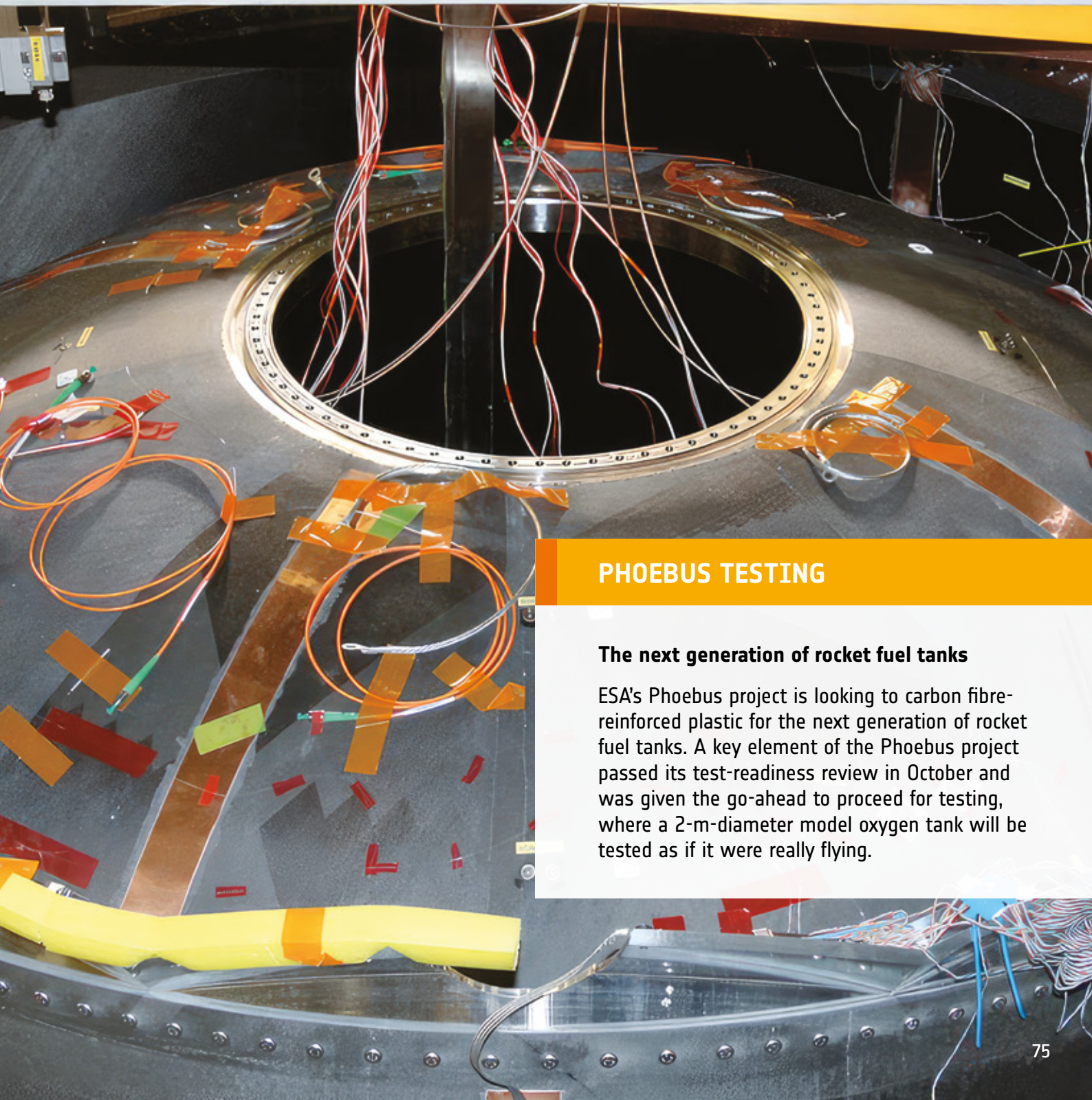
The Galileo project's ground segment recently welcomed a brand-new asset: the Telemetry, Tracking, and Control (TT&C) facility. Featuring a 13.5-metre diameter parabola dish mounted on top of a 10-metre-high steel and concrete structure, this facility, located within the premises of Europe's launch site in Kourou, French Guiana, enhances communication with Galileo's expanding satellite constellation.

THE LUNAR CAMERA

A new tool to document scientific discoveries

When astronauts return to the Moon, they will take more pictures of the lunar surface than any previous human visitors. To develop the best camera for the job, European astronauts and scientists are lending a helping hand to NASA's Artemis imagery team. We can see here ESA astronaut Thomas Pesquet documenting field exploration in the lunar-like landscapes of Lanzarote, Spain.





PHOEBUS TESTING

The next generation of rocket fuel tanks

ESA's Phoebus project is looking to carbon fibre-reinforced plastic for the next generation of rocket fuel tanks. A key element of the Phoebus project passed its test-readiness review in October and was given the go-ahead to proceed for testing, where a 2-m-diameter model oxygen tank will be tested as if it were really flying.

A REVOLUTION FOR ASTRONOMY

Euclid's view of the Perseus cluster of galaxies

ESA's Euclid mission began its exploration of the dark Universe with a spectacular view of the Perseus Cluster. This snapshot, showing 1000 galaxies belonging to Perseus and more than 100 000 additional galaxies further away in the background, is a revolution for astronomy. Many of these faint galaxies were previously unseen, some of them so distant that their light has taken 10 billion years to reach us.

SPACE SUMMIT 2023

Europe's sustainable and competitive space ambitions

At the ESA Space Summit held in Seville, Spain, on 6 November, government ministers representing ESA's Member States, Associate States and Cooperating States resolved together to strengthen Europe's space ambitions to better serve European citizens. Europe will harness space for a greener future, take decisive steps in exploration, and ensure autonomous access to space while preparing a paradigm shift towards a more competitive next generation of launchers.

PIONEERING SECURE COMMUNICATION AND BEYOND

ESA is leveraging quantum technologies to shape the future of communication systems, enhancing security and efficiency with the aid of satellites.

Will we soon be able to measure the thickness of a raindrop from space? The significance of this question lies not merely in the answer, but in the very act of posing it realistically. It mirrors the promises and aspirations initiated by the advent of a new era of quantum technology.

Having dismantled the conceptual certainties of classical physics and reshaped our understanding of reality, quantum mechanics now holds the potential to revolutionise our information processing and communication systems. It could offer unparalleled computing power along with the attendant opportunities and risks.

ESA occupies a pivotal role in this emerging era. On one front, it assumes the role of a potential beneficiary, with immense requirements for cutting-edge sensors and data management – especially given its Earth observation activities.

However, ESA is not just an end user; it is currently a key enabler collaborating with the EU on numerous programmes and projects. These initiatives lay the groundwork for the communication systems of tomorrow, in which satellites are poised to play a central and transformative role.

Our communication landscape is undergoing a transformative shift, envisioning networks that provide seamless connectivity between optical terrestrial and non-terrestrial assets. These networks promise high security, low latency, and enhanced bandwidth, revolutionising our connectivity experience.

Navigating quantum realities

If we encounter the terms 'superposition' and 'entanglement', it's likely to be within the realm of quantum mechanics, where these concepts describe the special properties of individual particles. While these phenomena have been observed and measured, they remain the subject of intense debate, showcasing a reality often deemed counter-intuitive. They provide a fresh perspective on the workings of nature and unveil promising technological horizons.

In the quantum realm, 'superposition' implies that a particle can exist in two opposite states simultaneously; its state is determined only upon measurement (at which point it collapses to a singular state). 'Entanglement', on the other hand, means that particles, such as a pair of photons, can share a joint state, irrespective of their physical distance. Remarkably, when one entangled particle is measured, the state of the other instantaneously correlates (thus, an entangled state). This phenomenon occurs without regard to distance, defying classical notions of space and time.

Significant uncertainties persist regarding the practical applications of quantum mechanics. But a wave of innovations are on the horizon, with real-world applications already in play. The Royal Swedish Academy of Sciences recognised this progress, awarding the 2022 Nobel Prize in Physics to three researchers for their groundbreaking experiments showcasing the potential to investigate and control particles that are in entangled states.

The areas that could benefit from the use of quantum technologies, based on quantum properties of particles, include computing, sensing technologies, and communication. Notably, the latter field assumes paramount importance due to the development of quantum computers, which will pose a formidable challenge to existing cryptographic methods safeguarding government and civilian communications, as well as stored data. These supercomputers, distinguished by their unparalleled

A visible green laser pierces the night sky, emanating from ESA's Optical Ground Station (OGS). Situated within the Teide Observatory, perched 2400 metres above sea level on the volcanic island of Tenerife, the OGS serves as a crucible for advancing optical communication systems for space and conducting cutting-edge quantum communication experiments. The laser looks curved because this picture was taken with a fisheye lens.

processing speed, could potentially unravel the predictable mathematical algorithms that underpin traditional cryptographic techniques.

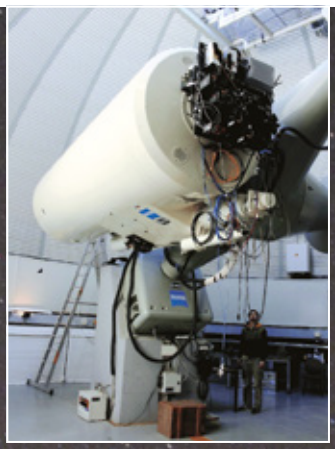
Unbreakable security?

Establishing secure communication has always revolved around the challenge of distributing cryptographic keys safely to the legitimate communicating partners. A quantum key distribution (QKD) system, a pioneering application of quantum mechanics, addresses this challenge in a new way by leveraging the properties of, usually, light (photons), which are used as signals between two users to communicate.

Christopher Vasko, who works at ESA as an optical and quantum innovation engineer, acknowledges that "employing the laws of quantum physics to prevent potential eavesdroppers may seem to amount to a kind of magic." Nevertheless, the underlying principle is straightforward: it involves generating and distributing a stream of photons with random features to both the sender and recipient of an encrypted message. The features of these photons are then used to create a cryptographic key.

The unparalleled security provided by such a system is rooted in the instant detection triggered by any eavesdropping. Eavesdropping acts as a measurement of the photon's state, causing it to change, just like the entangled photon with which it is paired. Consequently, any interference by an eavesdropper would be detectable by the users instantly, who could then just use another key that has not been tampered with to communicate. Additionally, the inherent unpredictability of quantum properties makes it impossible for the eavesdropper to replicate the state of the photon, even with the advanced capabilities of a quantum computer.

Hence, the quest to establish a new era of secure and reliable communication through quantum properties is



At the back of the telescope, the receiver station for entangled photons is prominently visible. This setup was part of an experiment in 2019 in collaboration with the Chinese Academy of Sciences, aiming to test intercontinental quantum communication.
The telescope captured incoming photons from the Chinese Micius satellite, which were then channelled through glass fibres into the detection setup.

gaining substantial interest. This breakthrough holds promise for safeguarding sensitive information, with far-reaching implications for sectors like secure banking and government data processing.

Connecting Europe

The transmission of photons relies on proven technology, optical fibre, which played a vital role in keeping us connected during the COVID-19 pandemic. However, there are limits to how far photons can travel through optical fibre without losing their quantum properties, which poses challenges for QKD using photons in those fibres.

Harald Hauschildt, ESA's Strategic Programme Line Manager for optical and quantum communication (ScyLight), explains that "while connecting cities within the Netherlands would be possible, extending this technology cross-border via cable over hundreds or thousands of kilometres is not feasible, due to the degradation of the quantum signals."

The solution lies in integrating photons into satellites. Satellites, in conjunction with specialised ground stations, would enable the secure exchange and distribution of encryption keys throughout Europe via optical quantum space-to-ground links.

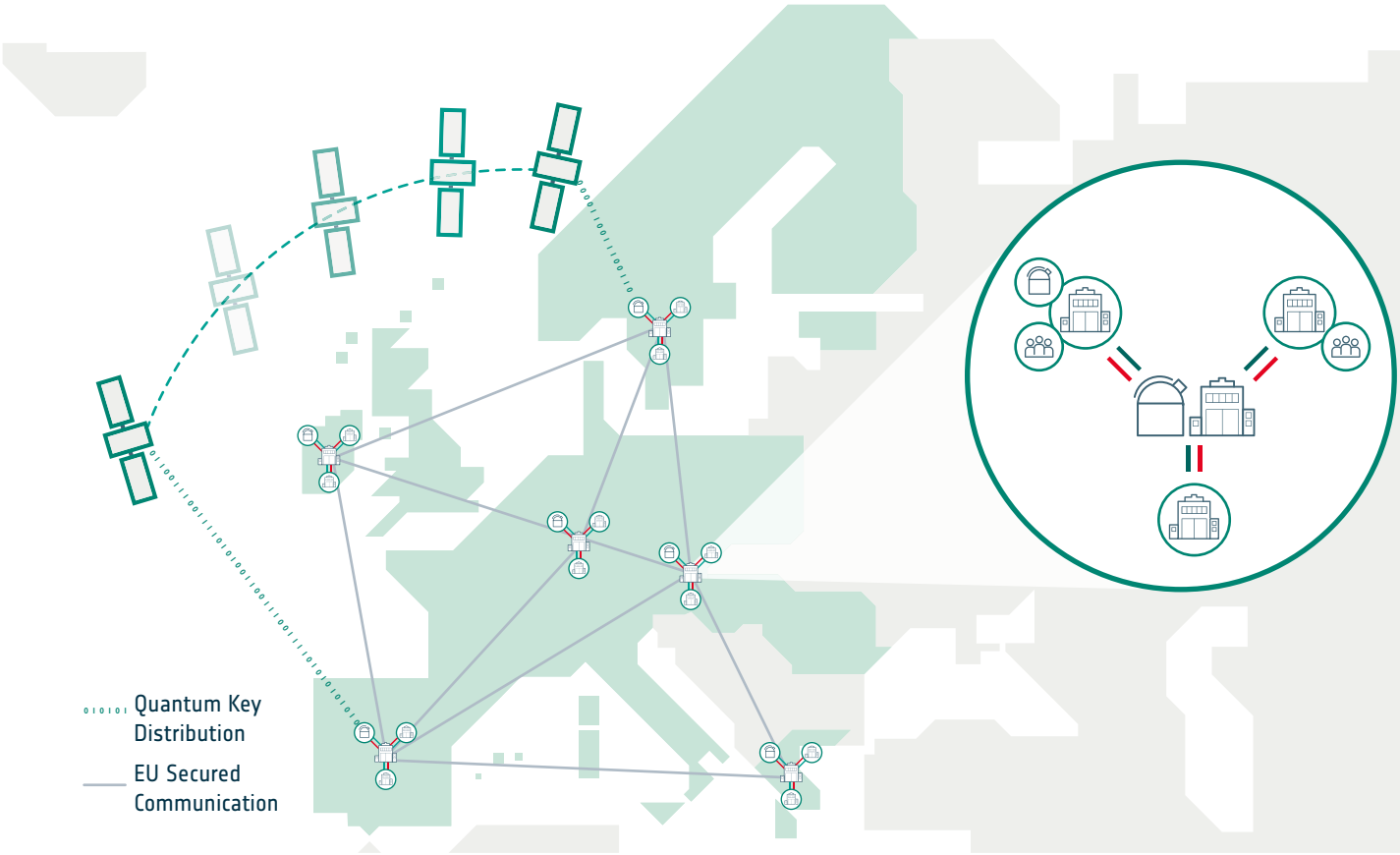
"Optical communication between satellites has been proven and is a very mature technology," says Christopher. Harald adds: "As the traditional satcom radio-frequency bands are experiencing bottlenecks due to many users interfering with one another, optical links are bringing unprecedented transmission rates, in the Terabit per second regime, which is supposed to be demonstrated in ESA's HydRON (High throughput optical network in space) project." In addition, optical links provide the benefit of avoiding interference and detection, as laser communication is extremely difficult to intercept due to a much narrower beam. Adapting this technology for quantum applications is one of the focuses of ESA's ScyLight program.

The ongoing effort aims to establish fully optical connections between two users through a satellite across borders. This objective is at the heart of the partnership between the EU and ESA, embodied in the European Quantum Communication Infrastructure (EuroQCI) initiative. It comprises a terrestrial segment using optical communication networks to establish a QKD system to connect strategic national and cross-border sites and a space segment with satellites developed under ESA's Security And cryptoGraphic mission (SAGA).

Yet, this is just the beginning. The broader vision extends far beyond secure communication, aiming to redefine the future of the Internet. According to Harald, "The initial step would be to establish a reliable infrastructure where both terrestrial and space networks are integrated, ensuring

A quantum test setup was integrated into the Air Zero-G aircraft for experiments conducted during an ESA parabolic flight in 2023. The results of this experiment demonstrated that current quantum communication platforms are remarkably robust – no effect due to the changes of acceleration was observed. This is especially important for the development of space-based applications.

EAGLE-1: EUROPE'S FIRST SATELLITE QUANTUM KEY DISTRIBUTION SYSTEM



seamless connectivity between optical terrestrial and non-terrestrial assets." Then, the superposition properties of photons could not only help securely transmit key material but also be used, in principle, as limitless information carriers.

Recognising this potential, the EU and ESA have strengthened their partnership, signing a 12-year agreement in September. This partnership supports the development of the new EU space-based communication system, called IRIS² (Infrastructure for Resilience, Interconnectivity, and Security by Satellite). It aims to establish a network that combines high security, low latency, and enhanced bandwidth. The first satellites and ground stations are set to be operational by the end of 2027.

Quantum pioneer in orbit

The establishment of a European quantum network is supported by a crucial in-orbit demonstration mission: Eagle-1. Expected to be launched in 2025/2026, the satellite is set to demonstrate a space-based QKD system, based on the quantum properties of photons and with technologies developed by European stakeholders. Eagle-1 is a Partnership Project involving ESA, the European Commission, and over 20 European companies.

Alberto Rubio, Eagle-1 Project Manager, explains the mission "is about designing, developing and demonstrating a comprehensive QKD end-to-end system. This entails integrating the satellite with the quantum key distribution payload and the development and deployment of all necessary ground elements for satellite control, photon reception and generation of cryptographic keys."

The system will build on key technologies developed under ESA's ARTES programme. Initial testing involves two user stations: one in Germany and another being developed by a Dutch company. The precise location for the latter station is yet to be determined. The in-orbit demonstration will span three years, extendable for an additional two years if needed. The satellite will orbit at an altitude of approximately 500 kilometres.

The challenges ahead

The challenges faced in the realm of quantum technology are substantial. Quantum systems, intricate and delicate, demand innovative protocols and specialised tools for their effective operation. One notable limitation lies in the fact that the transmission of photons via satellite can only take place at night. Furthermore, the scarcity of companies equipped with proven in-orbit technologies compounds the challenges, exacerbated by difficulties in recruiting skilled professionals in this field.

The feasibility of a space-based QKD system has already been demonstrated, notably by China. However, as Alberto points out, "Europe stands in a relatively strong position in terms of technology development for quantum key distribution, and it is up to us to continue supporting this development."

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.

April 2024 - Copyright © 2024 European Space Agency

Images copyright ESA unless otherwise stated

Published under the responsibility of the Head of the Foresight, Strategy and Coordination Department of the European Space Agency.

www.esa.int

87 FOREWORD

90 SCIENCE AND EXPLORATION

98 APPLICATIONS

112 SPACE SAFETY AND SECURITY

122 ENABLING AND SUPPORT

136 RESOUCES MANAGEMENT, CORPORATE ACTIVITIES AND EXTERNAL RELATIONS

150 ANNEX

Renato Krpoun, Chair of the ESA Council

FOREWORD

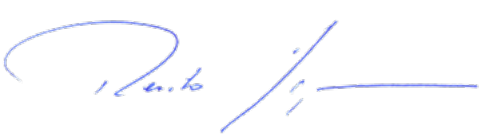
The ESA Annual Report is published every year, as laid down in the Convention. It provides the opportunity to highlight our accomplishments and showcase our pride in ESA. As Chair of the ESA Council, it is both a great honour and a pleasure to look back on what has been achieved. 2023 was an outstanding year for ESA, despite the ever changing, highly challenging environment that is today's space sector.

Success, cooperation, and perseverance are the notions that best characterise the past year for ESA. The success of the Agency is reflected in the scientific and technological domains, alongside its internal transformation as an intergovernmental organisation. The two science missions launched in 2023 – Juice and Euclid – are now seeking to uncover the mysteries of our Solar System and Universe, while our newly selected astronauts will, in time, set out to explore the vastness of the cosmos.

In the political and economic context of 2023, cooperation played a crucial role in the achievements of ESA. Strong ties with the European Union continue to be upheld and further reinforced. International partnerships with other space agencies such as NASA and JAXA and with private actors such as SpaceX have been blooming and are helping to unleash the full potential of space.

