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The German Federal Government's Space Strategy

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Foreword

The Federal Government has established this Space Strategy in order to address challenges of our times and to take account of the growing importance of space programmes and space exploration.

In addition to addressing factors such as a considerably changed geopolitical situation, economic competition, and the new system competition taking place between the major economic blocs, we need to respond to the dramatic changes occurring on our planet and to make use of space programmes' potential in confronting the challenges those changes present. Space-programme technologies hold great potential for applications on Earth, and they can significantly support efforts to achieve sustainability, protect the climate and conserve biodiversity. Importantly, as the level of space activities keeps growing, safe, sustainable space activities are playing a more and more central role.

In recent years, the importance of space for our economic and science sectors; for our security and our actions as a state; and for the daily lives of people worldwide has only continued to grow – and, in fact, space-based infrastructures are increasingly taking their place as part of our critical infrastructures. Consequently, the availability of space-based infrastructures, and of the space-programme technologies needed to build and maintain them, plays an essential role in Germany's and Europe's future viability and sustainability.

As a result, it is vitally important that we work to strengthen relevant cooperation at the European and international levels, and that we carry out national activities aimed at assuring our ability to contribute to and support such partnership. We need to work together to safeguard – and further expand, as necessary – Europe's own political strength and sovereignty. And this applies especially to the whole area of space. In the key areas tied to our sovereignty, we in Germany and Europe need to have our own capabilities, such as capabilities for launching satellites; for protecting communications between satellites and from satellites to ground stations and receivers; and for obtaining real-time information about the current situation in space. Along with our efforts within

relevant research and development programmes underway in Germany, we are working to this end in a European Union framework, as well as in the framework of the European Space Agency (ESA) and the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT), two key agencies of EU Member States. In the process, the German space industry has established itself as a producer and supplier of excellent space technologies.

The space sector has evolved from an area dominated by institutional programmes into a dynamic, increasingly competitive market. Developments in recent years have highlighted the capabilities and resources that the private sector can now make available to institutional customers. We in Germany and Europe want to make the best-possible use of this dynamic economic development in the space sector.

To this end, we want to establish a new framework for fruitful interaction between state programmes and market competition. By succeeding in this endeavour, we will improve our competitiveness, promote additional innovation in Germany's space sector and join with others in protecting Europe's position as a strong global player in space. In addition, we want to bring such added economic strength to our space research. In so doing, we will give Germany and Europe a strategic edge – and create benefits for all citizens, because space-programme research and work can improve living conditions on Earth.

Dr. Robert Habeck
Federal Minister for Economic Affairs and Climate Action

1. New times, new relevance

Image of ring nebula taken by the James Webb Space Telescope

Since the publication of the Federal Government's last Space Strategy, in 2010, human perspectives on climate and space have changed profoundly. In the process, the importance of space programmes has grown enormously, and the requirements for such programmes have become much more ambitious. Space infrastructures now play key roles in many different areas, including the economy, climate action, research, innovation, transport, telecommunications, security and our daily lives.

The limits of available orbital space are already making themselves felt. To ensure that these vitally important resources remain available for future generations, and to reduce negative impacts of space activities, we need to prioritize sustainable, safe uses. In the present strategy, the Federal Government outlines and highlights the importance of space and space applications, and it addresses additional new challenges and requirements in the space sector.

Germany has universities and non-university institutions that pursue excellent research, a broad range of relevant companies, including both established companies and start-ups, and a strong space agency. Also in the space sector, the Federal Government cooperates closely with ESA, EUMETSAT, the EU and international partners. At the same time, the Federal Government is well aware that new times, and a new relevance of space infrastructures, call for new types of action. In areas in which young companies seek to test new technology, the government will seek to support flexible options and innovative approaches, all with a view to meeting emerging needs. Since more and more space technologies are proving to be key technologies, the applications they are making possible need to be made widely available to industry, researchers, administrations and society as a whole. Technical and scientific sectors are urgently seeking to attract skilled workers and experts, and space programmes' power to inspire young people plays a key role in meeting this demand. And we want to encourage both women and men to let themselves be inspired by the potential of space and space activities.

1.1 Importance of space

Space is now of great importance for our economy, society, security and our daily lives, and the spectrum of space-based applications we now rely on is extremely diverse. The magnitude of such importance and diversity becomes clear when we try to imagine our modern lives without any space-based applications:

Suddenly, there would be no communications satellites, and this would directly affect the everyday lives of countless people: There would no longer be any live news and sports broadcasts on TV. Many of the telephone and data links in remote regions would fail, along with many of the interconnections between ships, aircraft and globally distributed Internet of Things (IoT) systems.

Disruptions of global satellite-navigation systems would profoundly affect global travel and the full range of satellite-based logistics for transport and mobility systems. Global value and supply chains would break down, along with their monitoring systems – and this would also affect local food economies and security. Also, the time signals generated with the help of satellites would no longer be available, and yet they are of key importance for the stability of our electricity and mobile communications networks, and for smooth processing of financial transactions, such as in international stock-exchange trading. In short, the absence of such satellites would significantly disrupt our societies and economies.

A lack of satellites for meteorology and Earth observation would seriously affect the quality,

continuity and capabilities of our resources for weather forecasting, environmental monitoring and climate forecasting. Needless to say, the negative consequences for our everyday lives and for our economy as a whole – including such sectors as agriculture, fisheries and forestry – would be enormous.

Unhindered, safe access to space is becoming increasingly central to our security. This is apparent in that much of our civil life depends heavily on satellite communications/navigation and on satellite-based Earth observation systems, and in that many military forces and security agencies rely on space-based services as well. Without the precise situation pictures provided with data from space-based resources, security agencies and civil protection would lack a key basis for the precautions they are charged with taking. In the German National Security Strategy, the Federal Government addresses these needs.

In light of current political and economic developments, the importance of space for our lives in Germany and in Europe, which is outlined in part here, will continue to grow considerably. Still other space-based activities serve to expand the frontiers of human knowledge and to help protect our planet in the long term. Furthermore, space programmes and related efforts are key drivers of innovations in virtually all areas of life. Whether in forward-looking solutions for extreme situations, pushing the envelope of what is technically possible; in space and astronomical research; or in new business models focussing on various Earth orbits and beyond – we need to make full use of space-sector innovation as we compete internationally. At the same time, we need to ensure that our space-based activities are as sustainable and safe as possible – in order to both protect our Earth orbits and to prevent any adverse impacts on life and natural systems on the Earth.

In keeping with the growing importance of space, and of the sector's current dynamism, and in order to play an active role in space-oriented global developments, the Federal Government plans to make its space activities ambitious, needs-oriented and sustainable, and to respond appropriately to the growing challenges in areas such as the resilience and the protection of our space-based systems.

1.2 Trends, challenges and opportunities

Miniaturisation of satellites, which has made the process of launching satellites into space much cheaper and easier, has revolutionised the space sector in recent years. And this trend can be expected to continue in the coming years. In general, space technologies and services have become more accessible for private companies and state actors alike, and the opportunities inherent in providing and using such technologies and services have grown.

Key figures for the sector highlight the explosive growth it is experiencing:

- Globally, state budgets for civil space programmes increased from US$ 36.8 billion in 2010 to US$ 55.3 billion in 2022 (+ 50%).[1]
- The total revenue of the global space sector grew from US$ 277 billion in 2010 to US$ 469 billion in 2021 (+ 70%).[2]

1 Source: Euroconsult Government Space Programs 2022.
2 Space Foundation (2022): Space Foundation, The Space Report (2022).

- In 2010, some 50 countries had space programmes in place. Today, that number has grown to 100 (+ 100%).[3]

- In 2010, a total of 70 launch vehicles were sent into space. By 2022, that number had increased to 179 (+ 155%). The total number of satellites carried by such vehicles increased from von 124 (2010) to 2,500 (2022) (+ 2016%).[4]

- The total number of satellites placed in Earth orbit grew from 3,380 as of 2010[5] to more than 10,133[6] as of the end of 2022 (+ 199%).

- In 2010 some 15,000 objects[7] larger than ten centimetres were orbiting the Earth as space debris. As of June 2023, the corresponding figure had reached about 36,500 (+ 143%). To it must be added some one million objects with sizes ranging from 1 cm to 10 cm and some 130 million still-smaller objects.[8]

These trends underscore the growing importance of space for a range of commercial and state applications – and for action at the national level and political decision-making. Increasingly, private-sector actors are conducting and promoting space-related activities. If space activities are to remain successful and feasible in the long term, it is vitally important that orbital space be used sustainably and safely.

German space activities in Europe

Germany and its European partners want their space sectors to thrive. The key bases for a strong space industry in Germany include the targeted support for space and key technologies provided by Germany's National Programme for Space and Innovation and by the Space Research Programme of the German Aerospace Center (DLR). This support enables the German space industry and research sector to position itself successfully at the national, European and international space-industry levels. Since 1975, the European Space Agency (ESA), an intergovernmental organisation, has served as the backbone of the European space sector. It is a key awarder of contracts to the European space industry. Since 1986, the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT), also a European intergovernmental organisation, has worked in close cooperation with ESA in contracting for and operating Earth observation satellites for weather, climate and environmental monitoring, and in promoting the use of the data they provide. For the German Federal Government, ESA and EUMETSAT are the most important institutions in the European space sector. Alongside the national space activities underway, and the work of ESA and EUMETSAT, the EU, in cooperation with its European Union Agency for the Space Programme (EUSPA), is also playing a strong role in the space sector. In recent decades, and with its Copernicus and Galileo programmes, the EU has created new European infrastructures that have set global standards. In the future, therefore, it will be crucially important to assure the continuity and further development of these programmes. Recently, the EU highlighted its ambitions for its future space activities by publishing the EU Space Strategy for Security and Defence (EU SSSD).

That said, the UK's departure from the EU (Brexit) on 31 January 2020 has left its mark on the European space sector, and now relevant new forms

3 Criterion: At least one satellite in orbit. https://nssdc.gsfc.nasa.gov/nmc/SpacecraftQuery.jsp.
4 AR-OL launch table.
5 https://www.orbitaldebris.jsc.nasa.gov/quarterly-news/pdfs/odqnv15i1.pdf, p. 9.
6 https://orbitaldebris.jsc.nasa.gov/quarterly-news/pdfs/odqnv27i1.pdf, p. 14.
7 https://orbitaldebris.jsc.nasa.gov/quarterly-news/pdfs/odqnv14i1.pdf, p. 12.
8 https://www.esa.int/Space_Safety/Space_Debris/Space_debris_by_the_numbers, as of 27 March 2023; last checked on 11 May 2023.

of association with the UK, which now has third-country status, need to be found. Nonetheless, as an ESA and EUMETSAT member, and as one of the largest contributors to those organisations, the UK remains closely tied to the European space sector.

Geopolitical changes

The scope and economic weight of global activities in the space sector have increased significantly. At the same time, the geopolitical environment has changed substantially, technical capabilities in space industries have improved and requirements pertaining to space-based services have expanded. The U.S. continues to be the German Federal Government's most important non-European partner. Other nations, such as Canada, Japan, the Republic of Korea, India, Australia, New Zealand and Singapore, have been expanding their space activities continually for years now, and are attractive partners for cooperation.

China has greatly expanded its space activities (in the civil sector, but especially with regard to military applications). China and the U.S. are now engaged in a new competition for space leadership that includes their astronaut programmes and their efforts to return to the moon. Bilateral cooperation is no longer possible with Russia, in light of its war of aggression, in violation of international law, against Ukraine.

Access to space

The availability of launch systems, and of the access to space that they provide, is of strategic importance for both Germany and Europe. The Ariane 5 programme, with over 100 launches in the past 20 years, has been a story of success in European space cooperation. Following the Ariane 5's most recent launch, in July 2023, the European space-transport sector is facing major challenges, including a need to revamp its cost and organisational structures, however. In the short and medium terms, the Ariane 6 and Vega C launch vehicles will provide independent launch capacities for Europe. The goals with regard to future European launch services including ensuring that such services are reliable, are oriented to the needs of the participating institutions, and that they are cost-effective and available at competitive prices. Also, the ground-based production, testing and launch infrastructures needed as a result, in addition to the vitally important Guiana Space Centre (Europe's Spaceport) in Kourou, have to be refined and expanded in keeping with future operational concepts.

The current momentum in the European market for launch services has the potential to reduce the costs for future launch services, and to open up new commercial opportunities for German industry, including German microlauncher companies. As this happens, it will be important to prevent adverse environmental impacts.

Global data for global challenges

Political responses to global challenges need to be based on information that is as comprehensive and precise as possible. In keeping with this need, satellites of institutional and commercial providers are providing growing quantities of data, services and other products. In addition, analysis and provision of satellite data, and of products based on such data, are areas that offer significant opportunities for public administrations, public-sector services, science and the business sector. Furthermore, value creation in the space sector's downstream markets is an area of great promise for German industry and innovators.

Earth observation data, and navigation services, play important roles relative to environmental protection; weather and climate forecasts; food

security; provision of support in crisis situations; civil protection; police investigations and operational planning; military reconnaissance; sea rescue; air and railway navigation; financial transactions; efforts to achieve sustainability in the agriculture, fisheries and forestry sectors; and monitoring of climate changes and the related impacts. With their importance for all these areas, satellite data benefit society as a whole. The federal administration has developed considerable expertise in handling satellite data, as well as many processes that make use of such data. More and more government agencies regularly use satellite data in their work.

Satellite communications play a key logistical role in responses to natural disasters and crisis situations; in emergency response situations; in law enforcement; and in peacekeeping operations. Satellite-based data and communications links are especially indispensable in situations in which terrestrial infrastructure has been destroyed or is completely lacking to begin with.