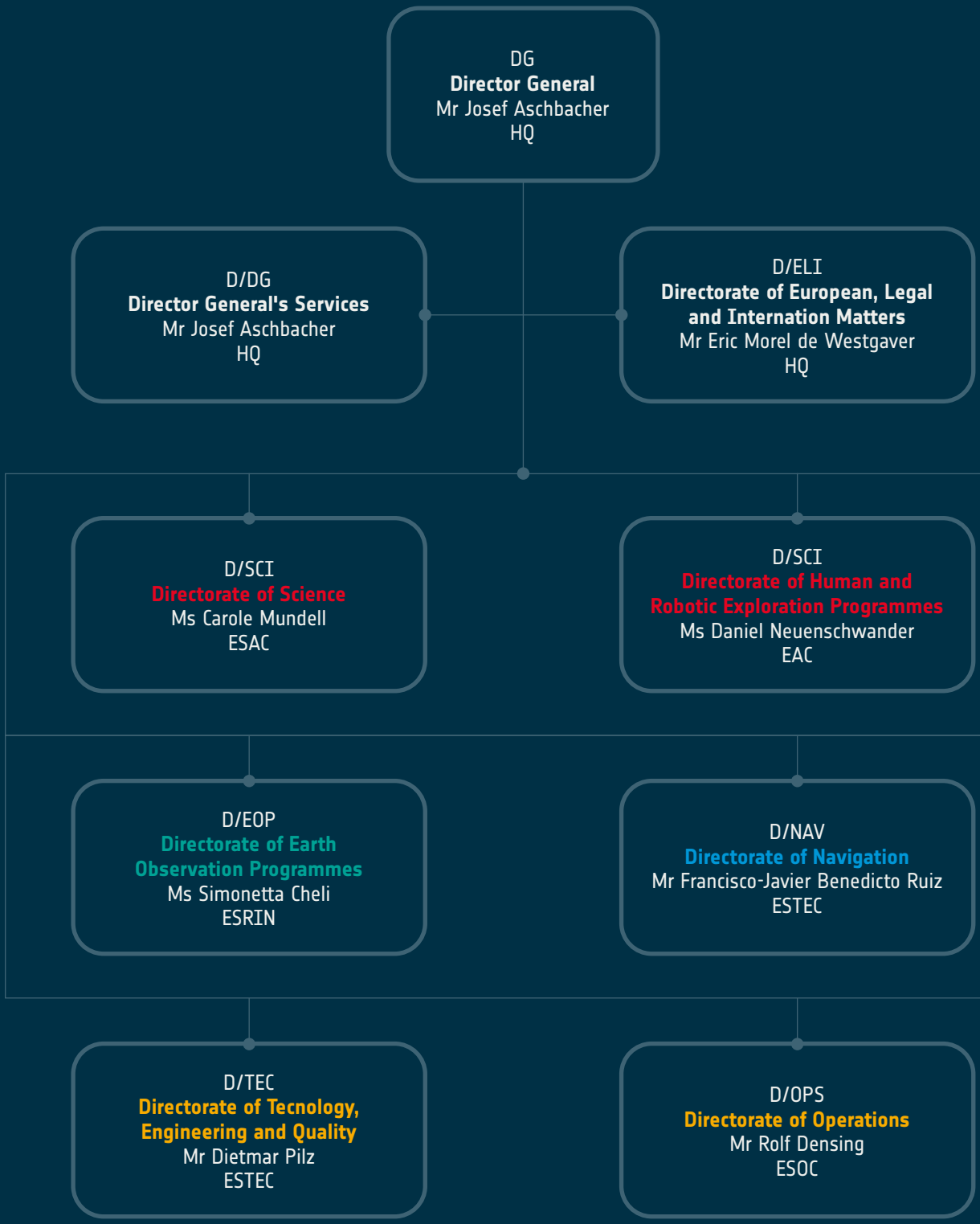
The space sector is undergoing a period of rapid change. Emerging private and public actors, unprecedented innovation and intensified commercialisation are driving this process, within a complex geopolitical context. The space industry as a whole is being challenged, and our Agency is no exception. Nonetheless, ESA has persevered and kept abreast of the challenges it is facing. Strong industry, scientific and technological excellence and the brilliant minds of Europe have allowed ESA to aim for the stars and maintain its position as a leader in the space domain.

To sum up, ESA is moving forward and evolving with immense ambition, revolutionary innovation and a vision that will help to achieve a strong and independent Europe, in space and beyond.



Renato Krpoun
Chair of the ESA Council

MANAGEMENT STRUCTURE



D/STS
Directorate of Space Transportation
Mr Toni Tolker-Nielsen (Acting)
HQ

D/CSC
Directorate of Connectivity and Secure Communications (*)
Mr Francisco-Javier Benedicto Ruiz (Acting)
ESTEC

D/CIC
Directorate of Commercialisation, Industry and Competitiveness
Ms Geraldine Naja
HQ

D/HIF
Directorate of Internal Services (*)
Mr Jean Max Puech
HQ

SCIENCE AND EXPLORATION

92 Science

96 Human spaceflight and robotic exploration

SCIENCE

One new Director, two ESA science missions launched, a steady stream of remarkable and inspirational discoveries, and plans taking shape for a visionary future programme: there has been much for the Science Programme to celebrate in 2023.

Management

Professor Carole Mundell took up duty as Director of Science on 1 March 2023. An internationally renowned scientist with extensive experience in inclusive leadership, operational management, strategy, and international science policy development, she immediately injected new energy into the Directorate, with a focus on reinvigorating engagement with all stakeholders: Member States and the scientific community first and foremost. As part of her engagement initiative, she has visited almost all the Agency's Member States (the final visits will be completed in early 2024) to present the content of ESA's Science Programme and her strategic vision for the future of ESA Science and, at the same time, to receive inputs from national politicians, industrial entities, and scientific communities. This valuable exchange of views and information creates a strong foundation for the preparation of the Science Programme for the 2040s and beyond.

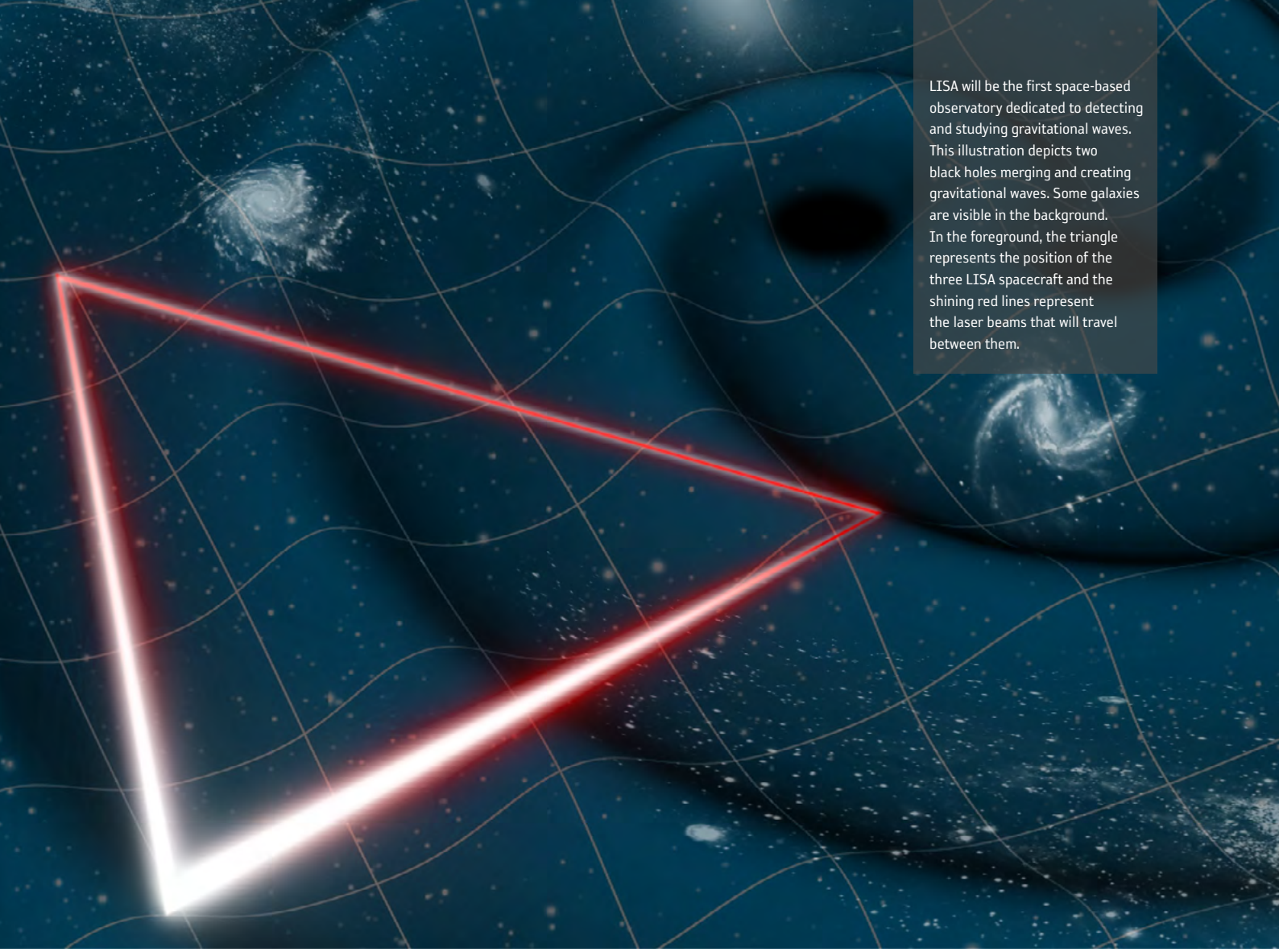
Launches

2023 has been a thrilling year in terms of launches of ESA scientific missions: the Jupiter Icy Moons Explorer (JUICE), the first "Large" mission in the Cosmic Vision programme – launched in April and is now en route to Jupiter to arrive in 2031, after a cruise which includes dramatic fly-bys of Venus, Earth, and the Moon.

July saw the launch of Euclid, ESA's "dark Universe detective", a mission to investigate how dark energy and dark matter have shaped the Universe as it is today. Euclid's exquisite first images, revealed to the public in November, provide a thrilling appetiser for what this mission will be capable of achieving for our scientific community.

Also launched in 2023 was JAXA's X-Ray Imaging and Spectroscopy Mission (XRISM). The mission aims to study gas in galaxy clusters, the chemical enrichment of the Universe, and extreme physics around accreting supermassive black holes. XRISM is classified a "mission of opportunity" within the Science Programme.

The successful launches of Juice and Euclid are a reminder of how ambitious science missions proposed by the European science community are brought to fruition under the umbrella of the ESA Science Programme, which can rely on the continued excellence of European industry and the scientific community.



LISA will be the first space-based observatory dedicated to detecting and studying gravitational waves. This illustration depicts two black holes merging and creating gravitational waves. Some galaxies are visible in the background. In the foreground, the triangle represents the position of the three LISA spacecraft and the shining red lines represent the laser beams that will travel between them.

Development and Studies

In the meantime, scientists, engineers, and industrial partners have proceeded at pace towards constructing the Laser Interferometer Space Antenna (LISA) and EnVision[1].

LISA, a European-led mission with a constellation of three spacecraft, will be a unique game changer for our understanding of the evolution of the Universe: it will detect, across the entire Universe, gravitational waves not detectable from the ground. These ripples in spacetime are caused when huge black holes at the centres of galaxies collide. LISA's detection of gravitational waves will enable scientists to trace the origin of these powerful, mysterious objects, to chart how they grow to be millions of times more massive than the Sun and to establish the role they play in the evolution of galaxies.

EnVision will host an array of innovative instruments based on cutting-edge technologies (in partnership with NASA) to study our sister planet, Venus from its inner core to its outer atmosphere, giving new insight into the planet's history, geological activity and climate, and providing a unique way to reveal the evolutionary paths that have made Venus so different from Earth.

Other missions currently in development – SMILE, PLATO, Ariel and Comet Interceptor – are proceeding smoothly towards their target launch dates, promising to make 2025–2035 another exciting decade of Science Programme mission launches.

In 2023, thanks to the tremendous, combined efforts of scientists, ESA engineers, Member States, and industry, the NewAthena mission was demonstrated to be financially affordable, technologically solid, and scientifically compelling, having the potential to revolutionise X-ray astrophysics in the 2030s timeframe.

In the spirit of offering a diverse and agile Science Programme, the second Fast mission, ARRAKIHS, was selected in 2022 as a future mission to hunt for dark matter and made significant progress in 2023 by successfully defining the mission baseline concept.

Operations and data

Missions currently in development and under study will one day join the fleet of operational Science Programme missions.

[1] LISA is the second "Large" mission under the Cosmic Vision Programme and EnVision is the fifth "Medium" mission within that programme. Both missions were proposed for adoption by the Science Programme Committee in January 2024.

The commitment of Member States, scientists, engineers, and industry has produced state-of-the-art spacecraft and instruments that are now exploring uncharted regions of our Solar System and providing deep insights into the cosmos.

Solar Orbiter continues its dance around the Sun, probing uncharted regions in its vicinity and providing never-before-seen details and features of our parent star with its unique orbit above the ecliptic plane. This high-tech mission also followed in the footsteps of ancient astronomers when it captured a transit of the planet Mercury, taking the opportunity to calibrate its onboard instruments.

On its way to a much closer encounter with Mercury is BepiColombo, an ESA-JAXA joint endeavour to explore the innermost planet of our Solar System. The planetary (ESA) and magnetospheric (JAXA) spacecraft, each carrying a suite of advanced probes and still flying as a single body, will use several gravity-assist manoeuvres in the coming years to finally enter orbit around Mercury in 2025. Once there, the spacecraft will separate to study this enigmatic planet and its interaction with the energetic particles produced by the Sun.

The NASA-ESA-CSA[2] James Webb telescope, the largest in space, continues to deliver new insights in our quest to understand the Universe. Among the many stunning views of the cosmos released in 2023 was a new detailed view of the Eagle Nebula, revealing (in mid-infrared) the pillars' layers of dust, and (in near-infrared) thousands of newly formed stars.

Meanwhile, CHEOPS, a "Small" mission, detected the shiniest exoplanet ever found: a surprising revelation that an ultra-hot exoplanet orbiting its host star in less than a day is covered by reflective clouds of metal.

All data provided by ESA science missions are used – with the support of the European Space Astronomy Centre's science data centre – by a constantly growing international community, as demonstrated by the steady increase in peer-reviewed scientific publications based on ESA mission data. Gaia, which celebrated its tenth anniversary on 19 December, continues to be the most prolific space observatory in operations today, with over 10,000 refereed publications to date and enabling close to 130 PhD theses. Data from the operational and legacy missions support a worldwide community of STEM enthusiasts, spanning school-age students to established researchers, fostering creativity and discovery, and producing a wealth of knowledge and results for the benefit of society.

Looking toward the future

A vital and vibrant Science Programme cannot, and should not, be content to focus solely on the short to medium term but must offer Member States, scientific communities, and industrial partners a vision of a future programme embracing new scientific ambitions and technological challenges. That

Solar Orbiter, launched in February 2020, carries a suite of ten advanced instruments to perform unprecedented close-up observations of the Sun, providing the first images of the uncharted polar regions of our star, and investigating the Sun-Earth connection.

[2]CSA: Canadian Space Agency

Euclid's spectacularly panoramic and detailed view of the Horsehead Nebula was captured in about one hour, showcasing the mission's ability to rapidly image an unprecedented area of the sky in great detail. Combining many observations of this quality covering large areas of the sky will be key to Euclid's core science of investigating the dark Universe.

is why, while working hard to complete the Cosmic Vision programme, with the engagement of a wide scientific community, ESA has set the scene for an ambitious future programme, Voyage 2050.

The first steps in preparing and implementing Voyage 2050 were taken in 2023, with the down-selection of three candidate missions – M-MATISSE, Plasma Observatory, and THESEUS – one of which will become the first "Medium" mission in the Voyage 2050 programme.

Voyage 2050 is designed to meet new, extraordinary challenges that see huge scientific communities in Europe mobilised to bring future Large missions to reality. The launch of these missions is envisaged in the 2035–2050 timeframe and will require investments in technologies in the near term to meet the scientific ambitions and technical challenges of the future.

The scientific themes for the Voyage 2050 Large missions, selected in consultation with Europe's science community, focus on the moons of the giant Solar System planets, temperate exoplanets or the galactic ecosystem, and new physical probes of the early Universe. Already, the first steps are being taken with studies and key technology development under way. An expert team of scientists has been developing the "Moons of the Giant Planets" theme throughout 2023 and ESA engineers have studied mission concepts using ESA's Concurrent Design Facility to shape the boundaries of scientific priorities and affordable mission scenarios, without precluding the possibility of pursuing ambitious and inspiring concepts with landing systems on exciting destinations, such as some of the most intriguing moons of Jupiter or Saturn. This tremendous effort will be completed in 2024 and will lead on to more focused studies to explore concrete mission designs responding to scientific ambitions and delivering significant public engagement.

The ESA Science Programme's commitment to excellence in space science continues to yield substantial results, as evidenced by the highlights in 2023, some of which are described above. Space science acts as a catalyst for technological breakthroughs, pushing industrial boundaries, building and consolidating industrial capability and capacity, and yielding innovations with widespread benefits. Space science missions help to answer the biggest scientific questions of our time, such as revealing the fundamental nature of our Universe, understanding how our Solar System formed, and searching for habitable worlds or even life elsewhere in the cosmos. The tremendously rich portfolio of operating missions in ESA's Science Programme provides a broad range of exciting opportunities enabling the scientific community to deliver first-rate science. These scientific achievements contribute in an important way to asserting European leadership in a key area of human endeavour. In addition, space science missions contribute to a secure return on investment by consolidating European industrial policies and by allowing smaller Member States to assume leadership roles. ESA recognises that space science generates stability and growth and is a tremendous instrument with which to build a peaceful, sustainable, and inclusive future. Furthermore, space science plays a crucial role in inspiring new generations, fostering expertise in STEM areas, and building and reinforcing the capabilities of European countries.

HUMAN SPACEFLIGHT AND ROBOTIC EXPLORATION

Terrae Novae – Expanding Europe's Space Exploration horizons

ESA's exploration programme is named Terrae Novae. This is implemented through the European Exploration Programme (E3P) created in 2016.

The third period of E3P was approved at the November 2022 Council meeting at ministerial level (CM22), with Estonia and Finland joining the programme, bringing to 24 the number of participating states in E3P. The increased financial envelope of Period 3 compared to the previous period (36% larger than Period 2) enabled the initiation of key new projects expanding Europe's exploration capabilities, in particular the Argonaut robotic lunar lander and the revised Rosalind Franklin mission and ensures the continuing implementation of ongoing activities.

2023 marked the 25th year of the International Space Station (ISS) and 23 years of permanent crew presence. Andreas Mogensen (Huginn mission) launched to the ISS in August, becoming the first non-American to serve as pilot of the SpaceX Dragon Crew vehicle. Subsequently, he became the sixth European to command the ISS starting in September. Meanwhile, a broad range of European science, technology and commercial utilisation activities were conducted on board the ISS through the course of the year.

The five newly selected career astronaut candidates (Sophie Adenot, Pablo Álvarez Fernández, Rosemary Coogan, Raphaël Liégeois and Marco Sieber) began basic training at the European Astronaut Centre in April, while the parastronaut feasibility project got under way, with John McFall reporting to the EAC in June. Furthermore, from the astronaut reserve, Marcus Wandt (SE) was assigned to the Axiom 3 mission, arriving at the EAC in June to begin training for his flight, which was launched in January 2024, while Sławosz Uznański (PL) began training at the EAC in September for a future flight to the ISS.

The SciSpacE element of E3P supported a wide range of science activities using the programme's ground-based, sounding rocket and orbital (ISS) platforms. In the course of 2023, a total of 241 science investigations were either in preparation, ongoing or completed, involving 1,611 scientists from 36 countries (both ESA Member States and international

partners). In terms of scientific output, a total of 148 peer-reviewed articles from SciSpacE research were published in 2023, while the information in the HRE Data Archive continues to expand, enabling further exploitation of the datasets from research studies.

Europe's human and robotic exploration of the Moon through this decade and the next will be enabled by a combination of key and critical-path contributions to the Artemis architecture, providing opportunities for European astronaut missions and research activities, along with direct robotic access to the lunar surface in the near term on international partner or commercial lunar missions until Argonaut provides a European capability in the early 2030s. Following the successful completion of the Artemis-I mission at the end of 2022, production and delivery of subsequent European Service Modules (ESMs) for future missions continued in 2023 with ESM-2 being handed over to NASA in June and ongoing development of the European contributions to the Gateway. Meanwhile, development and study work and mission studies for the Argonaut large logistics lander advanced, focusing on engine development and studies to support decisions on vehicle configuration and initial missions while tendering for subsequent development phases was initiated.

At Mars, the Trace Gas Orbiter (TGO) maintained science operations mapping trace gases in the Martian atmosphere, as well as acting as a data relay for the NASA Curiosity and Perseverance surface rovers. Results from TGO instrument observations were the subject of two scientific journal special issues in 2023, with over 50 peer-reviewed publications. Expanding Europe's Mars exploration to the surface, the Rosalind Franklin mission will be the first spacecraft to sample the sub-surface with the objective of searching for markers of past and present life. Following the renewed commitment by programme Participating States at CM22 to implement Rosalind Franklin, good progress has been made on the definition of the revised mission scenario in partnership with NASA aiming for a 2028 launch. The plan is to use the existing European hardware (primarily Rover and instruments) in combination with a new European entry and descent landing module as well as to have NASA contribute launcher and selected key systems.

Finally, the Space Summit in Seville in November provided the exploration programme with renewed political impetus, recommending an updating of the European Space Exploration Strategy as part of the overall ESA 2040 strategy enabling timely preparation of decisions for the next Council meeting at ministerial level. Furthermore, as a practical first step towards ensuring European utilisation of low Earth Orbit (LEO), development of a LEO cargo service was proposed and decided, with an invitation to tender for industry proposals for the first phase of the service being issued in December.

APPLICATIONS

100 Earth Observation

104 Connectivity and Secure Communications

108 Navigation

110 Focus on: Galileo Second Generation satellites take shape

EARTH OBSERVATION

ESA's world-class Earth observation systems – developed together with European and global partners – continued in 2023 to address scientific and societal challenges with a fleet of 14 operational satellites.

Europe's future Earth observation capacity will be secured by means of the 24 missions under development and nine in preparation along with a robust R&I programme – FutureEO – ensuring the next generation of technology, ground processing and operations and information products for new applications.

2023 saw the 25th anniversary of Copernicus, which is now a programme delivering more than 30 terabytes of free and open data every day from seven Sentinel satellites in orbit and contributing missions. 2023 was also the first year that all Sentinel data have been available on the cloud, serving more than 700,000 registered users.