Sustainability in space

Mega-constellations of satellites in low Earth orbit open up innovative new applications in satellite navigation, satellite communications, meteorology and Earth observation. On the other hand, because the numbers of satellites in orbit, and the quantities of space debris circling the Earth, have increased sharply, the risk of collisions and of restrictions on satellite operations has increased sharply as well. The increasing light and radio emissions emanating from satellites are interfering with viewing of the night sky – and thus having a negative impact on astronomical observations. The key measures that need to be taken in order to protect satellite systems in crowded orbits, and to support sustainable, safe use of orbital capacities, include ongoing identification and monitoring of the orbits of objects in space, including space debris; development of long-term strategies for preventing space debris; and ongoing assessment of the situation in orbital space.

Of keen interest for experts

In addition to facing challenges in connection with supply-chain disruptions and price increases, Germany's technology sectors are increasingly finding themselves in cross-sector and global competition for the best minds. The space sector needs highly trained personnel, and a society open to new technologies, in order to thrive. The types of personnel needed in the sector, and in the application areas based on it, include scientists, skilled workers able to work in areas that rely heavily on engineering expertise, IT specialists for software-driven applications, and specially trained personnel in public administrations. The fascination that space programmes and the cosmos can exert is especially effective in prompting young minds to take an early interest in STEM (science, technology, engineering, mathematics) subjects and careers. Consequently, it figures significantly in efforts to address overall shortages of skilled labour.

1.3 Status of the German space sector

The space sector, and the high-tech developments that emerge from it, is among the economic and research areas that make Germany "future-proof." In keeping with the growing importance of space-related activities, the majority of the Federal Government's federal-level departments promote and make use of such activities, with varying emphases. The activities involved include research and development (R&D), the establishment and operation of space infrastructures and user-oriented provision of space-based data, services and applications.

Since 2010, the Federal Government has increased the volume of its budgets for civil space programmes by nearly two-thirds. The German Aerospace Center (DLR) plays a key role in implementation of such funding. Other actors include German Länder (states); more and more of them are now involved in the German space sector.

In contrast to the global trend toward commercialisation of space activities, the German and European space industries are focussed strongly on institutional users. In recent years, up to about one-fourth of the German space sector's annual revenue has been generated in the private market, however. Along with a few major corporations, more than 400 small and medium-sized enterprises (SMEs) have played an important role in this turnover.

Also in recent years, an active NewSpace Community, with a first group of venture capitalists, has emerged in Germany. NewSpace marks a new economic approach to the execution of space activities. It is characterised by an orientation to commercial customers, a more-pronounced role for private investors, a high pace of innovation and a high risk tolerance. Although NewSpace is often associated with start-ups, and start-ups are important drivers in the community, companies of all sizes and ages can pursue NewSpace business models. According to the BDI, the umbrella organisation of German industry and industry-related service providers, a total of 125 space-oriented start-ups were active in Germany in 2021.

The space sector's industrial basis is supported by a strong, broad-based, world-class research sector. Many German aerospace companies cooperate closely with excellent universities, and with non-university research institutions such as the DLR and Fraunhofer-Gesellschaft. In addition, research institutions are increasingly emphasising commercialisation of space technologies and are continuously adding to their know-how and competence in forward-looking key technologies. German researchers are among the world's best in key areas such as Earth system and climate impacts research, communications, navigation, quantum technologies, robotics, space exploration and research carried out under space conditions.

The areas of growth in the German space sector include application-oriented research on fast, cost-effective production technologies – for example, in the context of Industry 4.0 – and innovative data processing technologies. German SMEs have an outstanding reputation as suppliers of components, subsystems and payload technologies, and they are thriving in international markets – increasingly, also as systems integrators. The National Programme for Space and Innovation is supporting German industry and researchers in developing key technologies and capabilities for competitive national and international markets, and in maintaining and expanding space-sector competencies in Germany. In the DLR's German Space Operations Center (GSOC), Germany has outstanding national capabilities in areas such as commissioning of satellites; regular satellite oper-

ations and satellite formation flying; and development of operational concepts for complex satellite missions and constellations.

In addition, the Center implements major space programmes and missions via European and international cooperation. ESA assumes responsibility for development and execution of civil space programmes in the areas of space research, Earth observation, astronautics and launch vehicles, and development of basic technologies – for example, in the areas of satellite communications and navigation. In the area of Earth observation, Germany works in the EUMETSAT framework on behalf of independent European space infrastructures. In addition, Germany also takes an active role in the EU's space and research programmes, which function as initiators and operators of space infrastructures for Earth observation and satellite navigation (and, the future, for satellite communications) and promote research and innovation in the space sector. Germany also serves as an important location for European space activities. Germany hosts outstanding European space institutions and their operations, for example, such as ESA's European Space Operations Centre (ESOC) and EUMETSAT's facility in Darmstadt.

Via its ESA astronauts Alexander Gerst and Matthias Maurer, Germany has also had a strong presence on the International Space Station (ISS). With their research and their effective public communication, they have helped shape public perceptions of space activities in Germany and brought Germany additional international recognition. The new astronaut class presented by ESA in late 2022 includes two German women, Nicola Winter and Amelie Schoenenwald. The two are the first German women to be part of ESA's Astronaut Reserve – and thus are important role models for girls and young women taking an interest in space activities.

2. Areas of activity for German space policy

Control room of the German Space Operations Centre (GSOC) in Oberpfaffenhofen

Germany has a successful space sector. The country's space sector is undergoing major changes, however, and it finds itself facing global dynamic trends toward commercialisation and digitalisation of space activities, in addition to a range of geopolitical changes. The Federal Government has identified nine key areas of activity that can enable it to turn these challenges into successes for German and European space activities.

- European and international cooperation
- Space as a growth market – high-tech and NewSpace
- Climate change, resource protection and environmental protection
- Digitalisation, data and downstream activities
- Security, strategic options and global stability
- Sustainable, safe use of space
- Space research
- International space exploration
- Space activities in the context of recruiting and attracting talent