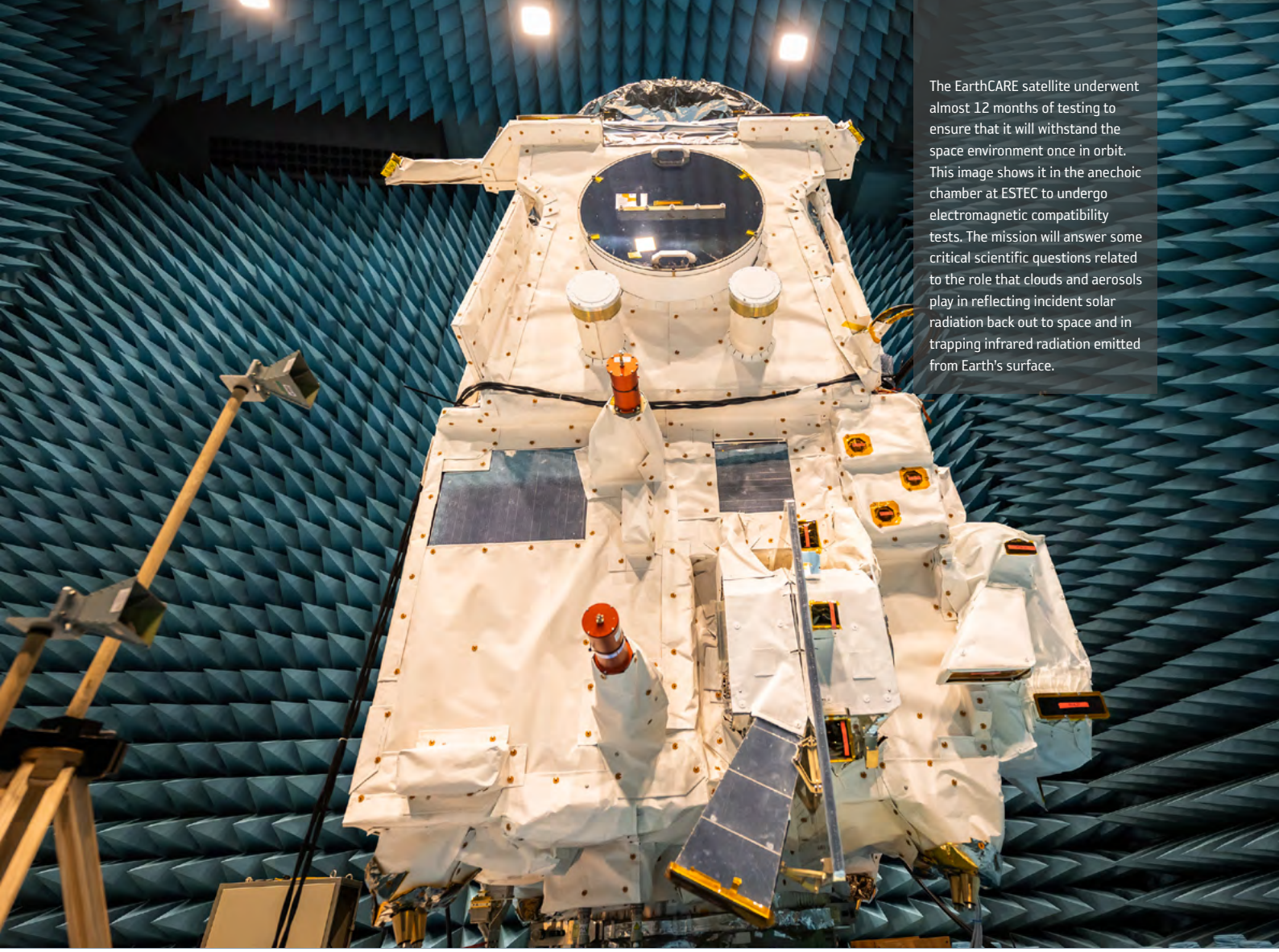
The data are used not only by the Copernicus Services of the EU, but also by scientists and in ESA-funded R&I projects and initiatives. 2023 was the hottest year on record, with the Sentinel-3 mission's radiometer measuring the land surface temperature across Europe with Rome reaching 46°C and Seville 47°C on 10 July. 2023 was also exceptional in terms of wildfires such that ESA's World Fire Atlas – also fed by Sentinel-3 data – was relaunched. The Atlas provides a detailed analysis of wildfires across the globe, bringing improved understanding of fire occurrences worldwide while also allowing more effective strategies for fire prevention and management to be devised.

Also last year, a demonstration was carried out using three Sentinels to help analyse and map methane emissions from "super-emitters". Sentinel-5P data were used to spot plumes with high methane concentration while Sentinel- and Sentinel-3 data zoomed in to identify, quantify and monitor the emission sources. Understanding and mitigating methane emissions are of paramount importance in the fight against climate change.

ESA's five science missions in orbit – many operating well beyond their expected lifetimes – continued to deliver excellent data in 2023 providing high-quality observations and allowing scientifically significant results.

Examples included early detection of drought conditions at the beginning of the year using data from the Soil Moisture and Ocean Salinity (SMOS) mission to drive a drought anomaly index comparing current measurements with those collected over a period of 13 years.

CryoSat, along with other missions, played a role in moving to annual assessments in 2023 of the Ice Sheet Mass Balance Intercomparison Exercise (IMBIE) which looks at changes in polar ice volume and flow. This information is widely used – including by the International Panel on Climate Change (IPCC) – to understand and respond to climate change. The polar ice



The EarthCARE satellite underwent almost 12 months of testing to ensure that it will withstand the space environment once in orbit. This image shows it in the anechoic chamber at ESTEC to undergo electromagnetic compatibility tests. The mission will answer some critical scientific questions related to the role that clouds and aerosols play in reflecting incident solar radiation back out to space and in trapping infrared radiation emitted from Earth's surface.

sheets have lost ice in every year of the satellite record, with the seven highest years of melting occurring in the last decade.

Aeolus – the trailblazing wind mission – came to an end with the controlled re-entry of the satellite in July. Data from Aeolus came to be used by major weather forecasting services worldwide and was deemed so valuable – with economic benefits estimated at over €3.5bn – that the decision was taken to move forward with an operational follow-up mission, Aeolus-2.

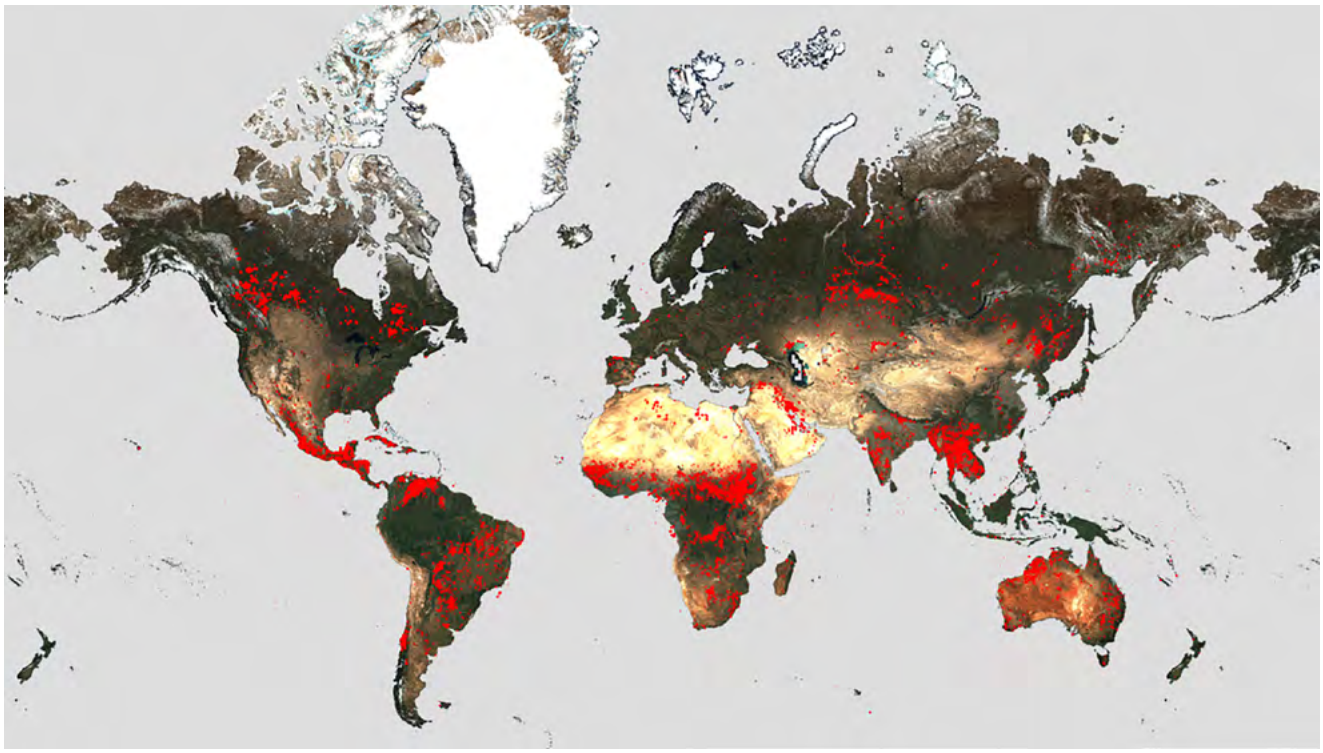
The Meteosat Third Generation Imager not only delivered its first view of Earth this year, but also provided striking animations of lightning – from the first-ever satellite instrument capable of continuously detecting lightning across Europe and Africa – and its capabilities promise to revolutionise the detection and prediction of severe storms.

In addition to work on individual missions and their data, 2023 saw great efforts by ESA to increase the use of Earth observation data by new users, for new applications, as well as piloting new modes of cooperation.

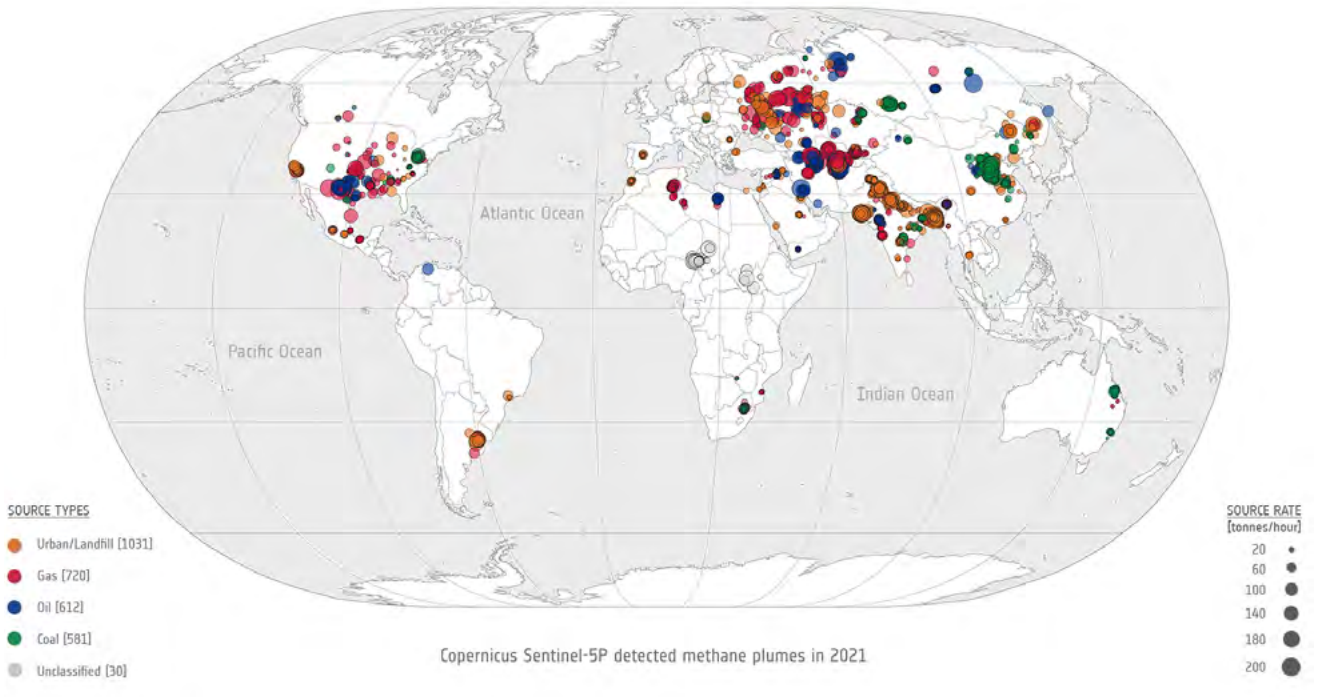
In terms of new users, agreements to cooperate were reached with significant partners such as the United Nations Environment Programme (UNEP) and the European Commission's Directorates-General for Climate Action (DG CLIMA) and International Partnerships (DG INTPA). An increased presence of ESA at the IPCCC 28th Conference of the Parties (COP28) enabled the Agency to showcase the role of Earth observation in addressing climate change and the activities of the ESA Climate Office, in particular.

2023 saw ESA move more and more from measuring and monitoring to managing and mitigating global risks. WorldCereal, one of several results of this move, is a worldwide platform to provide an accurate, seasonally updated crop and irrigation mapping system.

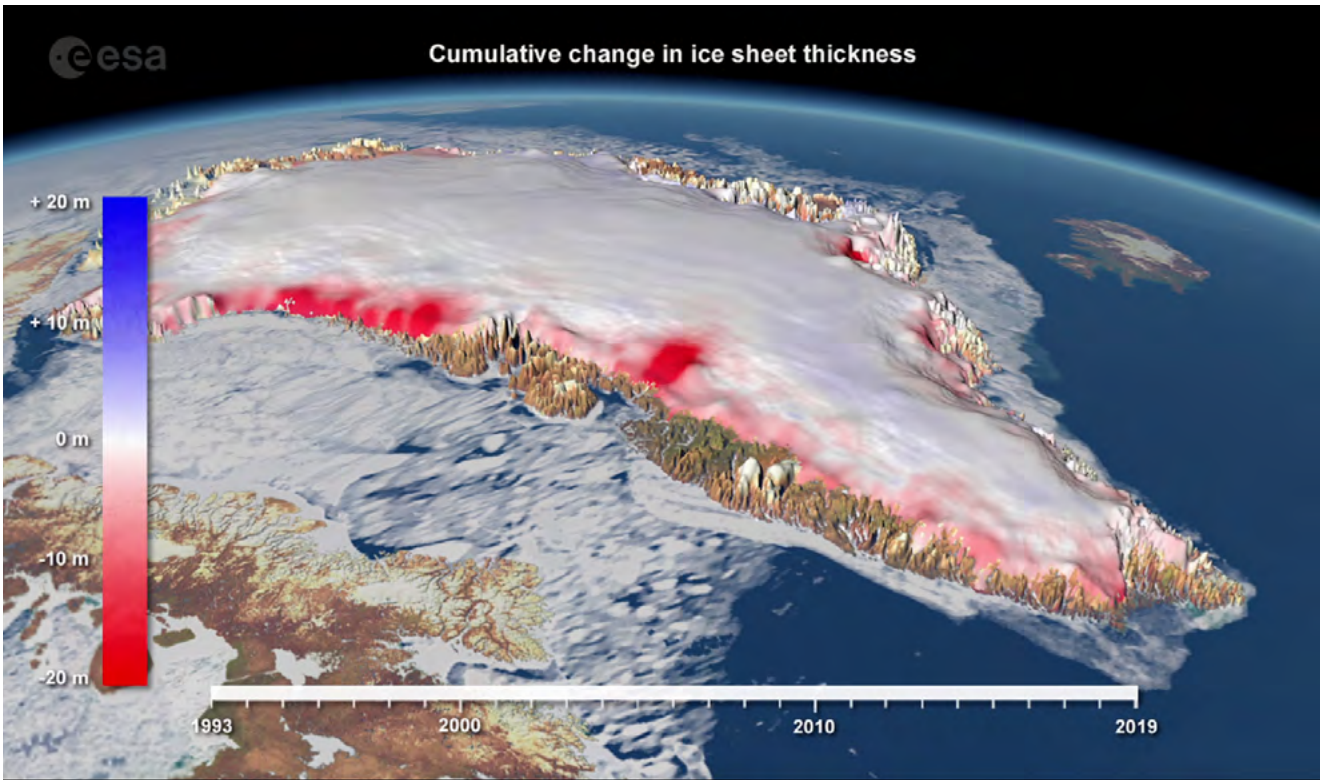
Several initiatives supporting the Space for a Green Future Accelerator link new users and partners with new initiatives in order to trial new modes of cooperation. One such pilot is the "green transition information factory", which is a cloud-based platform, fed by Earth Observation and other geospatial data, allowing users to explore the underlying challenges and opportunities of transitioning to carbon neutrality by 2050 utilising cloud-computing technologies and cutting-edge analytics.



World Fire Atlas 2016–2023: The map shows fires burning across the globe between May 2016 and June 2023, using data from the World Fire Atlas. The Atlas provides a detailed analysis of wildfires across the globe and utilised nighttime data from the Sea and Land Surface Temperature Radiometer (SLSTR) onboard the Sentinel-3A satellite. The data have been overlaid onto ESA's World Cover map which uses data from the Sentinel-2 mission from 2021. Working like a thermometer in the sky, the sensor measures thermal infrared radiation to take the temperature of Earth's land surfaces which is then used to detect the fires.



Sentinel-3 played an important role in 2023 as part of a first-time combination of satellite data from three different Sentinel missions for the mapping of methane super-emitters on a global scale. Typically, methane emissions are monitored by the Copernicus Sentinel-5P satellite. But this year, scientists combined data from multiple satellites to monitor methane from space for the very first time. Researchers from the SRON Netherlands Institute for Space Research spotted a continuous methane emission from a leaking facility using data from the TROPOMI instrument on Sentinel-5P. They then used a Sentinel-2 image to zoom in on the plumes' origins and pinpointed the exact location of the leak, while Sentinel-3 showed that the leak continued for six days. Combining the data from these satellites allowed researchers to zoom in with precision, identifying, quantifying and monitoring methane sources corresponding to plumes observed in Sentinel-5P's global scans.



While 2023 brought record highs in global land temperature, according to the WMO (World Meteorological Organization) , record lows were recorded when it came to the ice masses of Antarctica and Greenland. Scientists used data from satellites such as the Copernicus Sentinel-1 and ESA's CryoSat Earth Explorer to measure changes in ice volume and flow, as well as satellites that provide information on gravity, to calculate how much ice is being lost. The latest Ice Sheet Mass Balance Intercomparison Exercise (IMBIE) reported that ice loss from Greenland and Antarctica has increased fivefold since the 1990s, and now accounts for a quarter of sea-level rise.

CONNECTIVITY AND SECURE COMMUNICATIONS

Preparing the Future of Satcom and the Space Economy

Communications underpins everyday life and represents a substantial segment (38%[3]) of the space economy. The satcom domain is as disruptive as it is significant, supporting the competitiveness of European space and technology firms. In a world where secure, sustainable, effective and ubiquitous communications networks have never been more critical, ESA is preparing the way through an inspiring and diverse portfolio and programmatic instruments. ESA hosted the Space2Connect conference in June 2023, resulting in calls for action aimed at the entire space value chain.

ARTES Core Competitiveness is the Engine of Competition

This programme line drives innovation by challenging the status quo and enabling disruptive systems, services, and technologies. It facilitates the growth of SMEs and New Space initiatives and is highly appreciated by industry for its high return on investment.

ARTES is Partnering with Industry to Bring Innovative Solutions to Market Faster

ESA's ARTES 4.0 Partnership Projects provide the satellite communication industry with the right environment to introduce innovative space-based solutions to market. In the Novacom I and Novacom II partnerships, Airbus and Thales Alenia Space have sold nine OneSat and six Space Inspire satellites respectively on the commercial market, with the first launches planned for 2025. ESA and SME SWISSto12 have opened up a new market for small geostationary satellites through the HummingSat project with rapid and cost-effective production and a fully European supply chain. Four satellites have already been sold with a first launch due in 2025. A Phase C/D/E contract was signed in November 2023.

[3]Sources: Euroconsult "Space Economy Report" 2022, Euroconsult "Satellites to be Built and Launched" Report 2022

Javier Benedicto, Acting Director of ESA's Directorate of Connectivity and Secure Communications, and Emile de Rijk, CEO and founder of Swissto12, sign the HummingSat Contract in Paris on 16 November 2023

Space for 5G/6G and Secure Connectivity – NTN-TN Convergence

The next generation of mobile telecommunications will require different technologies and products to ensure convergence of 5G/6G satellite (non-terrestrial) and terrestrial networks. In 2023, the 5G/6G Hub at ECSAT expanded to address hybrid 5G/6G satellite network use cases in digital healthcare and planetary health. A 5G-6G hub also opened at ESTEC.

In the public-private Sunrise project, ESA is contributing to the technology and product development of the next 5G/6G is driving the future of connectivity.

generation of OneWeb systems. In May, the "beam-hopping" satellite and fully digital payload demonstrator JoeySat was launched and completed its in-orbit testing in July.

The JoeySat "beam-hopping" satellite ready for launch, Sunrise Partnership Project

Space Systems for Safety and Security

ESA works with partners to translate space assets into resilient, secure applications on the ground, in the air, and at sea. To that end, the first commercial aircraft using Iris satellite technology have taken flight with the airline easyJet, following official certification of ESSP in July 2023 as the Iris service provider. Iris will digitalise and modernise air traffic management and reduce carbon emissions in European airspace. The next project phase, Iris Global, will expand Iris worldwide.

The demand for secure and resilient communication is higher than ever. The Eagle-1 mission, also co-funded by the European Commission, passed its System PDR (preliminary design review) in September. This mission will demonstrate the feasibility and resilience of QKD (quantum key distribution) technologies. The SAGA mission with parallel Phase B1 contracts ongoing is a first generation of the space-based component to demonstrate all the required technologies for the second-generation space segment and to validate space-based QKD Services.

EasyJet was the first airline to make an inaugural flight using the Iris satellite technology on its route from Amsterdam to Milan.

European Leadership in Optical and Quantum Communications

Europe is a world leader in the fields of optical and quantum technology for space, and ESA is supporting R&D development and providing flight opportunities ahead of the establishment of a commercial market. ESA's strategic vision is to devise innovative high-throughput connectivity using cutting-edge optical technologies ("internet beyond the cloud(s)"). With that aim in mind, the initial HydRON project demonstration system with multi-orbit constellation in LEO and GEO is under consolidation.

Moonlight Programme

ESA's Moonlight initiative envisions a sustainable, permanent link to the lunar surface. This programme will enable public and private initiatives creating Cislunar Communication and Navigation Services, facilitating opportunities in the lunar market for European industry. The procurement process is ongoing with contract signature planned for mid-2024. Here on Earth, Moonlight is engaging in international partnerships and inter-agency collaboration with NASA, JAXA and others.

Civil Security from Space Programme

The frequency and intensity of global crisis events are growing. The Civil Security from Space (CCS) Programme proposes a federated solution to supporting European efforts to monitor, mitigate and resolve civil security and crisis events utilising space assets. Four partnership projects were launched in 2023 and a Crisis Management Hub is in preparation. The CSS programme is the primary seed for ESA's Rapid and Resilient Crisis Response Accelerator.

ESA Programme Related to EU Secure Connectivity

ICEYE CEO, Rafal Modrzewski, and ESA DG Josef Aschbacher at the signature event for the Civil Security from Space programme partnership agreement on 11 October 2023.

ESA DG Josef Aschbacher and Director General for Defence, Industry and Space at the European Commission, Timo Pesonen sign the Secure Connectivity Contribution Agreement on 21 September 2023.

ESA has launched its third flagship programme, following Galileo and Copernicus, in close collaboration with the European Union, known as IRIS². IRIS² is a highly secure satellite constellation providing strategic governmental and commercial services. In June 2023, the ESA-EU Contribution Agreement was signed for a duration of 12 years, defining ESA's role as Qualification and Validation Authority. The procurement process was very intense during 2023, with the ESA partnership Request for Best and Final Offer issued in December and a contract signature planned for end of Q1 2024.

NAVIGATION

In January, Galileo's High Accuracy Service entered into service, which allows specialised user communities to achieve unprecedented positioning accuracy of 20 cm.

As the European lead in global satellite navigation and Galileo's and EGNOS' system development prime, ESA is continuously working on the improvement of the systems performance.

- In September, Galileo's enhanced navigation message was upgraded to all the Galileo operational satellites in service, which improves Galileo's time to first position fix by a factor of two or three – depending on whether the receiver is in rural or more challenging urban environments.
- In December 2023, the European Commission and ESA agreed on an increase of more than €400m in funding, reflecting the ambition of the Galileo Programme.
- Throughout 2023, Galileo's Second Generation entered its full development phase with the majority of the industrial contracts signed by May and the first hardware and unit deliveries to ESTEC. Over the summer, ESTEC's Test Centre received two structural models of the G2 satellites developed by Thales Alenia Space which were subjected to various tests. In November, Airbus Defence and Space delivered hardware models at its premises in Friedrichshafen.
- In 2023, the Galileo project's ground segment welcomed a brand-new asset: the Telemetry, Tracking, and Control (TT&C) facility. Featuring a 13.5-metre diameter parabola dish mounted on top of a 10-metre-high steel and concrete structure, this facility, located within the premises of Europe's Spaceport in Kourou, French Guiana, enhances communication with Galileo's expanding satellite constellation.

In 2023, the Directorate of Navigation put in place the procurements for the newly approved ESA optional programmes from CM22 and was expecting the industrial kick-off of the GENESIS and LEO-PNT programmes in early 2024, allowing ESA to continue to demonstrate the many additional applications and benefits for both society and the economy of satellite navigation technologies and to further reinforce European leadership in navigation.

Airbus Defence and Space presented their Galileo Second Generation satellite structure manufactured by the Swiss branch of Beyond Gravity to programme stakeholders at their site in Friedrichshafen, Germany.

focus on

GALILEO SECOND GENERATION SATELLITES TAKE SHAPE

Europe's Galileo is the world's most precise satellite navigation system, providing metre-level accuracy to more than four billion smartphone users worldwide. It currently comprises 28 satellites in orbit with ten more due to be launched, after which a new generation of satellites, Galileo Second Generation, will revolutionise the fleet with enhanced capabilities.

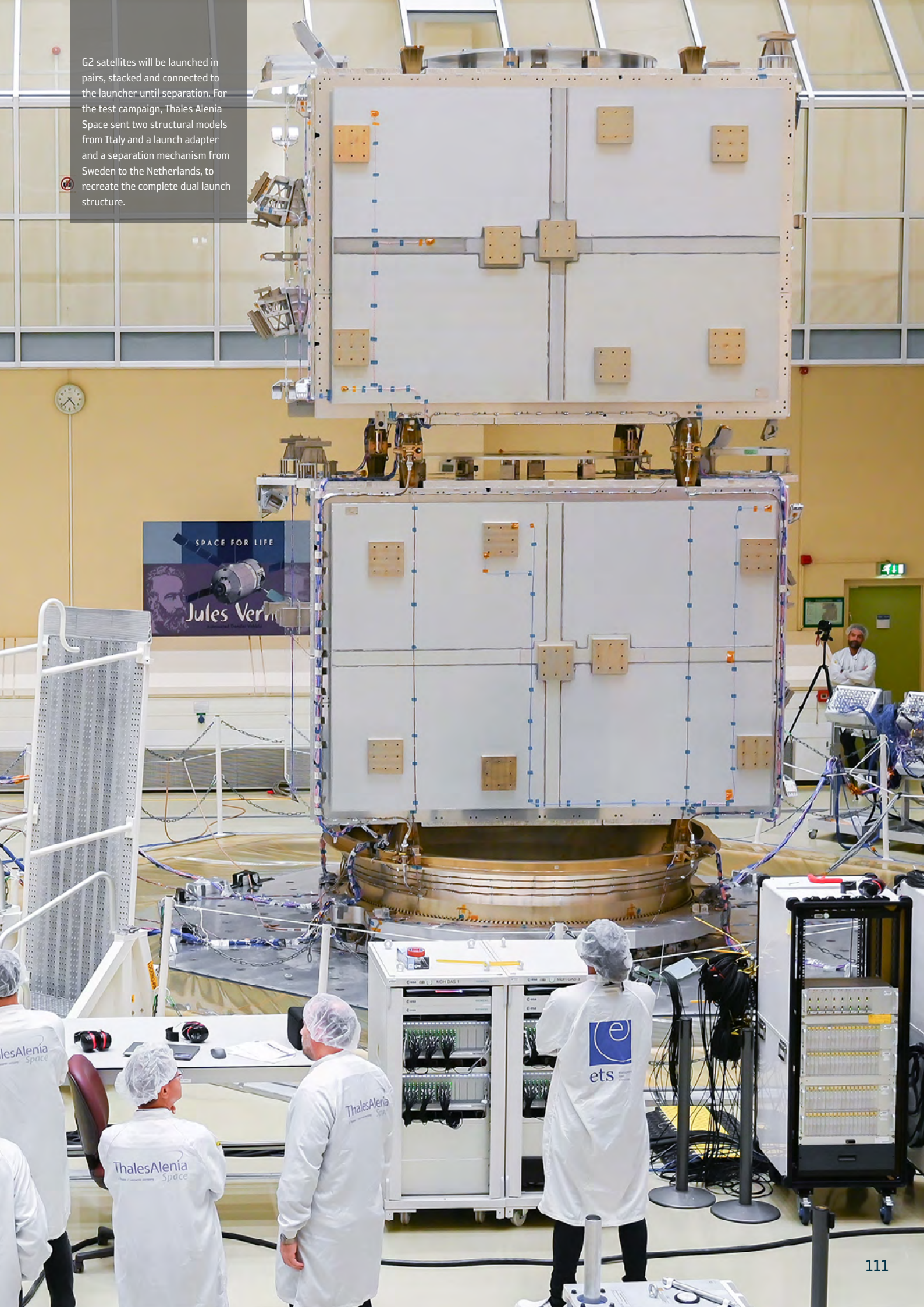
Galileo Second Generation satellites will be much larger than those of the First Generation, use electric propulsion, host a more powerful navigation antenna, carry more and even better atomic clocks on board and have fully digital payloads. In addition, the modular architecture will offer a high degree of flexibility to accommodate more equipment and inter-satellite links will be enabled.

The Second Generation is in full development phase after the main procurement batch was completed in the summer of 2023. European industry is now building the satellites and ultra-precise atomic clocks, and developing the system testbeds, ground mission and ground control segments.

Between July and September, two structural models of the Thales Alenia Space satellite and an electrical model of its navigation payload underwent mechanical and signal performance assessment at ESA's ESTEC Test Centre in Noordwijk, Netherlands. In parallel to Thales Alenia Space, Airbus Defence and Space is developing the other half of the constellation, which were tested for mechanical and signal performance at the company's facilities in Germany in November.

After all testing on the models is complete and the final design details confirmed, the first flight models of both families will be assembled and integrated before undergoing functional and environmental verification, including for some satellites a radiated test campaign in the new test chamber for space antennas being built at ESTEC, Hertz 2.0.

This new generation of satellites will begin joining the existing constellation in the coming years. Galileo Second Generation is designed to remain in orbit for at least 15 years. ESA is overseeing the development to ensure the new satellites enable our high-performance navigation system Galileo to go forward into the future with novel capabilities and additional robustness.



G2 satellites will be launched in pairs, stacked and connected to the launcher until separation. For the test campaign, Thales Alenia Space sent two structural models from Italy and a launch adapter and a separation mechanism from Sweden to the Netherlands, to recreate the complete dual launch structure.

SPACE SAFETY AND SECURITY

114 Earth Observation

118 Security and Cyber Resilience

120 ESES- European Space Security and Education Centre in Redu, Belgium

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 the last ESA Council meeting at ministerial level (CM22), representing an increment of 68%, and with Slovakia and Canada joining the programme.

Through its Zero Debris approach, ESA's Space Safety Programme has set groundbreaking standards for space exploration. This initiative entailed a thorough update to ESA's debris mitigation requirements and standards, influencing the design, construction, operation, and disposal phases of the Agency's missions. Additionally, the world's first Zero Debris Charter was introduced – a community-driven initiative that established a global goal for responsible space practices and fostered collaboration within the space community.

Vigil advances, reaching key milestones, now one step closer to providing operational space weather services for Europe

The Vigil project has continued with two major procurement activities under way, namely the Vigil Photospheric Magnetic Field Imager (PMI) and the Vigil Mission Space Segment. The PMI proposal was below the threshold to proceed to negotiation (overall mark of below 60) and consequently the procurement will go through the two-stage tendering process required under TEB (Tender Evaluation Board) procurement rules.

Enhancing Space Weather Services for more than 4,000 users in Europe and worldwide

The Space Weather Service Portal was updated throughout 2023 to make new capabilities resulting from development activities available to users, whose community includes providers of critical infrastructure such as power and telecommunications. The contract for Space Weather Service Network pre-operational service and product provision was extended by two years in March.

Future Vigil mission.

A world first, the upcoming ESA Vigil - ESA's space weather mission will ensure we are able to monitor, 'nowcast' and forecast potentially dangerous solar events, giving us time to protect at risk infrastructure on Earth, or life in space.

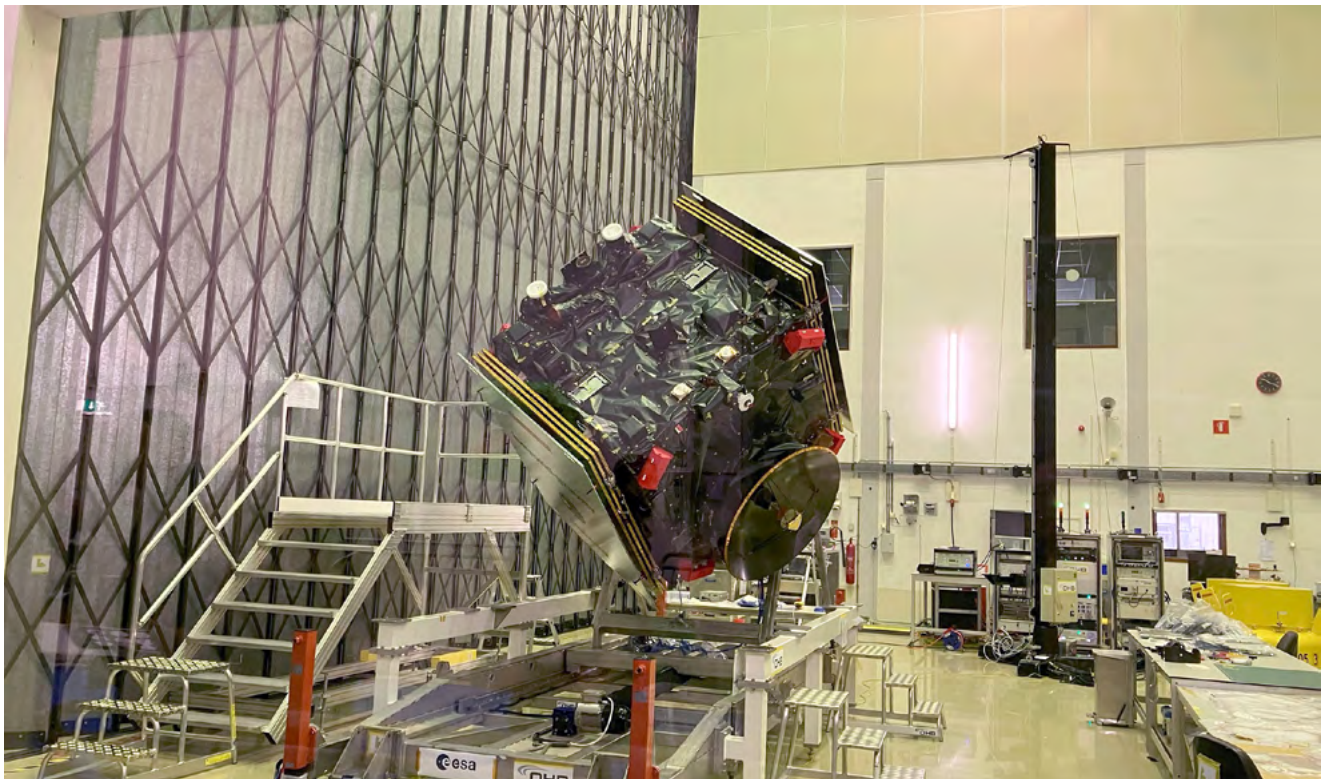
Near-Earth Object detection: Progress on more Flyeye sites providing European data:

The Flyeye-1 telescope, cameras and mount underwent preparations for shipment to Matera in Italy, marking a significant step towards its deployment and the anticipated first light planned for 2024. A suitable location for the installation of the Flyeye-2 telescope in the ESO site of La Silla (Chile) has been identified and first discussions have taken place. The arrangement is expected to be submitted for approval by the respective Councils of both ESA and ESO within the first half of 2024.

Flyeye: ESA's bug-eyed asteroid hunter.

Hera achieves key milestones to stay on track for 2024 launch

The spacecraft underwent successful mechanical integration and was transported to the testing facility in August. Environmental tests, including vibration tests, were completed successfully in September. On the CubeSats, integration work progressed, and ground segment testing supported software refinement. Notably, remote access to testing facilities was established, providing ESA with direct control. Despite challenges, the Hera mission remains on track for its scheduled October 2024 launch. Following the successful testing of asteroid deflection through NASA's DART mission, ESA's Hera will conduct an in-depth post-impact survey of the target asteroid, transforming the experiment into a replicable planetary defence technique.



Hera asteroid mission on show.

2023 Space Environment Report released

The 2023 Space Environment Report by ESA's Space Debris Office highlighted several key findings. It acknowledged technological improvements in tracking smaller space debris fragments and a positive trend in behaviour in space. However, the report also raises concerns, including the increasing number of satellite launches and insufficient removal of larger satellites from congested low Earth orbits. It emphasises that even if no more objects are launched into space, the debris population will continue to grow, necessitating stricter debris mitigation guidelines and active debris removal to achieve the goal of "zero debris".

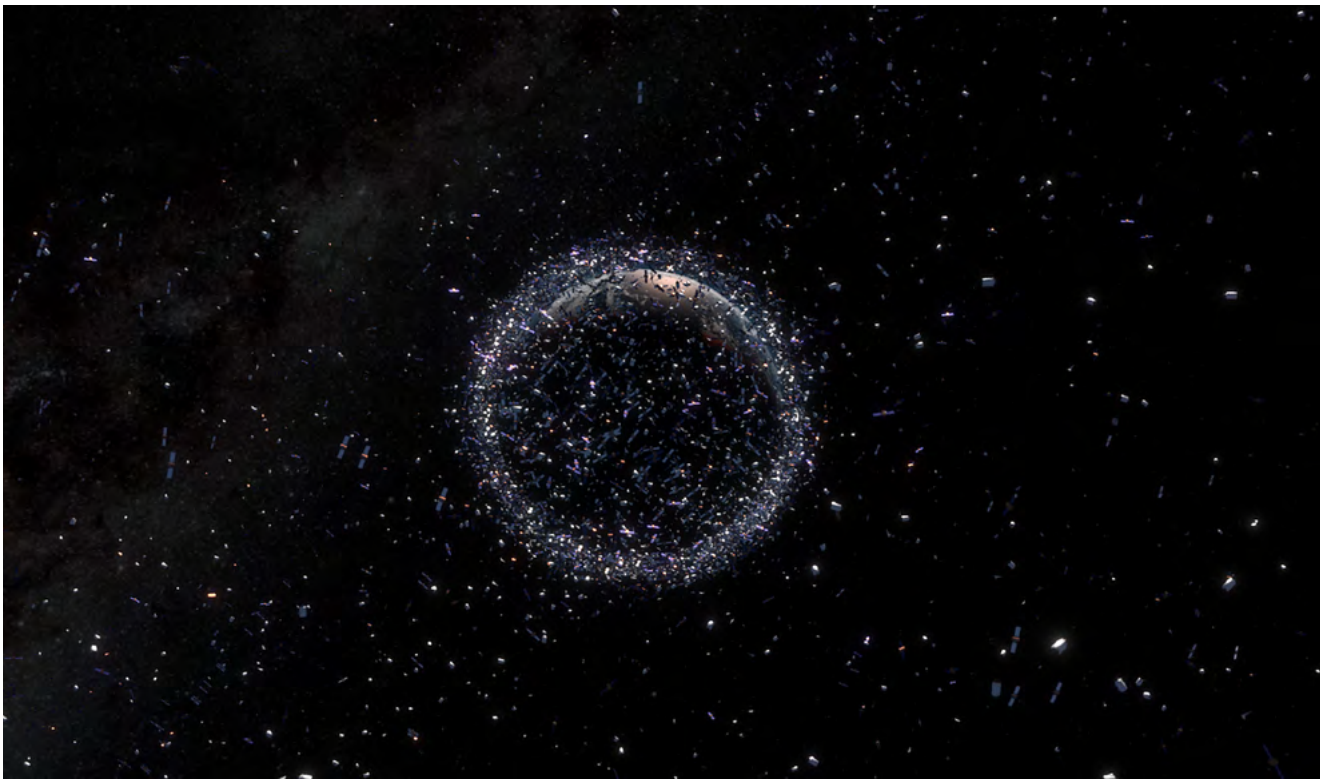
Zero Debris Charter launched: A Global Commitment for Sustainable Space Practices

ESA initiated the Zero Debris approach aiming to significantly reduce debris production in Earth and lunar orbits by 2030. To achieve this, ESA updated the Space Debris Mitigation Policy and Requirements applicable to all its missions. Importantly, these regulations extend to any collaborating company or institution engaged in ESA missions. Effective since November 2023, the policy requires, among other things, the disposal of all space systems operating within Low Earth Orbit (LEO) within five years of mission completion, aligning with the best international practices.

In fostering a global commitment to responsible space practices, ESA played a crucial role in facilitating the development of the world's first Zero Debris Charter. Unveiled at the Space Summit in November 2023, this charter, created collaboratively by industrial partners, organisations, and member states, has gathered over 100 registrations since its sign-up process opened. The Zero Debris approach stands as a testament to ESA's dedication to shaping a sustainable and clutter-free space environment for the future.

Focus on:

THE BACKBONE OF ALL SPACE ACTIVITIES: page 24-29
THE QUEST FOR A SUSTAINABLE USE OF SPACE: page 60-65



The latest figures related to space debris, provided by ESA's Space Debris Office at ESOC, Darmstadt, Germany.

SECURITY AND CYBER RESILIENCE

A malicious cyber-attack has the potential to disable, or take control of, satellites, electronics, communications, and positioning systems and can lead to misinformation, manipulation of data, or the obtaining of data through illicit means. ESA's Cyber Security Strategy has been designed to protect its Member States' and partners' interests and investments in space by strengthening the Agency's cyber resilience:

- The Cyber Security Operational Centre (C-SOC) and the Security Cyber Centre of Excellence (SCCoE) have completed the design and development phase and are about to go into operation.
- The next steps rolled out according to a coordinated cross-directorate roadmap of activities running up to 2027 will be:
- ESACERT and ESOC NOC evolution – reinforcing ESA's preventative/responsive capabilities;
- Quantum Security Verification Platform (QSVP) – establishing a unique capability in Europe;
- Cyber Security R&D Technologies – developing cutting-edge new cyber technologies;
- CyberCUBE – a cyber-CubeSat will assess threats and vulnerabilities in space;
- Harmonisation – the unification of these capabilities in a single platform available to ESA Member States and partners via the Cyber Portable Operational Platform (C-POP).

Security of Space Programmes

ESA's Member States and international partners rely on the Agency to design, develop and deliver secure complex space systems, safeguarding their investments and interests in space, and ESA's image and mission. Tasked with this responsibility, the ESA Security Office (ESO) is committed to providing security assurance across all ESA activities. ESA programmes are designed and developed through a system of security risk management, security engineering and accreditation and certification, using the Agency's cyber security capabilities, and enabling the realisation of ambitious security-critical space programmes. Working side-by-side with ESA's programmes, the ESA Security Committee and ESA's international partners, ESO ensures the Agency's security posture.

ESA's Security and Cyber Security Strategy is committed to providing Security Assurance and increasing Cyber Resilience in all activities, reinforcing the overall Security Posture of the Agency.

Security Agreements

ESA and the EU have together shaped the development of Europe's space capabilities, ensuring that joint security-critical projects in space deliver benefits to Europe. This collaboration is fundamental to ensuring that European citizens reap the benefits from investments in the European space sector and can only be achieved if the two entities can collaborate and exchange on sensitive projects.

The Agreement between the European Space Agency and the European Union on the security and exchange of classified information ("ESA-EU SoI Agreement") entered into force on 1 August 2008, and, over the past months, negotiation of a revision of the Agreement has been successfully concluded, incorporating new elements resulting from the signature of the Financial Framework Partnership Agreement in Brussels on 22 June 2021, and ensuring the extension of this successful collaboration.

ESA is entering into agreements to foster enhanced cooperation in cyber security with Italy, Belgium, Estonia and Slovakia and is beginning talks in this domain with the United States.

ESEC - EUROPEAN SPACE SECURITY AND EDUCATION CENTRE IN REDU, BELGIUM

2023 was an important year for ESEC with it beginning the service contracts under the responsibility of the selected new service providers. The phase-in/phase-out was smoothly executed, maintaining the initial level of quality.

The procurement processes for the ESEC Cyber Security Centre building, C-SOC and SCCoE operations were launched in close collaboration with ITC services, ESO and Estates and Facilities Management (EFM).

Moreover, in close cooperation with EFM, several site refurbishments (roads, Mars meeting room and water drainage facility) have been carried out, increasing the safety and further improving facilities on site.

ESEC supports PV-CC (PROBA-V Companion CubeSat) as a ground station using the PROBA antenna and radio frequency chain infrastructure as of the critical LEOP (launch and early orbit phase). PV-CC is a mission flying a scaled-down version of the vegetation-monitoring instrument aboard the Earth-observing PROBA-V. Aerospacelab (ASL) is the prime contractor (the PV-CC launch took place on 9 October 2023).

Discussions began on a new agreement between ESA, Belgium and Luxembourg aimed at enhancing the common vision on ESEC as with the agreement signed in 2014.

Committees with municipality, local police and national crisis centre representation have been successfully set up, thereby ensuring compliance with the Host and Site Agreements.

In 2023, the number of visitors to ESEC increased considerably.

In May, the Minister-President of Wallonia Elio Di Rupo visited the Centre and in the context of the Swedish Presidency of the EU, ESEC hosted a meeting of the space attachés of the EU Permanent Representation.

Hosted in a region concerned about nature, ESEC is proud of its first honey harvest in 2023. Additional beehives will be installed in 2024 to increase the next harvest. Finally, ESEC was closely associated with a special edition of Monopoly created by the local association “Redu village du livre et de l’Espace” to mark its 40-year anniversary that was gifted to the village inhabitants.

The European Space Security and Education Centre (ESEC) at Redu, Belgium on 19 April 2024.

ENABLING AND SUPPORT

124 Space Transportation

128 Ground Systems Engineering and Operations

132 Technical and Quality Management

SPACE TRANSPORTATION

Launches

The final two flights retiring Ariane 5 were successfully conducted in April launching the ESA Juice mission (VA260), and in July, launching the German Aerospace Center Heinrich Hertz experimental communications satellite and the French communications satellite Syracuse 4b (VA261), followed by the last to final launch of Vega in October, successfully deploying THEOS-2, FORMOSAT-7R and several passenger payloads (VV23).