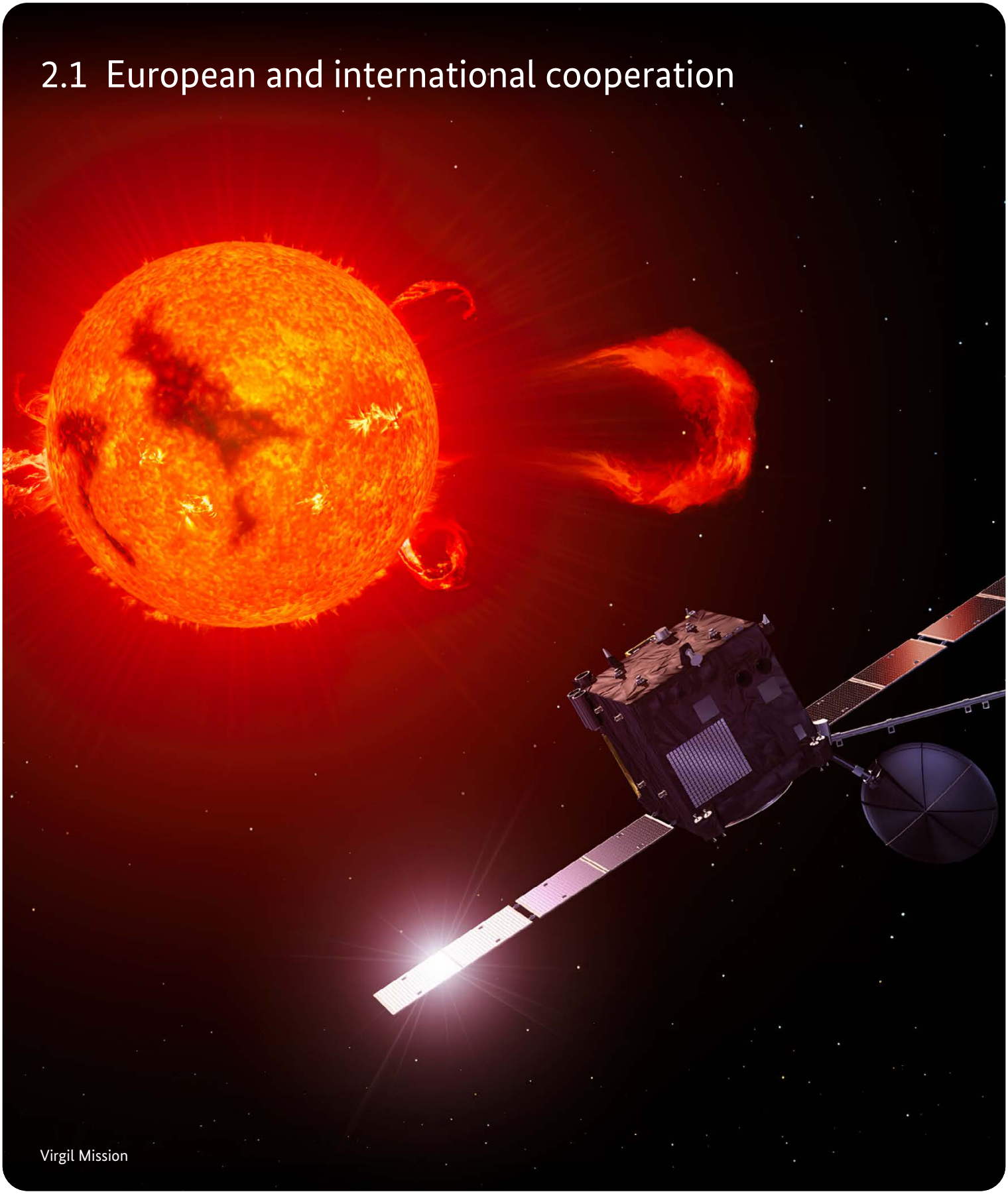
In the present strategy, these areas of activity are used as a basis for identifying and defining the strategic, political, socioeconomic and scientific goals of the Federal Government's space policy, for a target horizon of 2030. As a result, the Space Strategy supports the aims of Mission V of the Federal Government's Future Research and Innovation Strategy – especially those calling for strengthening astronautics and for exploring, protecting and sustainably using space.

The aims for the various areas of activity within the Space Strategy will be achieved via measures and resources of the ministries involved with space activities. The key federal ministries in this group include the Federal Ministry for Economic Affairs and Climate Action (BMWK), the Federal Foreign Office (AA), the Federal Ministry of Defence (BMVg), the Federal Ministry for Digital and Transport (BMDV), the Federal Ministry of the Interior and Community (BMI) and the Federal Ministry of Education and Research (BMBF). At the same time, all other Federal Government departments are in a position to profit from intensified use of space services and will contribute to the implementation of the Space Strategy. Networking of Federal Government departments with regard to matters of space activities and their applications is to be intensified.

Each of the nine areas of activity includes key projects, which comprise content of special importance within their relevant areas of activity. The Federal Government plans to begin implementing such projects within the current legislative period – and thereby act quickly to address key challenges.

For implementation of this Space Strategy, it will be necessary to expand coordination between the Federal Government and the Länder; between the Federal Government's various departments (including their divisions); and between public and private entities within the policy area of space. To support implementation – especially implementation of the key projects – the Federal Ministry for Economic Affairs and Climate Action (BMWK) will carry out relevant monitoring, in the role of lead ministry for space activities. In the process, it will draw on, and cross-check against, efforts for implementation of additional Federal Government strategies having to do with space in one way or another. Such strategies especially include the National Security Strategy and the future security strategy for space (Weltraumsicherheitsstrategie) that is to be derived from it; the Future Research and Innovation Strategy; and the Digital Strategy, along with the future national applications strategy that is to be derived from it. The various government departments will support implementation of the Space Strategy in keeping with their own responsibilities and their available resources under their own budgets. Where concrete measures, or follow-on future measures, lead to federal budget expenditures, they will be subject to the availability of funding and/or personnel.

2.1 European and international cooperation



Virgil Mission

Along with national programmes and activities, European and international cooperation – in particular, cooperation within the ESA, EUMETSAT and EU frameworks – is the basic pillar for successful implementation of German space policy. Global challenges such as climate change and climate-change mitigation and adaptation, design and maintenance of sustainable space programmes, and the growing volume of space debris, and issues such as the growing relevance of space security, can be effectively addressed only via targeted cooperation at the European and international levels. In addition, certain types of technology development and research projects are also best carried out via cooperation. Major space missions, in particular, are most feasible at the international level.

As an intergovernmental organisation, ESA will continue to play a key role in this context, as the primary aggregation of expertise within the European space sector. ESA's major joint research and development programmes facilitate targeted implementation of national priorities that would otherwise exceed the bounds of national budgetary resources. With its involvement in ESA – with personnel, and as the current largest contributor to ESA – Germany is safeguarding its leading technological position and the competitiveness of the German space industry. In 2022, Germany assumed the chairmanship of the ESA Council at Ministerial level, and this has heightened the Federal Government's sense of responsibility for moving ESA forward, in cooperation with the ESA member states.

For many years now, EUMETSAT has been making a globally recognised and indispensable contribution to global space-based Earth observation. In addition to carrying out its own satellite programmes, EUMETSAT operates a range of satellites and instruments for the EU's Copernicus Programme. Ongoing satellite-based measurements play a vital daily role in the areas of weather forecasting, disaster prevention and management, climate and environmental monitoring, and (the energy) industry. As EUMETSAT's largest current contributor, and as its host state, Germany plans to continue working with the EUMETSAT member states to further strengthen and develop the organisation, which serves as the European backbone of operational Earth observation.

The European Union plays a central role in this context, both as an operator of space infrastructures and as a customer for services. Via the EU's Galileo, EGNOS and Copernicus programmes, and its future IRIS2 programme, and via the activities of other European actors, such as EUSPA, EUMETSAT and the European Defence Agency (EDA), strategically important technologies and capabilities have been, and are being, developed and improved. These players also function as important customers for the European space industry. The EU also coordinates activities for space-situation evaluation. In addition, in its Horizon Europe funding programme for research and innovation, it funds space research oriented to the EU's space-based systems and services, also with the explicit aim of promoting synergies between space technologies and key industrial technologies. Furthermore, in the framework of the European Defence Fund (EDF), and in the Fund's "Space" category of action, Germany is availing itself of its opportunity to cooperate on development of defence-relevant space technologies, and thereby to help strengthen Europe's technological industrial base.