Ariane 6

Major progress towards the inaugural flight of Ariane 6 was achieved with the conduct of the combined tests at Europe's Spaceport in French Guiana, the upper stage testing in Lampoldshausen, Germany and by addressing open technical issues. This has made it possible to eliminate the main technical risks and to be on track for the inaugural launch between mid-June and the end of July 2024.

Under the Ariane 6 Competitiveness Improvement Programme, developments continued on various payload adapters and structures. The ASTRIS kick-stage development was jeopardised by the loss of the original anchor mission and is currently being redefined, also in view of many similar commercial developments ongoing worldwide.

Vega-C

Following the launch failure of Vega-C in 2022, the recommendations of the Independent Enquiry Commission to ensure a reliable return to flight and robust exploitation, including (delta-)qualification of the nozzle with a new carbon-carbon throat insert material on Zefiro 40, were implemented in 2023. Vega-C underwent further design changes of the Zefiro 40 nozzle following a failed Zefiro 40 engine static firing test in June and is expected to return to flight in the fourth quarter of 2024.

Under the Vega-C Competitiveness Improvement Programme, developments were reviewed following the VV22 failure and continued with regard to new avionic equipment, telemetry transmitters and actuators.

The P120C solid rocket booster, successfully flown on VV21 and VV22, is currently being evolved into P160C with increased loading and length and will eventually replace P120C on Ariane 6 and Vega-C in order to meet anticipated future launch service requirements. The contract for the development of P160C was signed in December.

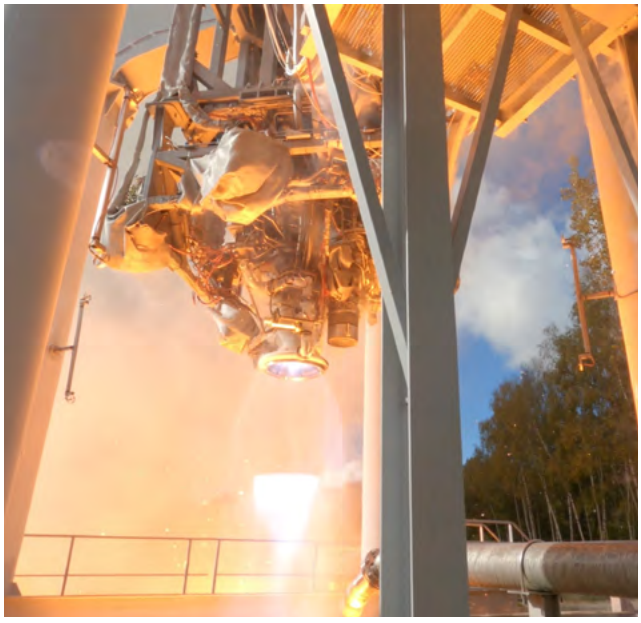
ESA's new Ariane 6 rocket passed a major full-scale rehearsal in November in preparation for its first flight: teams on the ground at Europe's Spaceport went through a complete launch countdown followed by a seven-minute full firing of the core stage's engine, as it would fire on a launch into space.

Europe's Spaceport

The renewed Agreement between the European Space Agency and the Government of the French Republic on the Centre Spatial Guyanais (CSG) and associated services for the period 2023–2035 was signed on 22 March in Paris by the CNES President and ESA Director General and entered into force on this date retroactively with effect from 1 January 2023. Subsequently, the Rider 1 to the ESA/CNES CSG contract (2023–2027) was signed at Le Bourget in June. In line with this contract, Europe's Spaceport in French Guiana will be maintained and modernised including through core launch range renewal activities and activities supporting a more flexible, more digital and more sustainable/carbon-neutral Europe's Spaceport.

Space Rider

The Space Rider Critical Design Review was successfully completed in mid-2023 and has entered, in turn, Phase D, qualification, and production. A first successful Flight-to-Ground System Validation Test campaign was completed in December.



The Prometheus engine, named after the Greek mythological figure who stole fire from the gods and brought it to humans, was fired for a 30-second burn with reignitions at ArianeGroup's test facility in Vernon, France, to test the new rocket engine fuelled by methane and oxygen. The Prometheus engine will feature in ESA's Themis rocket prototype – a flagship European demonstrator for low-cost rocket recovery and reuse technologies

Future Preparation

A series of new activities on space logistics and technology developments were launched under the Future Launchers Preparatory Programme (FLPP) and implemented throughout 2023.

The Prometheus engine test campaign at Vernon in 2023 culminated with a successful hot-firing test of 30 seconds and a subsequent reignition. Preparations for Themis flight tests in Kiruna have begun with final tank tests and assembly of the Themis T1H stage. Phoebus upper stage sub-scale tanks were successfully tested in December.

Boost! activities with commercial space transportation partners continued, with co-funding support contracts completed and new ones signed in 2023. Co-funding contracts with nine prime companies for new commercial space transportation services were in force in 2023; under the "Support to Participating States Element", providing assistance to Member States in the implementation of national space transportation objectives in the field of spaceport infrastructure and related services; and under the "European Flight Ticket Initiative", a new Boost! element approved and subscribed at CM22 and initiated in 2023 in collaboration with the European Commission, with the issuance of a call for IOD/IOV satellites and for launch services to be co-funded under Boost! following competitive procurement among European launch services.

Collaboration with the European Commission also continued under two Horizon Europe activities: SALTO (reuSable strAtegic space Launcher Technologies & Operations), linked to FLPP Themis, and ENLIGHTEN (European iNitiative for Low-cost, Innovative & Green High Thrust ENgine), linked to FLPP Prometheus.

ESA Council meeting in Seville

The ESA Council meeting in Seville in November 2023 provided the basis for decisions of principle pertaining to the stabilised exploitation of Ariane 6 and Vega-C, to the future use of launch complexes at Europe's Spaceport, to Vega commercialisation and exploitation, and to principles and a stepped approach for decision and funding of the European Launcher Challenge at the ESA Council meeting at ministerial level in 2025 (CM25).

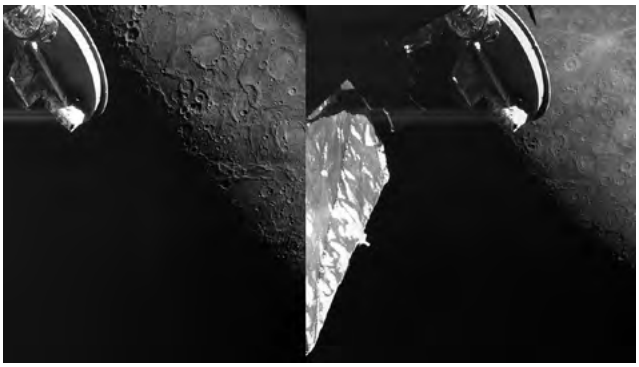
Signature of Rider 1 of the ESA/CNES CSG Contract (2023–2027) at Le Bourget on 1 June 2023.

Artist's view of the current European launcher family. Shown from left to right: Vega, Vega-C, the two booster Ariane 6 (A62) and the four booster Ariane 6 (A64) variants, as well as Space Rider.

GROUND SYSTEMS ENGINEERING AND OPERATIONS

ESA's Directorate of Operations and the European Space Operations Centre (ESOC) are recognised internationally for their excellence in E2E ground segment engineering, flight dynamics and flight operations services.

The Directorate currently operates 27 flying satellites, including astronomy, Earth observation, and interplanetary, and is preparing for the launch of a dozen more, including Europe's flagship planetary defence mission Hera, launching in 2024. The independent capability to fly Europe's institutional missions is critical to Europe's autonomy and resilience as a space power.



BepiColombo's third Mercury flyby.

Reliable and trusted provider of Launch and Operation Support for cutting-edge institutional missions

In April, ESOC played a crucial role in the successful launch and early operations of the Juice mission and ensured flawless performance and key deployments. The Mission Control team successfully deployed the key Radar for Icy Moon Exploration (RIME) antenna, which marked a major milestone with all Juice deployments completed. The Flight Dynamics team also calculated the optimal trajectory for Juice, guiding it through gravity assists and a historic orbit around Ganymede.

Special operations for ESOC's flying missions included BepiColombo's third gravity-assist flyby of Mercury. A correctional manoeuvre was executed weeks in advance, ensuring BepiColombo's precise trajectory past Mercury. These fly-bys are crucial to combatting the Sun's gravitational force, gradually reducing energy for eventual capture into Mercury's orbit in 2025.

In July, the New Norcia Estrack ground station captured Euclid's first signal, with ESOC overseeing its critical LEOP and commissioning operations, thereby marking the start

Cosmic rays sometimes unexpectedly caused 'artefacts' or false signals to appear in Euclid's observations. After a major combined effort of industry and ESA teams and in record time, a new on-board software was installed on Euclid during the science performance phase.

of the six-year routine phase. Despite initial issues, Euclid's Fine Guidance Sensor advanced to its final testing phase for a crucial six-year survey mission. OPS teams provided troubleshooting support to resolve the issues, and Euclid's impressive initial images were released at ESOC on 7 November. Euclid successfully joined the suite of 27 satellites operated by OPS, demonstrating the value of independent European ground segment operations.

This is the team at ESA's mission control that will fly Juice to Jupiter with four planetary flybys of Earth and Venus. The mission's tour of the icy, complex Jovian system includes 35 lunar flybys.

Advancements in Ground Segment Systems and Infrastructure

Estrack enabled cutting-edge interplanetary radioscience, supporting experiments on BepiColombo and Juice. This has prompted the evolution of ESA's deep space antenna network, enhancing capabilities at the Deep Space Antenna (DSA-3) in Malargüe, Argentina.

Each science mission comes with unique constraints and requirements for its ground segment due to specific scientific goals. Euclid's instruments capture highly precise, detailed images, resulting in gigabyte-sized files. The mission's key challenge is downlinking up to 100 GB of data daily within a four-hour window. Euclid's ground segment must efficiently enable this large data flow between Euclid and Earth, ensuring timely delivery to science project teams. Through years of technological advancements, standardisation efforts and the operational adoption of innovative engineering solutions, OPS has successfully tackled the challenges for the ground segment for this extraordinary mission.

Trusted International Partner

ESA's Mars Express, flown from ESOC, set a record by relaying data for seven international Mars surface missions. Collaborating with India's ISRO, ESA's Kourou Estrack ground station ensured the success of Chandrayaan-3 and Aditya-L1 solar observatory launches. ESOC's expertise also contributed to precise orbit determination for Aditya-L1. Additionally, ESA ground stations played a crucial role in Japanese firm ispace's historic HAKUTO-R Mission1, the first commercial Moon landing. ESA's Mission Operations infrastructure and engineering capabilities constitute an extremely valuable and attractive tool for cooperation and collaboration.

ESOC experience maximising science data return

ESOC demonstrated operational excellence in response to CryoSat's fuel leak, the teams at ESOC mission control performing an urgent reconfiguration, thereby successfully extending the satellite's life by up to ten years, aiming to ensure mission continuity until CRISTAL's 2028 launch.

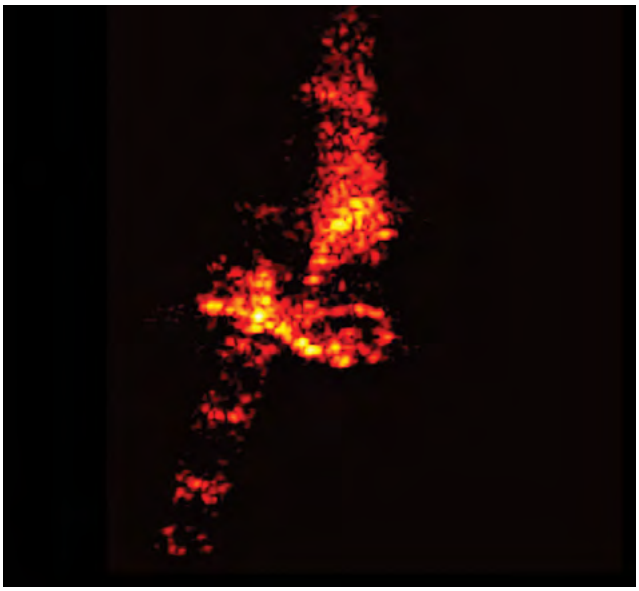
The Integral Flight Control Team at ESOC also demonstrated ingenuity by implementing a novel safe mode for the Integral space observatory. Opting for reaction wheels over traditional thrusters, they ensured spacecraft control and reorientation towards the Sun, safeguarding the mission's exploration of energetic events in the Universe.

ESA's 35m deep space station, Malargüe, Argentina, used every day for deep space missions.

Europe's pioneering Martian exploration mission Mars Express celebrated its 20th anniversary, far surpassing the planned one Martian year (687 Earth days). On top of the science data, Mars Express has proved an essential tool in Mars data relay downlink.

ESA's Deep Space ground stations in New Norcia and Malargüe celebrated milestones, marking 20 years and ten years in operation, respectively. These stations have been essential in order to meet the need for an ESA science data downlink. Their long lifetime can be credited to carefully planned maintenance and sustaining, which is much more efficient than investing in new replacement infrastructure.

These accomplishments highlight ESOC's ability to maintain mission functionality and longevity through innovative operational solutions and responsible long-term planning.



Last radar image of Aeolus acquired by the Tracking and Imaging Radar (TIRA) at Fraunhofer FHR in Germany.

Commitment to ESA's Zero Debris Charter with assisted satellite re-entry

ESOC achieved a historic milestone with the first-ever assisted re-entry of an ESA satellite, Aeolus. While it was never designed for such challenging operations, a concerted effort with industry and ESA expert teams (including flight control, flight dynamics and space safety) resulted in its safe disposal and removal from its congested orbit. This achievement contributed valuable knowledge to future space debris disposal and demonstrated strong commitment to ESA's Zero Debris Charter.

In 2023 a mission-threatening leak of CryoSat's smaller attitude thrusters was mitigateed, extending the life by up to 10 years.

The photo shows the team of ESA and industry experts who made this possible.

TECHNICAL AND QUALITY MANAGEMENT

ESA continues to blaze a trail for the future of Europe in space. The missions it flies are groundbreaking by definition, pushing forward the technical state of the art.

This constant striving for uniqueness and innovation is delivered in large part due to the Agency's Directorate of Technology, Engineering and Quality. It is the essential counterpart to European industry and drives many of the solutions they implement.

Based at ESA's largest establishment, ESTEC (the European Space Technology and Research Centre), the Directorate operates a suite of technical labs and the ESTEC Test Centre for satellite testing. These key resources are being constantly developed and adapted to the future needs of ESA's projects and the European space industry. In 2023, the three major adaptations to this technical infrastructure, namely Hertz-2 – an enlarged radio frequency test chamber for entire large satellites, the new ESTEC Cleanroom Extension and the update of the Optics and Optoelectronic laboratory facilities proceeded as planned. Hertz-2 will be available in time for the antenna tests of the next-generation Galileo satellites planned for 2026. The new Test Centre Clean Room Extension will become operational at the end of 2024 with the new connection to the present Test Centre and will improve the capacity of the Test Centre significantly. Satellites undergoing testing at the Test Centre in 2023 included the structural model of the PLATO spacecraft, consisting of the payload module, the service module and a sunshield solar array. It completed the major parts of the test campaign in ESA's Test Centre in June. Subsequent deployment tests of the sunshield solar array in Noordwijk and a micro-vibration test to be performed by IABG at OHB Bremen will complete the test campaign.

EarthCARE (Cloud, Aerosol and Radiation Explorer) successfully completed its environmental test campaign after the conduct of the last test in ESA's "Maxwell" EMC chamber. In this chamber, radiated emission and susceptibility tests were carried out to ensure the system's nominal performance and verify compatibility with the launcher. The chamber also allowed the customer to safely operate the spacecraft in the electromagnetic environment that it will experience in flight.

In addition, construction continued of the International Meeting Facility (IMF) conference centre, which is the first step in the ESTEC Site Renovation project, a major rehaul of the site for which funding was secured in 2023.

Successful recovery of Juice RIME Antenna

Meanwhile, the everyday technical work of the Directorate continued apace. A highlight in the project support provided by the Directorate was the recovery of Juice's RIME antenna. RIME is the 16m-long antenna on board the Juice spacecraft which suffered a critical in-orbit anomaly as it failed to

ESA ESTEC, ESA logo formed by People.

fully deploy on 17 April. Thanks to the detailed analysis of photographs captured by onboard cameras and the availability of a representative model on the ground, it was possible to identify the most probable root cause as jamming of the antenna at one of its HDRMs. It was assumed that the pin, which should automatically retract after NEA actuator firing, was not fully retracted, thus preventing the antenna from deploying.

Under the lead of ESA expert teams, the root cause was successfully identified. After several unsuccessful trials to release the antenna (e.g. with slew manoeuvres and thrusters firing) the recovery plan focused on firing the remaining NEA actuator (which was still holding some remaining segments of the antenna). It finally led to the successful deployment of RIME on 12 May, once again showcasing the need for top-class technical competence to save missions which would otherwise be lost.

Launch of Euclid

Another demonstration of the importance of strong and efficient technology management in the Agency was provided by the successful launch of Euclid on 1 July. The Directorate managed important technical developments enabling this mission to take place:

- Euclid's cold gas micro-propulsion thrusters were produced under a technology development contract (TDE). Although the system was developed and already used for Gaia and LISA Pathfinder, it is a key technology for the extreme pointing accuracy/stability of Euclid and is planned also for LISA, which has been very recently adopted.
- The engineering support provided by the Directorate was essential to help the team working on the national-funded instruments and save the schedule. The bake-out of VIS instrument electronics was carried out at ESTEC under the responsibility of specialists on contamination. Other tests performed were the VIS Instrument EMC test and the thermal testing of the VIS shutter.
- Detailed characterisation of ice scattering effect on performances was carried out.
- Similarly, the commissioning investigation of the Fine Guidance Sensor was conducted under the responsibility of a specialised team. The FGS acquisition cycle was initially unstable due to the "interpretation" by the software of the cosmic rays. A software update solved the issue.

Currently, the contamination specialists are participating

in the definition of the plan for the operation of water ice decontamination heaters, an activity led by project scientists and the Principal Investigators for the instruments included.

In September 2023, a StarTiger initiative – a specialised activity within the TDE – paved the way forward in order to demonstrate the Space Factory concept, a precursor to the construction of major components such as antenna reflectors, assembly of spacecraft components and satellite payload replacements directly in space. The activity successfully developed a ground demonstration – under simulated micro-g conditions – for the assembly of a very large structure. Manufacturing directly in orbit will revolutionise the way space systems are designed, built and operated, since it is not constrained by launcher mass and volume limitations. The concept has now been pushed even closer to implementation.

Preparation for ESA's Proba-3 double-satellite formation flying mission continued with preparations for the launch in 2024. Important milestones towards the final launch readiness review were successfully accomplished and the innovative mission is on track. The formation flying system testing and operations preparation (last testing required) are ongoing. The teams and resources are being put in place for the launch campaign, LEOP and commissioning (industry and ESA).

In addition, as part of the Directorate's In-Orbit Demonstration Programme, Vega launch VV23 on 9 October comprised ten CubeSats, nine of which were technology demonstration missions either managed by ESA (GSTP, EC IOD/IOV) or with their launch services supported by ESA (EC IOD/IOD). Among them, the following are particularly worthy of highlighting:

- M-NLP is a Langmuir probe to measure in situ plasma characteristics. This specific configuration is funded by Norway. M-N stands for multi-needle, a specific configuration of a Langmuir probe.
- PRETTY, funded by Austria, is a Passive REflecTometry and dosimeTrY mission. It receives signals from Global Navigation Satellite System (GNSS) satellites visible just above it. Two patch antennas on its forward face pick up the same signal from the same satellite – or rather one signal that has reached it through space and the equivalent signal that has reflected off Earth's cryosphere or oceans. It is an altimetry mission with a fully commissioned platform, and with performances that meet the mission requirements. Both payloads (GNSS-R and dosimeter) are producing scientific data.
  For the GNSS-R, both interferometric and clean-code replica approaches have been tested.

General Studies and Technology Programme

ESA's General Studies and Technology Programme hosted a special edition of the Industry Working Days in September to celebrate 30 years of innovation and groundbreaking technologies. Together with the Polish Space Agency, stakeholders and colleagues from across Europe were invited to join two days of presentations, lectures and discussions about GSTP's storied past and what the next 30 years of development hold for ESA R&D. In the programme's lifetime, almost 2,000 contracts have been awarded to do just that. The event focused on a few key areas our technology programmes must address. In addition, 30 years of success stories from GSTP ranging from robotics, power, manufacturing, materials and structures to space safety were presented.

The event concluded with the annual Space R&D Showcase (formerly the SET-FPDs) – where some of the Directorate's most interesting technology achievements of the past year were presented, including robotic drills for planetary environments, orbital traffic management systems and 4D printing.

The Directorate had published an updated version of its Technology Strategy in 2022, 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. Now, the implementation of this strategy has begun and a 2040 technology vision is being prepared.

Hera asteroid mission coming together

Hera's implementation is continuing on schedule. In 2023, all elements of the mission came together at ESTEC for final testing before being shipped to launch by Falcon 9.

In terms of securing components at the heart of Europe's space missions, in the area of high-density interconnect (HDI) printed circuit boards (PCBs), microvias have enabled increased density and functionality for HDI PCBs across a wide range of sectors, but they remain subject to lingering reliability issues that have raised industry-wide concern. Now an ESA-led consortium has achieved the first qualification of HDI PCBs for space missions, representing a major step forward in quality control. Specific HDI PCB qualification has, so far, not been available in line with the generic PCB guidelines issued under European Cooperation for Space Standardization, ECSS – the common European rulebook for undertaking space missions. Instead, case-by-case project qualification is required for individual designs and batches, which remains a significant hurdle in space projects. But now, PCB manufacturer ACB in Dendermonde, Belgium, has received ESA qualification for HDI PCBs, as the successful outcome of a recent GSTP contract led for ESA by Belgian research institute IMEC, with Thales Alenia Space Belgium as end user.

ZERO DEBRIS

To make ESA a role model driving space sustainability beyond today's principles, ESA proposed, in September 2022, to prepare and implement by 2030 a Zero Debris approach for all

Agency missions. In that context, the current Agency policy on space debris mitigation published in 2014 was updated in 2023 based on the work performed by a cross-directorate task force. The updated policy will initiate a step-by-step approach towards the implementation of the Zero Debris approach by 2030.

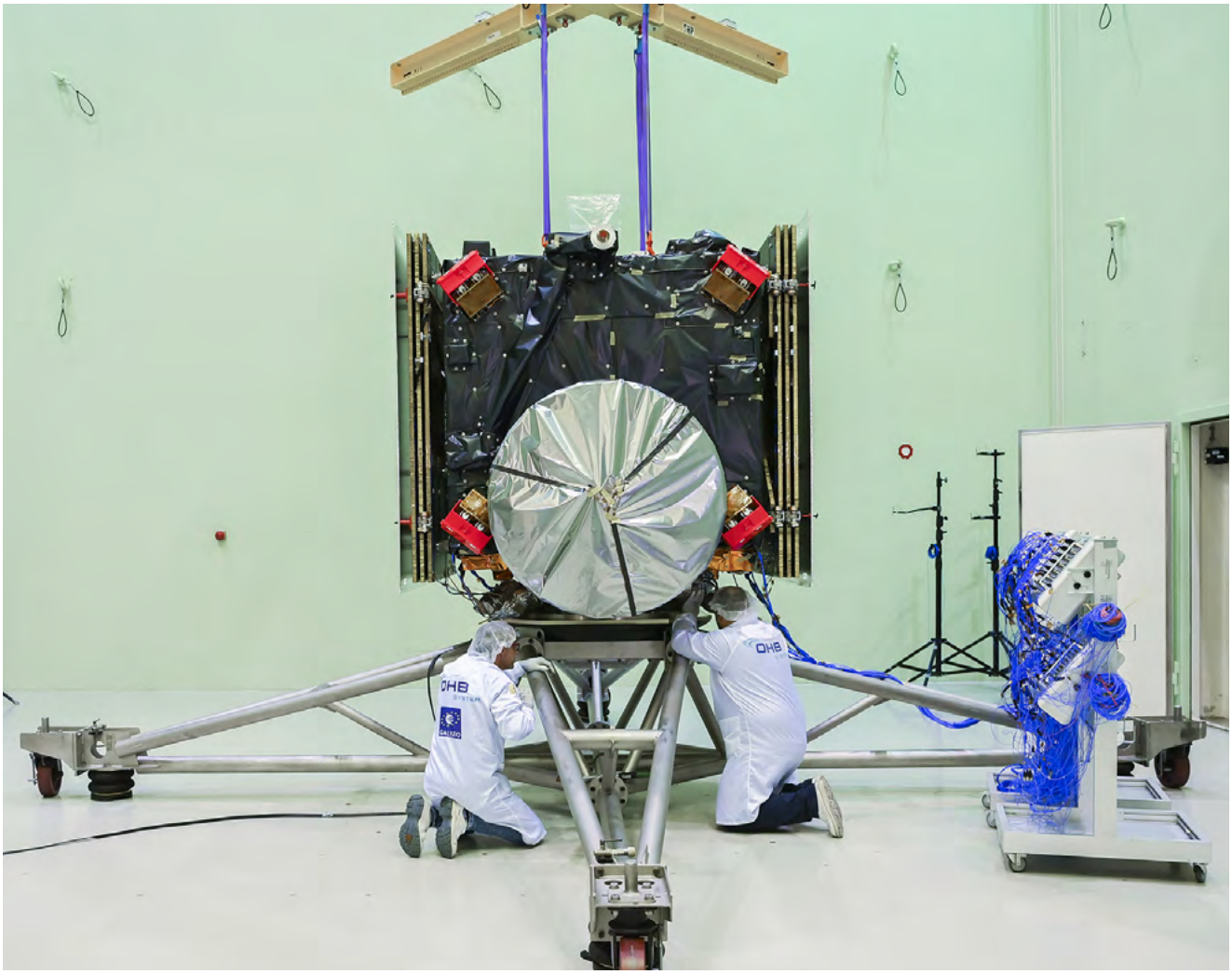
The revised ESA policy addresses, on top of the classical ESA mission implementation: (a) cooperative missions carried out together with international partners, (b) the procurement of launch services as well as (c) missions implemented under public-private partnership (PPP) schemes.

The update of the policy led to the development of a new ESA technical standard, ESSB-U-ST-007, successfully issued by the Agency, to be applied since July in ESA missions.

A third issue of the ESA Space Debris Mitigation Compliance Verification Guidelines is expected to be published in 2024. The generation of both documents was only possible thanks to the cooperation, motivation, and team spirit across ESA directorates, with both documents being published in record time.

Outreach: ESA Astrolabe

ESA Astrolabe is a unique, multi-purpose, modern knowledge and visitor centre. Inaugurated in September on the ground floor of the new ESA Headquarters site, ESA Astrolabe provides wide access to and a broad understanding of ESA activities, achievements and plans for the future through state-of-the-art technologies and physical models. In accordance with ESA's knowledge management programmatic aims, it aims to open a window on the Agency's knowledge and know-how in driving Europe's space capability and sharing with the public and its Member States the Agency's more than 50 years of experience and expertise in the exploration and use of space. Open to the public, the venue has a range of facilities to inform, engage, entertain and support learning in a state-of-the-art, space-inspired environment. It also provides a smart area where ESA's workforce can meet and brainstorm, sharing and processing knowledge and data. It can host knowledge-sharing talks, lectures and seminars for the public but also ESA-internal presentations. ESA Astrolabe was developed by the ESA Knowledge Management team, in collaboration with other departments and directorates.



HERA prepared for acoustic tests in the Large European Acoustic Facility (LEAF) in the ESTEC Test Centre in Noordwijk

RESOURCES MANAGEMENT, CORPORATE ACTIVITIES AND EXTERNAL RELATIONS

138 Human Resources, Facility Management and Digital Transformation

140 Commercialisation, Industry and Competitiveness

152 Corporate Social Responsibility, Communication, Relations with Member States, External Relations, Legal Services

HUMAN RESOURCES, FACILITY MANAGEMENT AND DIGITAL TRANSFORMATION

HUMAN RESOURCES

In 2023, an unprecedented number of job requisitions (JRs) were published, covering more than 400 positions – a significant increase of about 80 positions compared to 2022. This upward trend aligns with previous years, in which a substantial number of JRs were published due to a recruitment wave and to cover staffing requirements for the new programmes adopted by the Council meeting at ministerial level in November 2022. These initiatives led to the publication of approximately 190 JRs resulting from what was decided at CM22, while the additional positions were opened in order to replace ESA staff leaving the organisation.

Careers at ESA are promoted both online and in person. In 2022 and 2023, ESA attended Gamescom, the world's largest computer and video games fair, in Cologne, Germany, with 320,000 participants in 2023. ESA Careers Day, an online event showcasing the various facets of the Agency, took place in 2023 with over 1,000 participants. For some years now, ESA has been present on LinkedIn and, by the end of 2023, had over 630,000 followers.

The ESA Team Awards were introduced in 2010 to recognise exceptional team achievements, and awards have been presented each year since then. In 2023, the DG's Awards for Innovation and Transformation were launched to recognise outstanding individual achievements. Two categories were open for nominations: the DG Award for Innovation and Transformation in Science and Technology and the DG Award for Innovation and Transformation with ESA Organisational and/or Programmatic Impact, with one award presented in each category.

Following the adoption of the Policy on Reporting Unwanted Conduct and Investigating Harassment at ESA in February, a communication campaign was launched at the end of 2023 to provide information on mechanisms for resolving interpersonal issues in the workplace. In-person information sessions were held at ESA's main establishments, along with a virtual session accessible to all. An action plan is being rolled out to further increase staff awareness and to develop best practices so as to address issues relating to unwanted conduct and harassment more effectively and to minimise escalation.

DIVERSITY AND INCLUSIVENESS

In 2023, Diversity and Inclusiveness (D&I) was at the forefront of the ESA Transformation, having been selected as one of its ten priorities. The resulting initiative prompted the selection of two D&I priorities and related KPIs to be

adopted at Agency level, namely "Ensuring gender-balanced conditions supporting work-life and career evolution" and "Enabling a speak-up culture". Other D&I topics chosen as focal points by directors include "Increasing gender balance in the ESA workforce", "Setting the conditions for greater top management involvement", and "Catalysing ESA to become a driver for change in the space sector".

In parallel with this initiative, in 2023 ESA moved further toward the achievement of the D&I objectives introduced in 2022 with the "Eight Steps Towards Diversity & Inclusiveness". The percentage of female staff reached 29.2%, while the proportion of women in top management positions rose to 20.1%, a major increase from the 8.4% recorded in 2016. This result was achieved through key actions such as promoting gender diversity on interview panels, using inclusive language in communication, aiming to ensure that candidate shortlisting reflects the gender ratio of applications, and setting policies to help reconcile family and work. Other achievements include enhancing the awareness and use of digital tools for accessibility and the set-up of an informal network for LGBTQIA+ people and allies at ESA. As in previous years, communication actions were delivered to mark international days of celebration – Women and Girls in Science, Women's Day, LGBTQIA+ People in STEM and Persons with Disabilities – reaching a large audience.

SITES AND FACILITY MANAGEMENT

For the Estates and Facilities Management Department, 2023 was a year of considerable challenges. Its most high-profile project was the return of staff to the renovated ESA Headquarters in April. The building was constructed in accordance with stringent customer requirements, including significantly enhanced security standards, a radically different working environment and, perhaps most strikingly, a state-of-the-art conference centre designed for close interaction and cooperation with Member States. The building was completed on schedule and within budget.

Not least because of the success of the HQ Project, Member States approved a €200m investment project to be split between ESTEC and ESOC at a ratio of 3:1. With significant host nation contributions, the project will enhance sustainability standards and result in a more modern, flexible working environment. Early elements include a new space operations centre and laboratories.

At ECSAT, the UK-funded Magali Vaissiere Conference Centre opened in July and has proven to be a significant enhancement to the Harwell community. At ESRIN, the complex seismic reinforcement project is nearing completion, with work on the final major elements now under way. The overall outcome will be a resilient site with a wide range of modern facilities. At ESAC, work has begun to update a significant proportion of the site's working environment and technical facilities.

ESA continued to respond actively to major changes in working patterns, already apparent before and further accelerated by the COVID-19 pandemic. Increased numbers of staff have been coming to work on site, with overall attendance now only 15% below 2019 levels, in line with projections. ESA remains determined to stimulate innovation and exchange on and further contribute to the development of world-class science and engineering.

The challenging sustainability targets in Agenda 2025 are now subject to a tightly coordinated action plan. While maximising the exploitation of existing facilities, ESA has also launched funded Green Agenda work packages at all sites and centres.

DIGITAL AGENDA AND INFORMATION TECHNOLOGY

Digital governance to support Agency-wide transformation initiatives has been put in place with the establishment of a business-driven Digital Steering Committee. The ESA Data Factory expands the capabilities of the ESA Dashboard by consolidating multiple data sources across the Agency to build a "single source of truth" architecture and enabling more comprehensive reporting and decision-making.

The Space High-Performance Computer (HPC) has been procured and is on track for delivery to ESRIN in Q3 2024. The Space HPC will enable multiple directorates, as well as SMEs, to perform highly complex computations for their specific use cases.

The use of common shared IT services continued to increase in 2023. ESA's private cloud infrastructure, which supported critical mission operations such as the Juice and Euclid LEOP and the Aeolus re-entry in 2023, has increased by more than 60%. The number of projects managed within the shared software development platform has increased by 30%. Software-defined network connectivity has been rolled out to all ESA sites and establishments, providing optimised inter-site, internet and cloud connectivity.

Numerous digital functionalities and services supporting all key processes, such as procurement, finance and HR, have been released and made available through mobile applications. Pilots using ChatGPT and an AI search engine have been successfully developed.

ESA's cyber operations continue to be provided by ESACERT, ensuring appropriate detection, response and recovery actions for multiple security incidents. The future set-up of the new Cyber Security Operations Centre (C-SOC) has been fully defined and a tender has been issued to enable operations in 2024.

The migration to esa365 has been completed, enabling a much faster evolution, a more user-friendly IT workplace and more secure operations and evolutions of the ESA IT environment.

The videoconferencing system has been completely overhauled to align with the new hybrid working pattern at all Agency sites, achieving higher quality standards and levels of security.

COMMERCIALISATION, INDUSTRY AND COMPETITIVENESS

COMMERCIALISATION

Supporting European startups and scaleups ESA further developed its network of Business Incubation Centres (BIC) in 2023 with the opening of new ESA BICs in Vilnius (Lithuania), Milan, Padua and Brindisi (Italy), and Vaasa and Tampere (Finland). ESA now has 29 BICs in 21 countries, with more than 1,600 startups incubated and 5,000 jobs created over a 19-year period. The companies incubated in the BICs raised more than €400m in investments in 2023, generating €200m in revenue and filing 150 patents.

ESA supports companies with their financing needs and, in 2023, worked with its network of 40 investment companies to help them better understand the specific characteristics and attractiveness of space markets. ESA also facilitates introductions with the startups it works with and collaborates with the European Investment Fund, the European Commission and many other partners.

Through its Commercialisation Gateway and SME Office, ESA continued to facilitate business interaction between space and non-space sectors and ESA programmes in 2023 in order to facilitate access to all the opportunities and projects provided by the Agency.

INCREASING KNOWLEDGE AND AWARENESS ABOUT THE ECONOMIC IMPACT OF SPACE

In December, together with Eurostat, the Joint Research Centre, the OECD and the US Bureau of Economic Analysis, ESA published a comprehensive list of statistical codes for the US and Europe – the first of its kind – to measure the space economy at international level.

ESA established the European Centre for Space Economy and Commerce (ECSECO) in Vienna, which organised several webinars and conferences about the space economy and commerce in 2023.

SUPPORTING INNOVATION FOR NEW APPLICATIONS

ESA is developing a network of research centres in its Member States, where scientists and companies work together towards commercially oriented innovations. The first Φlab, based in ESRIN, is a centre for research into new technologies and applications for Earth observation.

ESA maintained its network of Technology Brokers working across ESA to increase the adaptation of space technology for

non-space applications. More than 200 technology transfers were initiated by the network.

ESA is working to increase the use of space applications and data in the everyday lives of European citizens. The ESA Business Applications and Space Solutions (BASS) programme supported more than 100 activities to use space for new business applications in domains such as the Green Transition, energy, transportation, maritime and smart cities. ESA monitors the societal and economic impact of these activities, which have created more than 1,000 jobs and have generated more than €1bn in projected revenue.

INCREASING THE POSITIVE IMPACT OF SPACE IN THE LIVES OF EUROPEAN CITIZENS

ESA strongly supports activities linked to the Green Transition. In the context of the ESA BASS programme, more than 300 ideas for space-based applications providing green benefits were developed in 2023, corresponding to an investment of €183m. ESA attended COP28, where it announced a partnership with the United Nations CEO Water Mandate initiative to advance the digital monitoring of 100 of the world's most water-stressed basins.

In other important sectors, new partnerships began in 2023 to support space-based innovation in agri-food, energy and smart cities. ESA began a cooperative initiative with COPA-COGECA, the strongest interest group for European farmers, to facilitate the sustainable transformation of farms through digitalisation and space. Two new partners, E.ON Innovation and DEWA (Dubai Electricity and Water Authority), have joined the Innovation in Energy through Space Task Force. In September, ESA launched the Space for Smart and Green Cities Task Force, bringing together cities such as Amsterdam, Paris, Bristol, Essen, Bologna, Naples, Taranto, Turin and Venice and international groups, such as ICLEI, to work on sustainable urban development and mobility using space applications.

To increase synergies with ESA's technical programmes in the domains of launchers, Earth observation and connectivity, ESA launched new marketing campaigns to advertise all opportunities and organised Agency-wide ESA Commercialisation Days on health and transportation in order to connect the ecosystem.

COMMERCIALISATION, PROCUREMENT AND INDUSTRIAL POLICY, AUDIT

The years that follow ESA Council meetings at ministerial level are characterised by extensive contractual activity, with more than 1,200 contracts placed in 2023, including a number of contracts for large missions. As the space ecosystem rapidly evolves, ESA works to adapt its rules and processes to ensure greater speed and flexibility in support of the competitiveness of the European space industry. The ESA Procurement Regulations and rules for the implementation of industrial return are being discussed with Member States. The Agency has also worked to mitigate the effects of economic instability in 2023 among its industrial partners and suppliers, renegotiating industrial rates and addressing claims linked to inflation. ESA's industrial policy is also aimed at developing or attracting new actors in the industrial space ecosystem, including in new and under-returned Member States. In 2023, the first SME and Mid-cap Days were held, attended by almost 150 companies, with a view to streamlining interactions with SMEs and mid-caps, and 115 activities were implemented in 12 new and under-returned Member States for a total value of €39m.

ECSECO General Assembly of the members, Vienna, 01 December 2023

FINANCE, PLANNING AND CONTROL

The ESA Executive is actively contributing to the implementation of the decisions taken at CM22 and to the ESA Transformation initiative, in particular by developing the matrix approach, strengthening project management and accelerating initiatives in the areas of digital transformation and streamlining of processes.

Financial Accounting & Operations

With the 2023 accounts, ESA aims to repeat its 2022 achievement, namely of achieving 11 straight years of unqualified financial statements and, for the second year in a row, to receive zero audit recommendations, thus fostering continued stakeholder confidence in ESA's financial management.

Through highly digitalised processes, ESA made over 38,400 payments, incorporating special payment acceleration measures for industry, with an average time-to-payment of 15 calendar days versus ESA's 30-day contractual terms. Digitalisation continued in invoice processing and travel expense management.

The treasury team successfully implemented a new treasury management system that supports end-to-end treasury operations and management, and provides greater automation, security and advanced reporting capabilities.

Corporate Planning, Budgeting and Controlling

Budgets, long-term planning and Agency-wide multi-year financial plans and strategies were developed. Following endorsement of the 2024 cost plans by the Programme Boards, Council adopted the record-high 2024 budgets (€7.8bn for mandatory and optional ESA programmes and for third-party activities).

Departmental digitalisation efforts made progress, including further development and automation of financial KPIs for management dashboards, requesting party database analysis and data model improvements.

ANNUAL REPORT - FINANCIAL STATEMENTS

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 2023. 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.

The net surplus of 2023 amounts to 1,512.5 M€ compared to a surplus of 452.3 M€ in 2022. The breakdown is as follows:

- 1,584.3 M€ net surplus for ESA activities and programmes (800.4 M€ net surplus in 2022)
- 86.4 M€ net deficit for Pensions (359.9 M€ net deficit in 2022)
- 14.6 M€ net surplus for Social Security (11.8 M€ net surplus in 2022)

The result of 2023 increased by 1,060.2 M€ compared to 2022 mainly due to increased operating revenues by 888.0 M€ compared to prior year, partially offset by increased operating expenses by 155.5 M€ compared to prior year.

The financial result amounts to a surplus of 224.2 M€ compared to a deficit of 103.5 M€ in 2022, resulting in an increase of 327.7 M€. The financial surplus in 2023 is mainly related to the positive bank interests of the treasury in 2023 and the performance of the Pension Buffer fund in 2023.

The Financial Information presented hereinafter, was extracted from the ESA Financial Statements 2023. ESA Financial Statements 2023 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 2023 audited Financial Statements give a true and fair view of the Financial Position of the European Space Agency as at 31 December 2023, and of its Financial Performance and its Statement Cash Flows for the 12 month period ended 31 December 2023, 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 18 June 2024.

I. STATEMENT OF FINANCIAL POSITION

	31 December 2023	31 December 2022 Restated*	01 January 2022 Restated*
Total Assets	**19,654.7**	**17,275.5**	**15,859.4**
Current assets	**6,500.6**	**4,931.4**	**3,952.4**
Cash and cash equivalents	3,971.9	3,194.4	1,954.4
Recoverables from non-exchange transactions	254.1	153.2	234.5
Receivables from exchange transactions	1,700.5	942.5	1,285.1
Inventories	574.1	641.3	478.4
Non-current assets	**13,154.1**	**12,344.1**	**11,907.0**
Recoverables from non-exchange transactions	2.4	12.0	12.0
Receivables from exchange transactions	811.4	824.8	665.6
Financial assets	1,320.8	1,200.8	1,164.2
Property, plant and equipment	10,712.7	9,974.0	9,742.1
Intangible assets	306.8	332.5	323.1
Total Liabilities	**11,513.8**	**10,007.2**	**12,528.5**
Current liabilities	**4,316.1**	**3,748.1**	**3,248.6**
Payables under exchange transactions	**3,655.2**	**3,146.1**	**2,720.6**
Current payables	1,616.9	1,410.6	1,516.7
Pre-financing from exchange transactions	1,661.3	1,486.6	1,072.7
Deferred income	377.0	249.0	131.2
Contributions and other payables	**330.3**	**249.6**	**234.1**
Prepaid contributions and other amounts payable to Member/Participating States	303.9	182.4	201.7
Pre-financing from non-exchange transactions	2.2	3.0	2.4
Other financial liabilities	0.5	0.0	0.0
Other payables	23.7	64.2	30.0
Employee benefits obligations	**287.7**	**270.7**	**232.7**
Provisions	**42.8**	**81.6**	**61.2**
Non-current liabilities	**7,197.8**	**6,259.2**	**9,279.9**
Employee benefits obligations	6,397.3	5,512.7	8,749.3
Other payables	299.7	392.2	229.0
Deferred income	276.3	287.8	280.7
Pre-financing from non-exchange transactions	0.0	0.2	0.0
Pre-financing from exchange transactions	224.5	66.3	20.9
Net Assets	**8,140.9**	**7,268.3**	**3,330.9**
Reserves	**10,819.6**	**10,647.3**	**6,352.4**
Amounts to be called from Member States	**-4,191.2**	**-3,831.3**	**-3,618.3**
Net Surplus/ (Deficit) for the period	**1,512.5**	**452.3**	**586.4**
Net Assets	**8,140.9**	**7,268.3**	**3,330.9**

(*) The current and non-current supplier advances related to Property, Plant and Equipment have been reclassified to advances for Property, Plant and Equipment as per 31.12.2022 and 31.12.2021

II. STATEMENT OF FINANCIAL PERFORMANCE

	Notes	2023 million €	2023 million €
Operating Revenues		**6,741.5**	**5,853.5**
Contributions from Member/Participating States		5,044.3	4,723.0
Other contributions and grants		17.5	26.2
Revenues from exchange transactions		1,253.8	735.3
Staff contributions		73.5	64.4
Other operating income		352.4	304.6
Operating Expenses		**-5,453.2**	**-5,297.7**
Purchases		-2,407.1	-1,796.6
External Servicies		-1,366.5	-1,367.2
Staff expenses		-706.9	-765.2
Other Operating expenses		-329.1	-304.9
Expenses from non-exchange transaction (*)		-30.4	-193.5
Depreciation and amortization		-581.7	-698.6
Impairment		-20.2	-134.9
Write-downs inventories and fixed assets, doubtful debts, provisions for future losses		-11.3	-36.8
Net Surplus / (Deficit) from Operating activities		**1,288.3**	**555.8**
Financial Activities		**224.2**	**-103.5**
Financial revenue		255.7	26.4
Financial expenses		-31.5	-129.9
Net Surplus / (Deficit) for the period		**1,512.5**	**452.3**