Via its involvement in relevant bodies in intergovernmental organisations, such as the ESA Council, the EUMETSAT Council and the Council of the European Centre for Medium-Range Weather Forecasts (ECMWF), Germany exercises its responsibility, and its influence, with a view to representing its national interests within joint European processes.

In addition to its active partnerships in ESA, EUMETSAT and the EU, Germany also cooperates with partners in the context of bilateral and multilateral efforts, such as the Franco-German MERLIN climate mission, which it finances via its national space programme, and the GRACE Gravity Recovery And Climate Experiment underway in cooperation with the U.S. Germany places priority on remaining able to function as a reliable partner, on an equal footing. For Germany, bi-national and multinational cooperative efforts in the space sector play an indispensable role, because they facilitate major space programmes, both technically and financially, and because they enable Germany to further enhance its technological and economic options. Since 2010, German companies and research institutions have contributed to numerous major international missions that, overall, have yielded important findings in the study of our solar system and of the universe. These efforts include the Jupiter Icy Moons Explorer (JUICE) mission; the Rosetta comet mission, including the German (DLR) Philae lander; and the Mars Express mission to Mars.

Ongoing international cooperation plays an essential role in many different global research and application projects. The United Nations is an important forum for international cooperation on matters pertaining to space. As part of its efforts in this regard, the UN focuses on measures for sustainable, safe use of space, with a view to ensuring that future generations have access to space. Such measures especially include international provisions for minimisation of the risks from space debris, and for traffic management in space, as well provisions pertaining to activities on celestial bodies and on use of their resources. With its 2015 resolution "A Global Geodetic Reference Frame for Sustainable Development," the UN General Assembly recognised the importance of a globally coordinated geodetic infrastructure as a basis for precise navigation in space and on the Earth's surface. In 2023, the G7, under its Japanese Presidency, acknowledged the UN's space research activities.

Aims and measures:

- Germany is working to ensure that **ESA** retains its independent status as a space agency for its member states. ESA should be strengthened for the future in its role as a provider of European space systems and technologies. Germany supports ESA's ongoing development, with a view to ensuring that ESA remains able to address challenges with the necessary expertise, efficiency and agility.

- Germany is working to ensure that **EUMETSAT** retains its important role in provision and support of applications based on Earth system observation and modelling. EUMETSAT's flexibility, efficiency and innovativeness should be safeguarded and strengthened.

- We support a **clear distribution of roles** between ESA, EUMETSAT and the EU. In this regard, and in accordance with the principle of subsidiarity, the aim must be for the EU to assume the roles of both operator of/customer for major public-sector infrastructures.

- European space programmes should support **Europe's technological and strategic sovereignty**. Excellence and competitiveness are the pillars of any capability to contribute to international projects.

- We are working to ensure that **ESA**, **EUMETSAT** and the **EU** award public contracts in a manner that strengthens European competition, promotes innovation and, where possible, leads to sustainable use of space and promotes sustainable development on the Earth. In the process, it needs to be ensured that tendering processes remain open to SMEs and start-ups.

- Germany views both the continuation of established partnerships and the creation of new partnerships as keys to successful European space policy. In addition, Germany seeks to consult closely with other **ESA**, **EUMETSAT** and **EU** member states that are active in space or that are considering become active in space.

- We want to expand **international cooperation and strategic partnerships** with selected partners, including partners outside of ESA, EUMETSAT and the EU, with the aims of reducing technological and economic dependencies on certain key technologies and facilitating joint research activities. To this end, we are strengthening the development of bilateral and multilateral cooperation between Germany and important partner countries.

- By creating joint structures, international cooperation contributes to security preparedness. With its technological developments and capabilities, Germany is enhancing its **effectiveness as a partner**.

- Also, and in an international context, we want to use our bilateral and multilateral cooperation in support of joint interests and to achieve greater **freedom of action**. In this sense, Germany is also actively involved in the U.S.-initiated Artemis Accords, which are principles for cooperation on exploration and use of the moon and other celestial bodies.

- International cooperation in this context supports countries that are seeking to build space programmes, by enabling them to participate in development of the global space economy and of cross-sectoral use of space data.

- Internationally, Germany is working to help bring about binding regulations on the sustainable use of space.

- In international institutions such as the UN Committee on the Peaceful Uses of Outer Space (COPUOS), Germany is taking part in the development of an international legal framework for space activities, and it is facilitating agreements on joint guidelines, standards and norms for safe, sustainable space exploration and use – including exploration and use by future generations.

- Germany supports the Global Geodetic Centre of Excellence (UN-GGCE), which was established in mid-2023 at the Bonn UN Campus (with financing, initially, until the end of 2025). In so doing, it is playing a central role in efforts to establish the geodetic infrastructure and ensure it has a long-term future.

- Germany is supporting the temporary **ECMWF Bonn facility**, with a view to assuring the Centre's continuing function and excellence after Brexit – and, thereby, to assuring proper implementation of the EU's Copernicus and Destination programmes.

KEY PROJECT:

(1) European Launcher Competition

Unhindered, independent access to space is a key element in Europe's strategic sovereignty. It thus plays an indispensable role in implementation of our political, economic and societal goals in connection with space programmes. The Ariane 5 system has long provided Europe with its own independent access to space. During its service life, this European heavy-lift launcher provided key services, including the widely noted launch of the James Webb telescope, and its successful last launch, with Germany's Heinrich Hertz communications satellite and France's Syracuse 4B satellite on board. In the coming years, the Ariane 6 system will make important contributions to Europe's access to space. Germany is supporting near-term commissioning of the Ariane 6 system, and it plans to support its regular operations.