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**	**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**	**70.9**		**3,537.0**	**-53.3**	**15.0**	**-0.1**	**-35.9**
Revaluation Reserve		852.2	-339.1				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**	**3,390.0**	**0.0**	**452.3**	**3,537.0**	**-53.3**	**0.0**	**1.5**	**7,268.3**

		31 December 2022	Allocation of audited 2022 surplus/ (deficit)	2023 Net Surplus	Change in the present value of the Employee Benefit Defined Benefit Obligation	Fair Value adjustments	Allocation of financial interests	Other changes	31 December 2023
		million €	million €	million €	million €	million €	million €	million €	million €
RESERVES	**A**	**10,647.3**	**812.3**		**-665.4**	**30.9**	**-5.5**	**-0.0**	**10,819.6**
Member States Capital and Reserves		**-35.9**	**-276.7**		**-665.4**	**30.9**		**-0.2**	**-947.3**
Revaluation Reserve		700.6	-114.4					-0.1	586.2
Currency Exchange Gains Reserve		2.6	-0.2					-0.2	2.3
Other Reserves		-739.2	-162.0		-665.4	30.9			-1,535.8
Social security reserve		51.5	11.7			3.1			66.3
Buffer Fund fair value reserve		-41.2				27.8			-13.5
Reserve Barter		-295.8	-173.7						-469.4
Actuarial gains and losses		-453.8			-665.4				-1,119.2
Accumulated Surplus		**10,683.3**	**1,089.0**				**-5.5**	**0.2**	**11,766.9**
Accumulated Surplus ESA programmes		10,578.0	1,095.1				-5.5	0.3	11,667.7
Accumulated Surplus Third Party programmes		85.3	-5.4						80.0
Accumulated Surplus PECS		20.0	-0.8					-0.0	19.2
AMOUNTS TO BE CALLED FROM MEMBER STATES	**B**	**-3,831.3**	**-359.9**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**-4,191.2**
Member States pension scheme receivable		-3,831.3	-359.9						-4,191.2
Accumulated Deficit									
Net Surplus / (Deficit) for the Period	**C**	452.3	-452.3	1,512.5					1,512.5
TOTAL NET ASSETS	**A+B+C**	**7,268.3**	**0.0**	**1,512.5**	**-665.4**	**30.9**	**-5.5**	**-0.0**	**8,140.9**

IV. STATEMENT OF CASH FLOWS

	31 December 2023 million €	31 December 2022 Restated* million €
Net Cash Flows	**774.3**	**1,238.6**
Net Cash Flows from Operating Activities	**2,130.3**	**2,515.4**
Surplus/(deficit) from ordinary activities	1,512.5	452.3
Reclassification to investing activities	**-14.9**	**-2.1**
Non-cash movements	**524.1**	**966.9**
Depreciation and impairment	601.9	833.5
Provisions and Accruals	-56.0	20.0
Write-downs / Adjustments inventories and fixed assets, provisions for future losses on inventories	44.4	16.5
Revaluation of financial assets at fair value	-67.1	98.4
Effect of exchange rates on operating activities	0.9	-1.5
Decrease (Increase) in Deferrals/accruals of past or future operating cash receipts or payments	**108.6**	**1,098.3**
Decrease/(increase) in inventories	82.5	-163.6
Decrease/(increase) in recoverables from Member States	-100.1	80.7
Decrease/(increase) in other receivables	15.6	38.2
Decrease/(increase) in other current assets	-764.1	146.6
Increase/(decrease) in payable to Member/Participating States	116.1	-17.8
Increase/(decrease) in pre-financing	331.8	460.1
Increase/(decrease) in other payables	190.5	215.8
Increase/(decrease) in provisions for employee benefits	236.3	338.3

	31 December 2023 million €	31 December 2022 Restated* million €
Net Cash Flows	**774.3**	**1,238.6**
Net Cash Flows from Operating Activities	2,130.3	2,515.4
Net Cash Flows from Investing Activities	**-1,356.0**	**-1,276.8**
Acquisition of fixed assets	-1,349.2	-1,090.7
Proceeds from sales of fixed assets	0.1	0.1
Purchases of financial investments (portfolio)	-169.3	-384.9
Proceeds on disposal of financial investments (portfolio)	151.9	192.2
Interests received on financial assets	10.5	6.5
Net increase/(decrease) in cash and cash equivalents	**774.3**	**1,238.6**
Cash and cash equivalents at the beginning of the year	3,194.4	1,954.4
Effect of foreign exchange gain/loss on foreign-denominated cash & cash equivalent	-3.2	-1.4
Cash and cash equivalents at year-end	3,971.9	3,194.4

(*) The current and non-current supplier advances related to Property, Plant and Equipment have been reclassified to advances for Property, Plant and Equipment as per 31.12.2022 and 31.12.2021

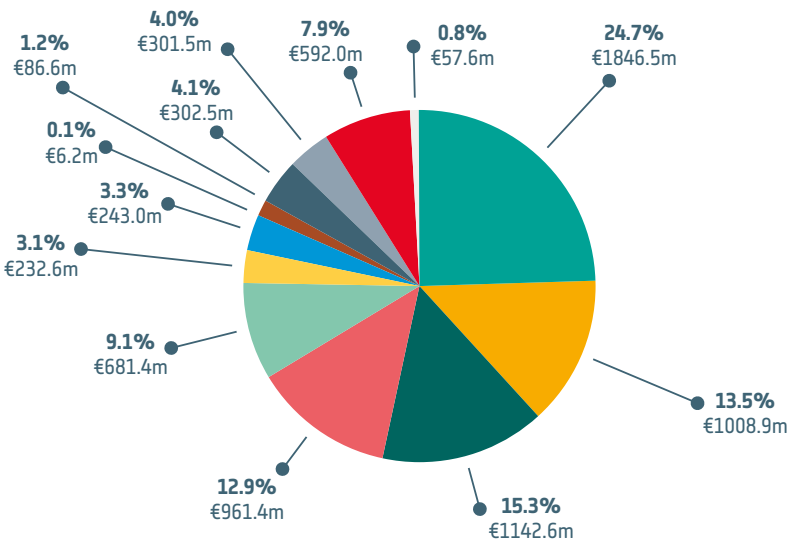
Income

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.

FUNDING FOR ESA ACTIVITIES AND PROGRAMMES

Final budget by domain for 2023: €7.46 bn

- Scientific Programme
- Human and Robotic Exploration
- Space Transportation
- Technology Support
- Commercialisation
- Connectivity and Secure Communications
- Earth Observation
- Navigation
- Space Safety
- European Cooperation States Agreememts
- Basic Activities
- Associated with General Budget
- Prodex



* Includes activities implemented for other institutional partners

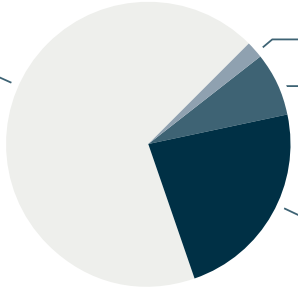
ESA 2023 BUDGET BY FUNDING SOURCE

- Austria: €65.5m (1.2%)
- Belgium: €284.6m (5.4%)
- Czech Republic: €49.2m (0.9%)
- Denmark: €35.1m (0.7%)
- Estonia: €8.9m (0.2%)
- Finland: €39.0m (0.7%)
- France: €1079.4m (20.4%)
- Germany: €1064.2m (20.2%)
- Greece: €21.0m (0.4%)
- Hungary: €24.7m (0.5%)
- Ireland: €32.3m (0.6%)
- Italy: €680.1m (12.9%)
- Luxembourg: €42.0m (0.8%)
- Netherlands: €95.6m (1.8%)

TOTAL: €5.28 bn

- Other: €212.0m (4.0%)
- Canada: €33.8m (0.6%)
- Slovenia: €5.1m (0.1%)
- Slovakia: €3.0m (0.1%)
- Lithuania: €1.8m (0.0%)
- Latvia: €1.7m (0.0%)
- United Kingdom: €694.0m (13.1%)
- Switzerland: €201.6m (3.8%)
- Sweden: €89.7m (1.7%)
- Spain: €285.7m (5.4%)
- Romania: €56.4m (1.1%)
- Portugal: €30.8m (0.6%)
- Poland: €68.6m (1.3%)
- Norway: €75.4m (1.4%)

67.9% Income from Member States for ESA programmes and activities



1.7% Income from EUMETSAT

7.4% Other income

22.9% Income from EU

TOTAL: €7.46 bn

Cost

ESA's total cost in 2023 amounted to €5,992m, of which €4,264m related to ESA programmes and activities and €1,729m to Third-Party activities.

Mandatory Activities represented 15% (€928m), 53% was accounted for by Optional Programmes (€3,176m), 2% by activities associated to the General Budget (€134m), and 29% by programmes financed by Third Parties (€1,729m).

Most of the cost accrued in 2023 by domain is provided below.

Basic Activities: Discovery, Preparation & Technology Development (38%), Mission Operations Infrastructure (12%), Sites & Common IT Investment (8%) and Engineering Labs & Test Centres (15%)

Scientific Programme: Missions in implementation (67%) Missions in operation (16%), Mission preparation (13%)

Space Transportation: Ariane 6 Development (13%), Ariane 6 & P120C Transition (8%) and Space Rider Step 2.2 (5%)

Earth Observation: Copernicus Space Component (31%), EOEP Period 5 (9%), Future EO (29%), MetOp Second Generation Development (6%).

Human and Robotic Exploration: Mars Sample Return (16%), European Service Module (ESM) (24%), Gateway (14%).

Connectivity and Secure Communications: Core Competitiveness (46%), PARTNER (23%) and IAP/BASS (14%)

Technology Support: General Studies Technology Programme R&D (86%) and Proba-3 (13%)

Space Safety: HERA Mission (65%) and COSMIC (17%)

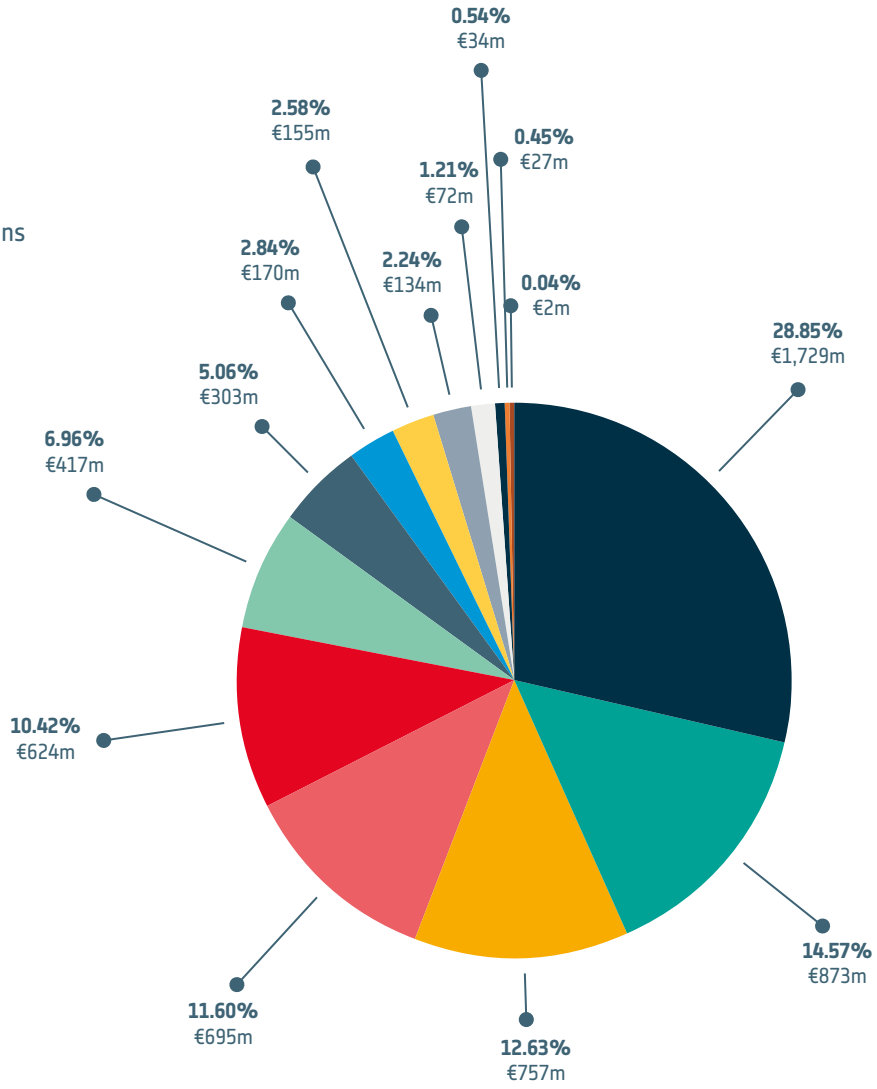
Navigation: NAVISP (91%)

Third-party: EU programmes, Galileo FOC DC - GSA – EUSPA (43%) in Navigation and Copernicus MFF (22%) in Earth Observation

Associated to General Budget: CSG 2020–2024 (88%)

COST BY DOMAIN (€M)

- Scientific Programme
- Human and Robotic Exploration
- Space Transportation
- Technology Support
- Commercialisation
- Connectivity and Secure Communications
- Earth Observation
- Navigation
- Space Safety
- Third Party & ECSA
- Basic Activities
- Associated with General Budget
- Prodex
- Miscellaneaous



WORKFORCE MANAGEMENT

Recruitment activity continued to be intensive in 2023, reaching a level of 229 new staff members (an increase of 7.5% on 2022) excluding the recruitment of Young Graduate Trainees and Research Fellows and without considering temporary staff hired to support National Projects. Additional increases in the staff ceiling were approved by Council in 2023 to implement additional tasks requested by the European Commission for the European Union Secure Connectivity Programme, support new National Projects and strengthen core competencies to retain the required knowledge and shape the workforce of the future. In addition to this, the Agency is progressing in the redefinition of the overall Agency Resource Strategy that will drive the future sourcing of manpower resources.

The table below provides an overview of the distribution of staff by nationality and grade at 31 December 2023.

Member States	Hors Classe	A	L	B	C	Total Staff
Austria	1	33	1	2		37
Belgium	1	117		3		121
Czech Republic		10				10
Denmark		9		1		10
Estonia		5		2		7
Finland		23		2		25
France	2	549	9	46	3	609
Germany	2	470	4	28		504
Greece		28		2		30
Hungary		13				13
Ireland		16	1	2		19
Italy	1	413		15		429
Lithuania		3				3
Luxemburg		5				5
Norway		23		2		25
Poland		35		1		36
Portugal		35		2		37
Romania		40				40
Slovakia		1				1
Slovenia		2		1		3
Spain	1	225		3		229
Sweden		36		1		37
Switzerland	1	21		1		23
The Netherlands		65		8		73
United Kingdom	2	274	2	17		295
Total	**11**	**2451**	**17**	**139**	**3**	**2621**
Non-Member States	**11**	**2451**		**139**	**3**	**2621**
Canada		23		1		24
Grand Total	**11**	**2474**	**17**	**140**	**3**	**2645**

CORPORATE SOCIAL RESPONSIBILITY

The ESA Green Agenda (EGA) aims to reduce the Agency's greenhouse gas (GHG) emissions and increase ESA's contribution to the sustainable development of society and the space sector. Specifically, GHG emissions will be reduced by 2030 by 46% for Agency operational activities and by 28% for the activities carried out by suppliers with 2019 as a baseline. To achieve these goals, a number of different initiatives and areas of work have been developed. A methodology was created to measure the GHG emissions of any ESA space mission, with special focus on downstream applications, which was assessed on Sentinel 1 and 2 through project Arrhenius. This methodology will be made more robust and will be systematically applied to all ESA programme and activities. Agency-wide, projects have been implemented to reduce energy consumption and increase efficiency at all levels. The Agency has also moved forward with the systematic application of ecodesign and life cycle assessments (LCAs), which will be reflected in the ESA LCA Handbook 2024. Corporate Social Responsibility (CSR) has been key to the development of a CSR Code of Conduct to ensure responsible procurement. Change Management has been an overarching effort, with one of the goals of EGA's Change Management approach being to bring awareness about the importance and urgency of embedding sustainability into ESA's core activities through strategic communication and engagement events such as the ESA Earth Days, which gathered more than 300 participants, 60 volunteers, 13 speakers and ten climate frescoes throughout ESA's eight main sites. The Agency has also been part of the global discussion surrounding the sustainable development of the space sector through its participation in the Global Space Conference on Climate Change 2023 organised by the International Aeronautical Federation, holding a seat in various round tables and technical panels. Furthermore, ESA organised multiple signature events of the Statement for a Responsible Space Sector in 2023, as well as the first plenary meeting with signatories at ESA Headquarters in Paris in November.

COMMUNICATION

ESA participated in the European Space Conference in Brussels on 24 and 25 January 2023, teaming up with the European Commission to jointly advance Europe in space, focusing on green space, Galileo and Copernicus.

ESA and CNES shared a pavilion at the Paris Airshow in Le Bourget from 19 to 25 June, presenting dedicated joint events on the future of human spaceflight, space transportation, commercialisation in space, applications in space and space for a green future.

The historic achievements at the Space Summit in November in Seville as well as the debate surrounding it were successfully communicated. ESA was able to set the tone as the most prominent party featured in the discussions. Part of the ESA Council meeting was live-streamed, including an inflight call with Andreas Mogensen on board the ISS, media were hosted in a press centre on site, Council documents were made publicly available in advance and the first images of Euclid were released and presented to Ministers. This together with various photo opportunities and press conferences allowed for a successful communication package leading to very positive coverage in the media for this important milestone of Agenda 2025.

Nine ESA Days in close cooperation with Member States were organised in 2023. Slovakia, Belgium, Latvia, France, the United Kingdom, Luxembourg, the Netherlands, Slovenia and Denmark, together with ESA, each developed a programme combining political networking, edutainment/entertainment for the general public and information for media and implemented these days together at national locations helping greatly to bring European space to the general public.

The preparation of Ariane 6 for its maiden flight took place under the watchful eyes of the public. The Communication Department has put considerable effort into communicating progress – as far as possible – transparently and in real time. Regular reports of the Launcher Task Force were published, media briefings were held and for the first time a hot-firing test in Kourou was streamed live over the internet, resulting in almost 140,000 viewers.

Fully-fledged launch communication campaigns were implemented for the launches of Juice and Euclid, featuring multiple launch events at the launch sites in French Guiana and Florida as well as in Darmstadt, combined with national events in various Member States. Based on the live ESA Web TV broadcasts, VIPs were able to witness the launch, and journalists to report on them. Dedicated merchandising sets, brochures, media kits, videos and infographics were made available and helped make these two launches among the most impactful ESA communication campaigns of 2023.

Not only the number of communication activities increased in 2023 with, for example, 50% more web stories and images published in the second half of the year. Visibility and impact also increased by 20% with respect to 2022.

RELATIONS WITH MEMBER STATES

In 2023, the Director General continued to visit and exchange with Member States, often taking the opportunity offered by various major events. This included appointments with Ministers and politicians in charge of space matters and related fields, with delegations, and addressing parliaments, industry, the press, academic institutions and the general public whenever possible. Some meetings were held remotely. In addition, the ESA Executive remained in close touch with all relevant national counterparts.

EXTERNAL RELATIONS

Relations with European Union Institutions

In 2023, ESA and the European Commission continued to build upon the strong foundation of cooperation established by the Financial Framework Partnership Agreement (FFPA), placing Europe and European skills and knowledge at the centre of innovation in the space sector. The historic Contribution Agreement for IRIS² – the EU's Secure Connectivity programme signed in September 2023 between ESA and the Commission for a period of twelve years – showcases the organisations' joint commitment to long-lasting cooperation. IRIS², one of the Commission's flagship programmes, holds particular importance in the context of current geopolitical challenges – all the more reason to celebrate ESA's key role in this critical initiative. In November, the ESA Space Summit took place in Seville during the EU Space Week, a three-day gathering of key European space stakeholders and leaders. During the Space Summit, the Resolution on Lifting Europe's Ambition for a Green and Sustainable Future, Access to Space and Space Exploration was adopted, cementing ESA's renewed commitment to sustainability and innovation. In addition, the progress made since CM22 on the Space for a Green Future, Rapid and Resilient Crisis Response and PROTECT Accelerators was presented to the Ministers and delegates at the Summit.

This call for innovation was further emphasised during ESA's joint informal meeting with the Commission, with both entities recognising the vital importance of strategic and autonomous access to space as well as the development of space commercialisation. ESA-EU relations will continue to prosper in 2024, which marks 20 years since the signing of the 2004 Framework Agreement, a key forerunner of the FFPA. The Space Council will reconvene on 23 May 2024.

International Relations

ESA's Associate Members –Slovenia, Latvia, Lithuania and Slovakia – contributed to optional programmes and Requesting Party Activities. Slovenia notified ESA of its intent to become an ESA Member State upon the expiry of the Association Agreement.

Cooperation with Members of the European Union which are not Member States of ESA was marked in 2023 by the celebration of the 20th anniversary of the European Cooperating State (ECS) scheme established in 2001. The ECS Agreement with Malta was signed by the Director of Legal and International Matters, Eric Morel during the event held on 25 October in Larnaca, Cyprus. Croatia also became an ECS in 2023, and the PECS contributions of Cyprus and Bulgaria were raised.

The six-month Huginn mission of ESA Astronaut Andreas Mogensen was one of the highlights of ESA-NASA cooperation, with Andreas playing a pivotal role as the pilot of Crew-7 and ISS Commander. Mutually beneficial cooperation with NASA and other US entities was successfully pursued. Several agreements between ESA and NASA were formalised in 2023, including MoUs on the BepiColombo, Ariel, EnVision and Mars Express missions. The NASA-ESA-CSA James Webb Space Telescope continued to produce remarkable scientific data.

The Director General hosted a visit by Keiko Nagaoka, Japanese Minister for Education, Culture, Sports, Science and Technology (MEXT), the first ministerial-level visit to take place in the new ESA Headquarters building. The visit highlighted the strength and solidity of cooperation between ESA and Japan. ESA and JAXA initiated a joint exercise to define a future generation of ESA-JAXA cooperative projects. An ESA delegation visited Tokyo in early December to forge ahead with the cooperation. The agreement on ESA-JAXA cooperation on the JAXA-led Solar-C mission was signed.

ESA contributions to the Chinese Academy of Sciences' Einstein Probe were finalised and the mission launched successfully on 9 January 2024. Development of the SMILE mission continued successfully. In September, the Dragon Symposium was held in Hohhot to review the results of the Dragon joint Earth science cooperation project.