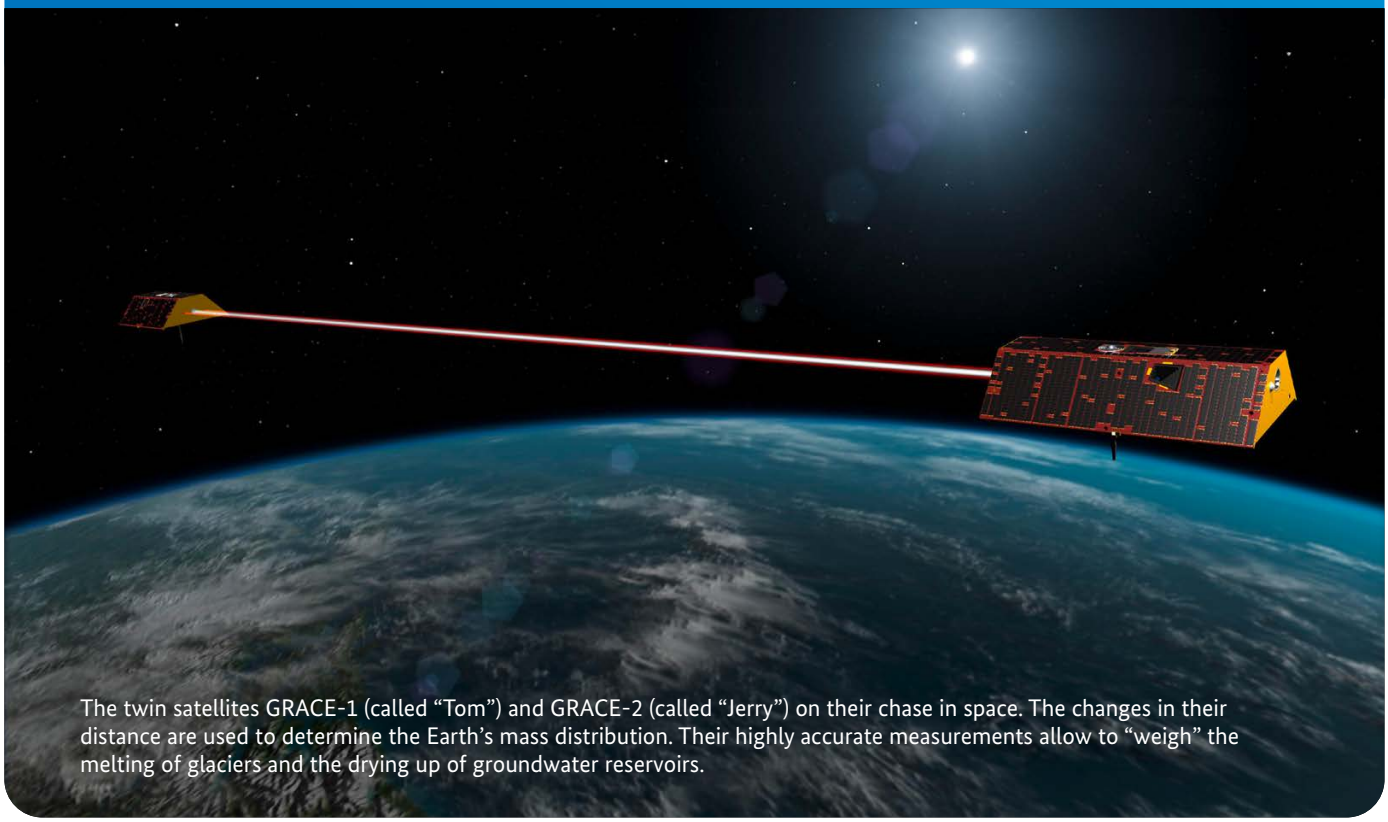
In today's new global space environment, we urgently need a new and viable approach in the development and procurement of launch services in Europe – an approach emphasising greater intra-European competition between private companies. In short, we need a paradigm change in the development and procurement of launch services in Europe. In keeping with this need, we are working within ESA on behalf of a European Launcher Competition aimed at facilitating a competition-based approach to launch-vehicle procurement. In doing so, we are preparing the way for efficient, independent access to space, obtained on the basis of fair competition. In the process, sustainability principles will be applied throughout the entire life cycle of the system, from the development and production of the rocket to sustainable ground operations and sustainable in-flight operations. This effort will make it easier to pursue innovative solutions and operational concepts, including the reusability of infrastructures and components, and to develop a feasible overall concept for Europe in this area. The extensive know-how available from new and established actors, and in Europe's excellent science sector, provides an ideal basis for taking such a new approach in Europe.

KEY PROJECT:

(2) Participation in international missions

International cooperation enables Germany to participate, both scientifically and technologically, in missions that would otherwise not be possible in a purely national framework or even in the framework of a European alliance. For German industry, such cooperation opens up new markets for relevant cutting-edge technologies, and makes it possible to remain attractive as partners for other nations that are leading space powers. In addition, such cooperation helps German research institutions remain able to carry out research at the highest possible standards.

Numerous partner countries are making efforts to combat climate change and address its impacts. This is opening up good opportunities for bilateral and multilateral projects in the areas of Earth observation, climate monitoring and environmental monitoring. Via the GRACE mission, which is being carried out in cooperation with NASA, we are expanding our worldwide leading position in space activities. In addition to Earth observation missions aimed at improving our understanding of the Earth system, our thematic focus in international missions includes science missions for exploration of outer space. One example of such a mission is the Japanese-German DESTINY+ mission, which will explore the asteroid 3200 Phaethon. Its launch is scheduled for 2024.



The twin satellites GRACE-1 (called “Tom”) and GRACE-2 (called “Jerry”) on their chase in space. The changes in their distance are used to determine the Earth’s mass distribution. Their highly accurate measurements allow to “weigh” the melting of glaciers and the drying up of groundwater reservoirs.

2.2 Space as a growth market; high-tech and NewSpace

Small satellites as driving force for the dynamic space market of the future

Worldwide, the space sector is undergoing major upheavals. With costs decreasing sharply, space has become accessible for numerous new actors, as well as for "NewSpace" business models. According to estimates, the value of the global space market will exceed US$ 1.1 trillion by the year 2040.[9] NewSpace marks a new economic approach to the execution of space activities. It is characterised by an orientation to commercial customers, a more-pronounced role for private investors, a high pace of innovation and a high risk tolerance. Although NewSpace is often associated with start-ups, and start-ups are important drivers in the community, companies of all sizes and ages can pursue NewSpace business models.

To be well-positioned for international competition, German space companies need attractive basic conditions. Efforts to shape such conditions should be aimed at facilitating a space market oriented to competition and innovation, a market in which private capital plays an important role alongside the public sector.

To properly address the market's dynamic trends, and the needs of young companies seeking to establish themselves in the market, it is necessary to use the entire available repertoire of funding instruments – and to expand it as appropriate. For example, use of functional specifications for tenders gives companies opportunities to capitalise on their agility. Approaches involving "anchor customers" can provide added entrepreneurial security, while also facilitating access to private capital.

Another important basic condition for companies in international competition is the availability of a complete financing chain, meaning a chain that includes venture capital and that reaches from the point of start-up to the point of any market success. The German venture capital market has developed considerably in recent years, in part due to the Federal Government's broad, successful range of instruments for start-up financing, with instruments that also benefit companies in the area of NewSpace. Germany now has a globally noted and recognised economic ecosystem comprising investors, start-up founders and the science community. The Federal Government's aims in connection with its start-up strategy include bringing in capital from German and European investors, especially in late-phase segments and, thus, in major rounds of financing. Germany's well-established system for early-phase support, with ESA Business Incubation Centres focussed on space activities, is being expanded to include suitable instruments, open to all types of technology, for the pre-start-up phase (Start-ups from Science (EXIST)), as well as federal investment instruments for the growth phase. The HTGF (Hightech-Gründer-Fonds) fund, a seed investor for high-tech start-ups, and the "Deep Tech and Climate Fonds," which was launched in 2023, have considerably expanded the range of available venture capital for start-ups, including start-ups in the space sector. In the same context, the European Tech Champion Initiative must be also be mentioned. In it, Germany alone has made one billion euros available for investments in European funds. With its start-up strategy, the Federal Government is also strengthening the start-up ecosystem in Germany and Europe overall. Start-ups in the aerospace sector are also profiting from the resulting improved basic conditions.

Transfer of know-how and technology from German space research both benefits the space industry itself and enables numerous other sectors and application areas to profit from high-tech developments from the space sector. At the same time, the space industry learns from other sectors, and it makes use of new technologies to become more

9 Morgan Stanley Research, Space – Investment Implications of the Final Frontier, 7 Nov. 2018, https://www.morganstanley.com/ideas/investing-in-space.

effective and efficient. DLR researchers and the Federal Government's INNOspace initiative promote technology transfer – through intersectoral networks, for example – and promote commercialisation of space activities that reaches outside of the bounds of space-related activities pure and simple.

European space activities, whether institutional or commercial, depend on having a cost-effective, independent European access to space. In Germany, as in other countries, the growing worldwide market for launch vehicles has brought forth start-up companies seeking to establish themselves in this market segment with the help of private investments, innovative technical solutions and overall agility. In keeping with Germany's successful commitment within ESA, such young companies are being supported via an anchor-customer approach. In the European launch-vehicle market, plans call for private companies to play a more and more important role; this is to be promoted via competitive tendering, for launch services, oriented to specific needs and to sustainable development criteria.

For the dynamic, emerging space market, small satellites offer a way of meeting many different types of space-related requirements cost-effectively – and quickly, when so required. As a result, they offer a pathway to many new types of business ideas for space applications. The Federal Government is facilitating this trend via the NewSpace Small Satellite Initiative, which was launched in 2021 and is designed to support development of a relevant complete, upstream/downstream value chain in Germany, and to create a balanced competitive framework, taking account of security and sustainability aspects, for companies operating in Germany. Options for development projects in the space sector are also being provided via EU funding.

Aims and measures:

- We are working on behalf of **attractive basic conditions, and of an innovation ecosystem for German space-sector players** in which major corporations, SMEs, start-ups and research institutions can all play a role, and which is oriented to the goal of achieving a resource-conserving, low-emissions value chain.

- We want German companies to be able, by making full use of their outstanding technological resources, to successfully position themselves within the international competition in the **value chain for small satellites and microlaunchers**.

- We want to support **space-sector start-ups** in developing successful new types of financing, especially from private sources, as well as in acquiring public-sector funding.

- We are promoting increasing use of the **anchor-customer principle** in the framework of ESA and EU tenders.

- We want to promote use of new, **competitively oriented European models for procurement of launch services**, with a view to ensuring that Europe's access to space is independent, reliable and cost-effective.

- In the process, we are intensifying cooperation between ESA and other innovation actors, such as the Federal Agency for Disruptive Innovation (SPRIND) and the German Federal Armed Forces' Cyber Innovation Hub (CIH).

- We want to make better use of the flexibility inherent in our models for tendering, in order to be able to reach a larger group of companies. This can be expected to promote competition and enable products to become available more quickly, at lower prices.

- In addition, we are strengthening civil-military cooperation, with the aim of creating joint-use synergies in the provision and operation of space infrastructures.
- Also, at research institutions involved in space research, we are efficiently strengthening transfer to industry.

KEY PROJECTS:

(3) Small Satellite Initiative

Small satellites are now driving the emerging space market, and offering major opportunities for the German space industry – especially for start-ups. For this reason, we are moving the Small Satellite Initiative forward, with a view to preparing the way for a complete relevant value chain in Germany. German SMEs and start-ups are being supported in achieving good competitive positions in this market, especially with regard to the development of innovative technologies and services. Research institutions and universities are also being taken into account in this connection in their roles as innovation drivers and incubators for NewSpace approaches.

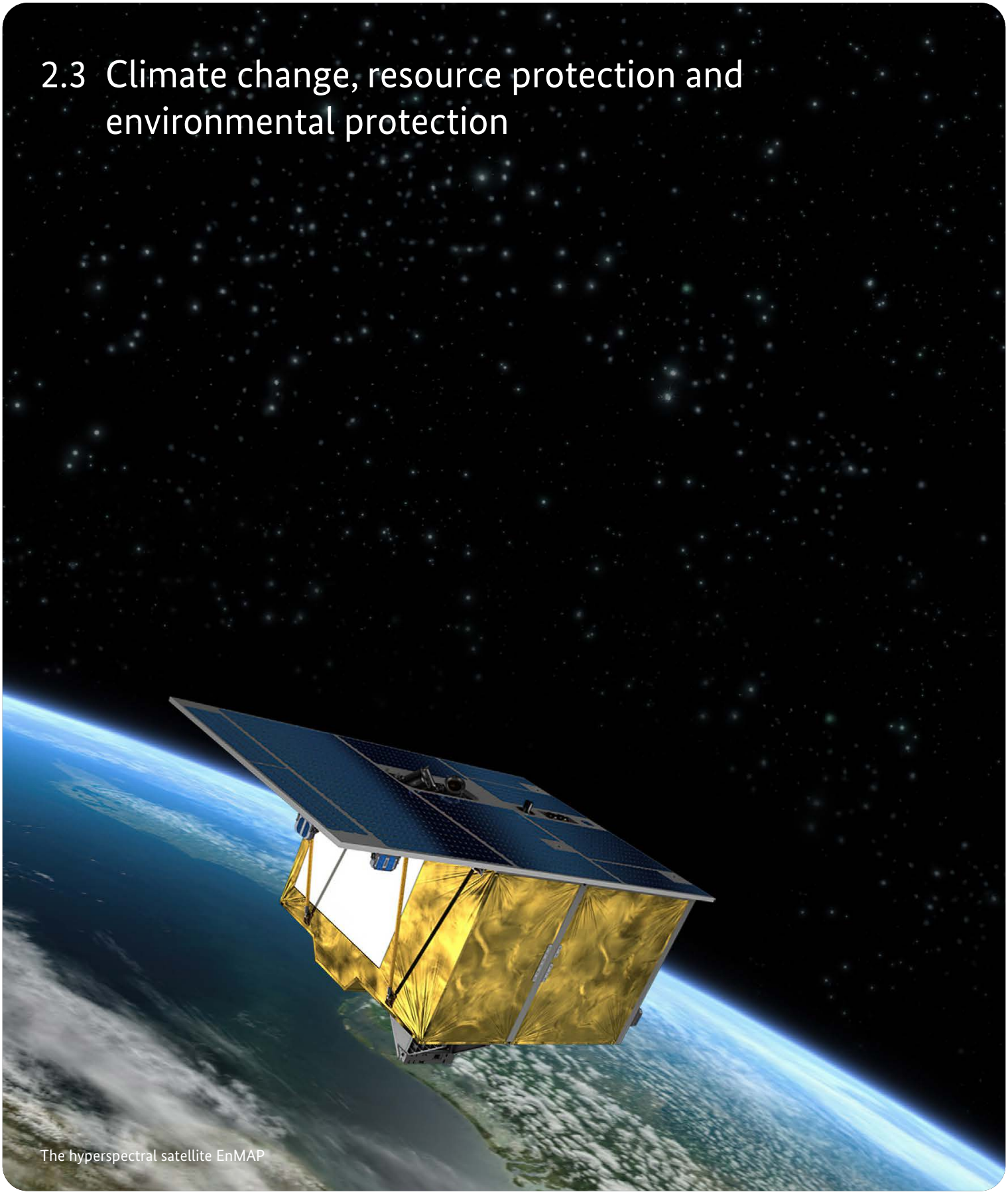
(4) Space-Innovation Hub

Interaction between a) public-sector consumers and b) providers of space services needs to be intensified. Procurement processes need to become more innovative and transparent, and use of synergies needs to be intensified. To address these needs, the Federal Government plans to initiate a special platform, via the German Space Agency. The platform, a Space-Innovation Hub, will serve as a point of contact for the NewSpace sector, for development of ideas for innovative projects and implementation options, in cooperation with civil and military actors.