An ESA delegation visited several ISRO (Indian Space Research Organisation) establishments in Ahmedabad and Bengaluru to revitalise the ESA-ISRO cooperative relationship. Follow-up discussions were held to refine areas of specific common interest.

An ESA visit to the United Arab Emirates led to concrete exchanges on future cooperation.

Brazil indicated its wish to reestablish cooperation with ESA in the Earth observation domain. The Cooperation Agreement with Argentina was extended. ESA and the Mexican Space Agency signed a cooperation agreement.

ESA pursued specific cooperation projects with multiple partners in Africa.

LEGAL SERVICES

During 2023, the Legal Services Department provided a wide range of legal services to internal and external clients, supporting the implementation of approved programmes, facilitating the establishment of new activities and partnerships, safeguarding the consistent application of ESA's institutional legal framework, providing analysis and advice, and contributing to legal discourse and development in the broader context of the Agency's purpose.

The preparation and conduct of the Space Summit – including the drafting and negotiation of the associated resolutions and decisions, in particular for European access to space – was one of the Department's focal areas in 2023. Other milestones included the signature of the host agreement with France, the revision of the Agreement between ESA and the European Union (EU) on the security and exchange of classified information, various amendments of delegation agreements and contribution agreements in the context of ESA's long-standing cooperation with the EU, and support for the implementation, for the first time, of the ESA private astronaut mission scheme.

For these and many more activities, the Department's team of lawyers and legal assistants cooperated closely throughout the year with the Agency's directorates and service units, handling the revision of declarations and implementing rules across ESA's programmes, enabling novel legal schemes and solutions, and processing and ensuring legally sound decisions, among other things.

The team also supported Council and its subordinate bodies with dozens of meetings – and the issuing of hundreds of official documents – throughout the year, reviewed and co-shaped internal policies such as the new ESA space debris mitigation policy, and provided assistance to Member States for the elaboration and implementation of national space laws. The review of the Agency's Procurement Regulations was initiated in 2023 through an interdisciplinary effort, with a view to its being concluded in 2024.

As ESA is not only a mechanism of international cooperation but also an actor and partner in international endeavours, the Legal Services Department also supported the negotiation and establishment of new cooperative frameworks. A list of international agreements entered into by ESA in 2023 is provided in Annex 2.

Group photo - ESA Council at Ministerial level at the Space Summit 2023 on 6 November in Seville, Spain.

315th ESA Council at the new ESA Headquarter in Paris, France on 22 March 2023.

ANNEX

152 Annex 1 – Advisory bodies

153 Annex 2 – International Agreements signed in 2023

154 Annex 3 – List of Communication events organised in 2023

155 Annex 4 – 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

Council Advisory Group

- Oversight Committee (OC)

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 2023

The following international agreements and acts between the Agency and third parties were concluded or entered into force in 2023, issued in the ESA/LEG series accordingly:

LEG/553: Agreement between the European Space Agency and the Mexican Space Agency of the United Mexican States concerning space cooperation for peaceful purposes

LEG/554: Contribution Agreement between the European Union, represented by the European Commission, and the European Space Agency on the Regional Copernicus Centre in Panama (CopLAC)

LEG/555: Contribution Agreement between the European Union, represented by the European Commission, and the European Space Agency on the National Copernicus Capacity Support Action Programme for the Philippines (CopPhil)

LEG/556: Agreement between the European Space Agency and the National Aeronautics and Space Administration on the flight of CURIE on Ariane 6 inaugural flight

LEG/557: Agreement between the European Space Agency and the Government of the French Republic on the Guiana Space Center and Associated Services (Period 2023-–2035)

LEG/558: European Cooperating State (ECS) Agreement between the European Space Agency and the Government of the Republic of Croatia

LEG/558, add.1: The Plan for European Cooperating State (PECS) Charter between the European Space Agency and the Government of the Republic of Croatia

LEG/559: Memorandum of Understanding between the European Space Agency and the Japan Aerospace Exploration Agency (JAXA) concerning the JAXA-led mission SOLAR-C

LEG/560: Memorandum of Understanding between ESA and NASA concerning the Bepi Colombo Mission

LEG/561: Memorandum of Understanding between ESA and NASA concerning the ESA-led Ariel Mission

LEG/562: Multilateral Agreement concerning the Comet Interceptor

LEG/563: Multilateral Agreement concerning the Gaia Mission

LEG/564: Memorandum of Understanding Between the European Space Agency and the Japan Aerospace Exploration Agency (JAXA) concerning the Comet Interceptor Mission

LEG/565: Contribution Agreement between the European Union, represented by the European Commission, and European Space Agency on the Implementation of the European Union Secure Connectivity Programme

LEG/566: Agreement between the European Space Agency and the European Space Policy Institute (ESPI)

LEG/567: Agreement for the European Space Agency's Assistance to Spain concerning Earth Observation and Telecommunication Activities

LEG/568: Arrangement between the European Space Agency and the Government of Canada concerning the participation by the Government of Canada in the Space Safety Programme

LEG/569: Agreement for the European Space Agency's Assistance to the Republic of Poland concerning the Earth Observation Project "Country Awareness Mission in Land Analysis"

LEG/570: Memorandum of Understanding between the European Space Agency and the United Nations Environment Programme on cooperation in the use of Earth observation data and technology for the environment.

ANNEX 3

List of Communication events organised in 2023

MONTH	EVENT
23 January	Director General's annual press conference
24–25 January	15th European Space Conference Brussels
9 February	Media Visit of ESMs at Airbus, Bremen
21 February	Euclid at Thales Alenia Space, Cannes
3 March	Media event regarding the Independent Enquiry Board for Vega-C
8–9 March	Media pre-launch programme to see Juice spacecraft at CSG
21 March	Visit of ESA's New Headquarters in Paris
23 March	Presentation of the HLAG Report
2 April	Astronaut class of 2022 begin basic training
14 April	Juice launch events at CSG, ESOC
23–25 May	Global Climate Change Conference, ESA received 'Space for Climate' Award
31 May – 2 June	European Navigation Conference, ESA ESTEC
2 June	Ready for the Moon event, Vienna
19–25 June	Paris Airshow, Le Bourget,
1 July	Euclid launch events at KSC and ESA ESOC
3 July	First data from Meteosat Third Generation satellite's Lightning Imager
5 July	Ariane 5 final flight
11 July	Inauguration of ESA ECSAT's new Conference Centre
28 July	Re-entry of Aeolus
26 August	Launch of Andreas Mogensen, launch event at KSC and in Denmark
1 September	Ariane 6 upper stage motor test firing
2 October	Media event regarding Vega-C Zefiro 40 motor Independent Enquiry Commission
9 October	VV23 Vega launch
6 November	Space Summit in Seville, Euclid's first images
23 November	Ariane 6 long hot fire test of Vulcain 2.1 motor, live broadcast

ANNEX 4

List of ESA Publications in 2023

The following publications were produced for the ESA Communication Department:
ESA Impact Q1, Q2, Q3 and Q4 (interactive)
Space Ambition book interactive book
Esa Highlights 2023 magazine (printed and interactive)
ONE ESA Brochure printed in 5 additional Member State languages besides previous English-only version
Esa 2023 Christmas cards
Ariane 5 media kit
Esa Annual Report 2022
High-Level Advisory Group (HLAG) report
ESA Crew-7/Dragon VIP launch booklet
Huginn mission brochure
Muninn mission preflight brochure and launch kit
Esa Ax-3 VIP launch booklet

IMAGE CREDITS

All images are the copyright of ESA unless stated otherwise.

Highlights 2023

02	FOREWORD | © *ESA–D. DOS SANTOS*
04 - 05	ESA TRANSFORMATION TOWN HALL | © *ESA*
06	THE NEW ESA HEADQUARTERS – COUNCIL CHAMBER | © *ESA–S. CORVAJA*
	ESA SPACE SHOP | © *ESA–P. SEBIROT*
07	ESA HEADQUARTERS SITE, 1976 | © *ESA*
	THE NEW ESA HEADQUARTERS – BUILDING | © *ESA–P. SEBIROT*
	THE NEW ESA HEADQUARTERS – STAIRCASE | © *ESA–P. SEBIROT*
10	SCIENCE | © *ESA/GAIA/DPAC; CC BY-SA 3.0 IGO, CC BY-SA 3.0 IGO*
	SPACE TRANSPORTATION | © *ESA–M. PEDOUSSAUT*
	HUMAN & ROBOTIC EXPLORATION | © *NASA*
	OPERATIONS | © *ESA–J. MAI*
11	EARTH OBSERVATION | © *CONTAINS MODIFIED COPERNICUS SENTINEL DATA (2021), PROCESSED BY ESA, CC BY-SA 3.0 IGO*
	NAVIGATION | © *ESA/CNES/ARIANESPACE OPTIQUE VIDÉO DU CSG–P. BAUDON*
	COMMERCIALISATION, INDUSTRY AND COMPETITIVENESS | © *GETTY IMAGES*
	TECHNOLOGY | © *ESA*
	CONNECTIVITY AND SECURE COMMUNICATIONS | © *AIRBUS*
	SPACE SAFETY | © *GETTY IMAGES*

November 2022 to January 2023

12	ARTEMIS I MISSION | © *NASA*
14	EUROPEAN SERVICE MODULE | © *ESA–A. CONIGLI*
15	MARS' FOR METHANE | © *ESA (Data source: CCI Greenhouse Gases project/contains modified Copernicus Sentinel data 2020)*
16	FIRST MTG LAUNCH | © *ESA–M. PÉDOUSSAUT*
17	WEBB VIEWS CREATION | © *NASA, ESA, CSA, STSCI, J. DEPASQUALE (STSCI), A. PAGAN (STSCI), A. M. KOEKEMOER (STSCI); CC BY 4.0*
18	SAFER SPACE | © *HTS*
19	MERCURY TRANSIT | © *ESA & NASA/SOLAR ORBITER/PHI TEAM*
20	A PREDICTABLE ASTEROID | © *ROBERT WERYK*
21	ATOM-SCALE SCAN | © *ESA–REMEDIA*
22	HERA'S TINY RADAR | © *JURA TEAM / UGA*
23	WARMER WINTERS | © *CONTAINS MODIFIED COPERNICUS SENTINEL DATA (2023), PROCESSED BY ESA, CC BY-SA 3.0 IGO*

The backbone of all space activities

25	NEW NORCIA DEEP SPACE STATION | © *ESA/DSA–G. HOBSON*
28–29	ESOC CONTROL ROOM | © *ESA–J. MAI*

February to April 2023

30	TÜRKIYE-SYRIA INTERFEROGRAM | © *CONTAINS MODIFIED COPERNICUS SENTINEL DATA (2023), PROCESSED BY ESA, CC BY-SA 3.0 IGO*
32	BACK TO SCHOOL | © *ESA–P. SEBIROT*
33	A REVOLUTION IN WEATHER FORECASTING | © *EUMETSAT/ESA*
34	HAPPY BIRTHDAY, HUBBLE | © *NASA, ESA, STSCI; CC BY 4.0*
35	TESTING 'ZERO GRAVITY' | © *ESA/NOVESPACE*
36	ESA'S TECHNICAL HEART EXPANDSES | © *A-F. SHEASBY*
37	PRACTICE MAKES PERFECT | © *ESA–H. HANSEN*
38	SPACE HOPPING | © *ESA*
39	HERA GETS TESTED | © *HPS*
40	WORLD CEREAL | © *CONTAINS MODIFIED COPERNICUS SENTINEL DATA (2022-23), PROCESSED BY ESA, CC BY-SA 3.0 IGO*
41	JUPITER MISSION LEAVES EARTH | © *ESA–S. CORVAJA*

ESA's icy moons mission

43	JUICE FAIRING SIGNATURES | *© ESA–M. PEDOUSSAUT*
44	EXPLORING JUPITER AND GANYMEDE (ARTIST'S IMPRESSION) | *© ESA (ACKNOWLEDGEMENT: ATG MEDIALAB)*
47	JUICE'S TEAM AT ESA'S MISSION CONTROL | *© ESA–J. MAI*
	JUICE LEAVES EARTH | *© ESA/JUICE/JMC, CC BY-SA 3.0 IGO*
	JUICE'S LONGEST ANTENNA AWAITS DEPLOYMENT | *© ESA/JUICE/JMC, CC BY-SA 3.0 IGO*

May to July 2023

48	GLOBAL MARS IN COLOUR | *© ESA/DLR/FU BERLIN/G. MICHAEL, CC BY-SA 3.0 IGO*
50	REVOLUTIONISING STORM PREDICTION | *© EUMETSAT/ESA*
51	CHEOPS DISCOVERY | *© RICARDO RAMÍREZ REYES (UNIVERSIDAD DE CHILE)*
52	THE POWERFUL CYCLONE MOCHA | *© CONTAINS MODIFIED COPERNICUS SENTINEL DATA (2023), PROCESSED BY ESA, CC BY-SA 3.0 IGO*
53	WATER-POWERED INNOVATION | *© URA THRUSTERS*
54	READY FOR ASSEMBLY | *© NASA*
55	THE HOTTEST SUMMER | *© CONTAINS MODIFIED COPERNICUS SENTINEL DATA (2023), PROCESSED BY ESA, CC BY-SA 3.0 IGO*
56	OUT OF THE SHADOW | *© ESA/BEPICOLOMBO/MTM, CC BY-SA 3.0 IGO*
57	THE FINAL MISSION | *© ESA/CNES/ARIANESPACE/OPTIQUE VIDEO DU CSG–P. PIRON*
58	GOOD LUCK, EUCLID | *© SPACEX*
59	FAREWELL AEOLUS! | *© ESA/ATG MEDIALAB*

The quest for a sustainable use of space

61	SPACE DEBRIS | *© SPACEJUNK3D, LLC*
62–63	FINAL IMAGES OF AEOLUS DURING ITS BRIEF PHASE AS SPACE DEBRIS | *© FRAUNHOFER FHR*

August to October 2023

66	HUGINN BEGINS | *© ESA/NASA*
68	HERA IS COMPLETE | *© OHB*
69	ARIANE 6 DRESS REHEARSAL | *© ESA/ARIANEGROUP/CNES - OPTIQUE VIDÉO DU CSG*
70	MOROCCO EARTHQUAKE FRINGES | *© CONTAINS MODIFIED COPERNICUS SENTINEL DATA (2023), PROCESSED BY ARISTOTLE UNIVERSITY OF THESSALONIKI AND THE DIAPASON INSAR SERVICE OF CNES INTEGRATED BY TRE ALTAMIRA ON THE GEOHAZARD EXPLOITATION PLATFORM GEP/ESA*
71	A GOLDMINE OF KNOWLEDGE | *© ESA/GAIA/DPAC, CC BY-SA 3.0 IGO*
72	23RD VEGA FLIGHT | *© ESA/CNES/ARIANESPACE*
73	GALILEO'S LATEST ASSET | *© ESA–B. NEJAD*
74	THE LUNAR CAMERA | *© ESA–A. ROMEO*
75	PHOEBUS TESTING | *© ESA*
76	A REVOLUTION FOR ASTRONOMY | *© ESA/EUCLID/EUCLID CONSORTIUM/NASA, CC BY-SA 3.0 IGO*
77	SPACE SUMMIT 2023 | *© ESA–S. CORVAJA*

Pioneering secure communication and beyond

79	NIGHTTIME VIEW OF A PORTION OF THE GLOBE | *© GETTY IMAGES*
80–81	ESA'S OPTICAL GROUND STATION | *© IAC–DANIEL LÓPEZ*
81	OGS TELESCOPE | *© AUSTRIAN ACADEMY OF SCIENCES–THOMAS HERBST*
82	QUANTUM HARDWARE DURING PARABOLIC FLIGHT | *© AUSTRIAN ACADEMY OF SCIENCES–DANIEL HINTERRAMSKOGLER*

Focus on programmes, activities and directorates

86	FOREWORD RENATO KRPOUN | *© SERI*

Science and exploration

93	LISA-INSPIRED ARTWORK | *© ESA, CC BY-SA 3.0 IGO*
94	SOLAR ORBITER | *© ESA/ATG MEDIALAB*
95	EUCLID'S VIEW OF THE HORSEHEAD NEBULA | *© ESA/EUCLID/EUCLID CONSORTIUM/NASA, IMAGE PROCESSING BY J.-C. CUILLANDRE (CEA PARIS-SACLAY), G. ANSELMI, CC BY-SA 3.0 IGO*
97	SPACE MEN AT WORK | *© NASA*

Application

101	EARTHCARE IN SPACE ENVIRONMENT TESTING AT ESTEC | *© ESA–SJM PHOTOGRAPHY*
102	WORLD FIRE ATLAS 2016–2023 | *© ESA*
	SENTINEL-5P DETECTED METHANE PLUMES | *© ESA/SRON*
103	ICE LOSS FROM GREENLAND AND ANTARCTICA | *© ESA/PLANETARY VISIONS*
105	5G/6G IS DRIVING THE FUTURE OF CONNECTIVITY | *© ESA*
	THE JOEYSAT "BEAM-HOPPING" SATELLITE READY FOR LAUNCH | *© ONEWEB*
106	INAUGURAL PRE-COMMERCIAL FLIGHT USING IRIS TECHNOLOGY | *© EASYJET*
	COSMOS PARTNERSHIP PROJECT SIGNATURE | *© ICEYE*
107	SIGNATURE OF CONTRIBUTION AGREEMENT BETWEEN EU AND ESA ON THE EU SECURE CONNECTIVITY PROGRAMME | *© ESA*
109	GALILEO SECOND GENERATION AIRBUS SATELLITE | *© AIRBUS DEFENCE AND SPACE*
111	G2 DUAL LAUNCH VIBRATION TEST | *© ESA–SJM PHOTOGRAPHY*

Space safety and security

114	FUTURE VIGIL MISSION | *© ESA/A. BAKER*
115	ESA'S SPACE WEATHER MISSION - ESA VIGIL | *© ESA*
	FLYEYE TELESCOPE | *© ESA/A. BAKER*
116	HERA ASTEROID MISSION ON SHOW | *© ESA–S. BLAIR*
117	SPACE DEBRIS | *© ESA/ID&SENSE/ONIRIXEL*
119	SIGNATURE CEREMONY | *© ESA–P. SEBIROT*
121	EUROPEAN SPACE SECURITY AND EDUCATION CENTRE (ESEC) | *© ESA–A. MAHIN*

Enabling and support

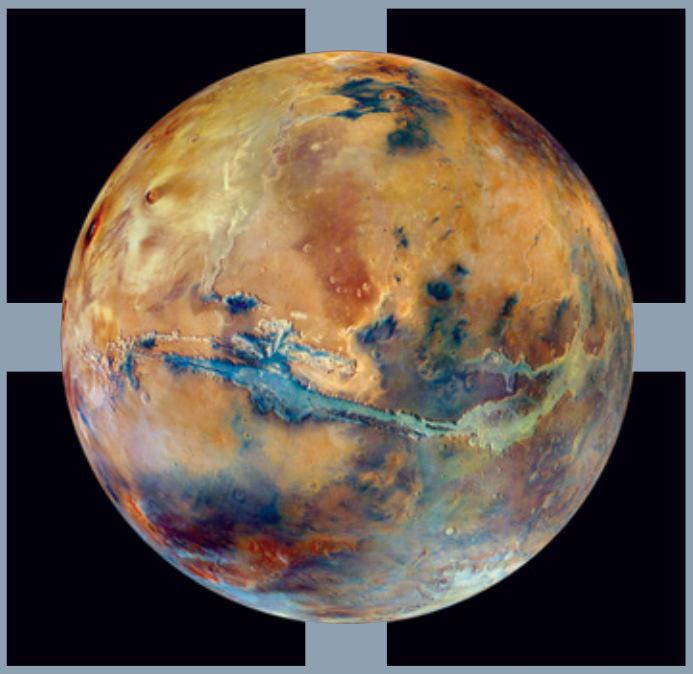
125	ARIANE 6 HOT FIRE | *© ESA–M. PÉDOUSSAUT*
	PROMETHEUS ROARS | *© ARIANEGROUP*
126	ARTIST'S VIEW OF EUROPE'S LAUNCHER FAMILY | *© ESA–D. DUCROS*
	ESA/CNES CSG CONTRACT | *© ESA–M. POLO*
127	ARTIST'S VIEW OF EUROPE'S LAUNCHER FAMILY | *© ESA–D. DUCROS*
128	BEPICOLOMBO'S THIRD MERCURY FLYBY | *© ESA/BEPICOLOMBO/MTM*
129	LOOPY STAR TRAILS SHOW THE EFFECT OF EUCLID'S FINE GUIDANCE SENSOR INTERMITTENTLY LOSING ITS GUIDE STARS *© ESA/EUCLID CONSORTIUM/TAS-I*
	JUICE'S TEAM AT ESA'S MISSION CONTROL | *© ESA–J. MAI*
130	ESA'S MALARGÜE TRACKING STATION | *© ESA/U. KUGEL*
	FINAL IMAGES OF AEOLUS DURING ITS BRIEF PHASE AS SPACE DEBRIS | *© FRAUNHOFER FHR*
131	ESA'S ICE MISSION | *© ESA/AOES MEDIALAB*
	EXPERTS TEAM | *© ESA*
133	ESA ESTEC, ESA LOGO FORMED BY PEOPLE | *© AIRBUS/ESA*
135	HERA INSIDE THE LEAF ACOUSTIC CHAMBER | *© ESA–SJM PHOTOGRAPHY*

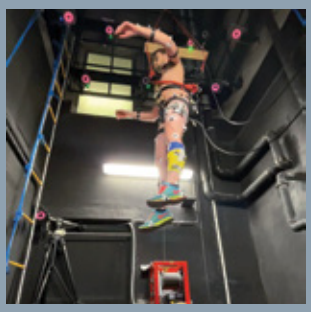
Resources management, corporate activities and external relations

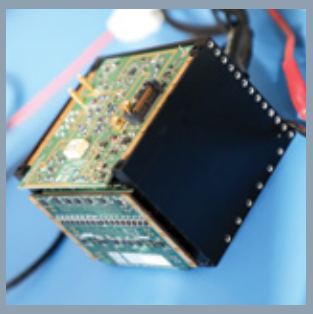
141	ECSECO GENERAL ASSEMBLY OF THE MEMBERS | *© ESA*
153	ESA GREEN AGENDA | *© ESA*
154	SPACE SUMMIT 2023 - GROUP PHOTO | *© ESA - S. CORVAJA*
155	315TH ESA COUNCIL | *© ESA - S. CORVAJA*

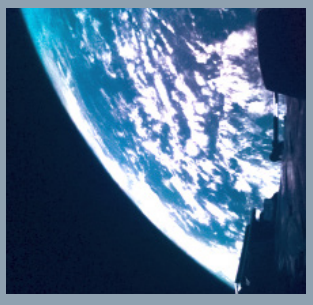
ESA Member States

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









An ESA Production

Copyright © 2023
European Space Agency

www.esa.int