Microlauncher competition

In May 2020, the German Space Agency, housed within the German Aerospace Center (DLR), started a microlauncher competition, with sponsorship funding totalling 25 million euros for German start-ups that are developing microlaunchers and seeking to operate them commercially. During the two-year term of the competition, which was open to up to five companies, a jury of experts selected two winners. Now, the two winners will receive funding for the final qualification phase of their launcher systems, including the execution of two demonstration flights each, scheduled to take place in the period 2023-2024. The aims of the competition are to promote a) the development of commercial, cost-effective access to space, and b) truly viable business models in the microlauncher sector.

2.3 Climate change, resource protection and environmental protection



The hyperspectral satellite EnMAP

If there had never been any space programmes, we would now have a much less clear understanding of climate change, and of the crisis it is unleashing. Satellite-based Earth observation provides the data we need in order to monitor climate changes, climate-change impacts, requirements for adaptation to climate change, and our environment as a whole.

Climate change is a global phenomenon, affecting people worldwide, and Germany is giving high priority to efforts to mitigate it. It is doing so, for example, in the context of the EU's Green Deal and of the Paris Agreement on climate, both of which Germany supports. Space programmes play an indispensable role in implementation of relevant measures. For example, they provide key data for fact-based decisions on climate action and on protection of biological diversity, and for effective, efficient management of climate change adaptation. Also, space-based systems facilitate monitoring of compliance with climate-action agreements, as well as reporting relevant to such agreements. Remote-sensing data, with high chronological and spatial resolution, play a decisive role in environmental and resource conservation. They are used in monitoring of ecosystems, land use and sealed soils. For example, they yield data on the condition of forest and peatland ecosystems, data that support conservation and renaturation measures. Satellite data also support transitions to sustainable, climate-adapted practices in the agriculture, forestry and fisheries sectors. For example, they facilitate precise determination of fertiliser and plant-protection requirements – and, thus, more-precise application of fertiliser and plant-protection products.

Furthermore, space-based resources are supporting our energy system transformation, which is oriented to a full transition to renewable energies. As a result, they are supporting our entire economy's ecological transformation. In addition, satellite-based data provide key indications relative to productive selection of sites for, and optimised operation of, solar and wind energy systems. Because active research in this area is bringing about continual improvements, the importance of space programmes for the energy sector will continue to increase.

From the perspective of the Federal Government, therefore, the long-term capabilities of European Earth observation programmes are of essential importance. Since 2010, the number of active Earth observation satellites in orbit has increased more than fourfold. The start of operations of the EU's Copernicus programme was of special importance for Europe and Germany. The European Copernicus system has been fully operational since 2014, and it is continually being improved. Thanks to the high-speed European Data Relay System (EDRS), which includes optical inter-satellite links, the Copernicus satellites can transmit their data to the Earth in near real-time. With both the EDRS and Copernicus itself, Europe has set standards worldwide. In addition, the Copernicus programme's policy of free/open data access has led to an enormous increase in usage by both institutional users and commercial downstream providers.

In the area of meteorological satellites planned and operated by EUMETSAT, vigorous development of new generations of polar-orbit and geostationary-orbit satellites, with a wide range of improved instruments, is underway. The new satellites will provide data of essential importance for weather forecasting and for climate and environmental monitoring. The application programmes operated by EUMETSAT and its member states include Satellite Application Facility on Climate Monitoring (CM-SAF), which provides climate data on a long-term basis.

Also, both the EUMETSAT meteorological satellites and the Copernicus-programme satellites provide data that support maritime- and air-transport safety, disaster management in connection with extreme weather events, and climate monitoring. They thus also provide a basis for planning and decision-making in weather-sensitive and economically important sectors. In the area of satellite-based climate monitoring in particular, Germany has achieved a leading position, a position that should be maintained and expanded. The ESA research satellites contribute significantly to the preparation of operations of satellites such as those described above. EarthCARE (to be launched in 2024), for example, will provide new insights into the interactions of aerosols and clouds in the atmosphere, and thus decisively improve future weather and climate forecasting.

The TerraSAR-X and TanDEM-X satellites, which carry out radar-based remote sensing, and which have reliably been providing high-quality data since 2007 and 2010, respectively, also play an important role in this context. The whole-Earth digital elevation model that has been developed via the two missions, and the resulting high-precision detection of ground movements via the model, remain unsurpassed.

EnMAP, a new, national environmental satellite featuring cutting-edge technology, was launched in April 2022. By sampling a total of 228 spectral bands, it is providing data of unprecedented quality for study of Earth systems – for example, for study of forest damage and soil characteristics. In the area of geosciences, the GRACE-C mission, working in cooperation with NASA, is continuing the gravitational field measurements that have become so important for climate science. Gravitational field measurements are the only available means for studying and monitoring the full range of the global water balance, including deep groundwater regimes, and they make it possible to quantify glacial-melting rates and sea-level rises. Future missions will continue to be oriented to users' needs.

Germany is promoting high-tech specialisation in the area of operational Earth observation – for example, by providing the METimage radiometer for relevant missions and developing a laser especially for meteorological missions.

In sum, space programmes are contributing the achievement of several of the United Nations' Sustainable Development Goals (SDGs). At the international level, Germany is working to highlight space programmes' importance for environmental protection, nature conservation and climate action, and for climate change adaptation. In Germany's perspective, countries that are seeking to develop and build space programmes should be supported in the areas of space technologies and sustainability. At the same time, adverse impacts within the meaning of the UN's Agenda 2030 for Sustainable Development need to be avoided.

Private companies – including, increasingly, start-ups – play a significant role in making space services available for scientific research and for efforts to mitigate climate change. Their efforts in providing satellite services that help protect our planet (for example, for areas such as wildfire detection, and mapping of water reserves) are to be welcomed and supported.

With its pioneering work in various technological areas – such as high-performance solar cells and water-processing systems, for example – and with its cross-sectoral transfers of findings and technology, the space sector is helping to address the challenges of our time.

Aims and measures:

- We want **Germany to continue to be a leading European location and technological leader in the area of innovative Earth observation**. For this reason, we are supporting the continuity and further development of the Copernicus (civil European) Earth observation systems, the EUMETSAT weather-satellite systems, and national and European research aimed at providing users with reliable Earth observation data at the highest quality standards and on a long-term basis.

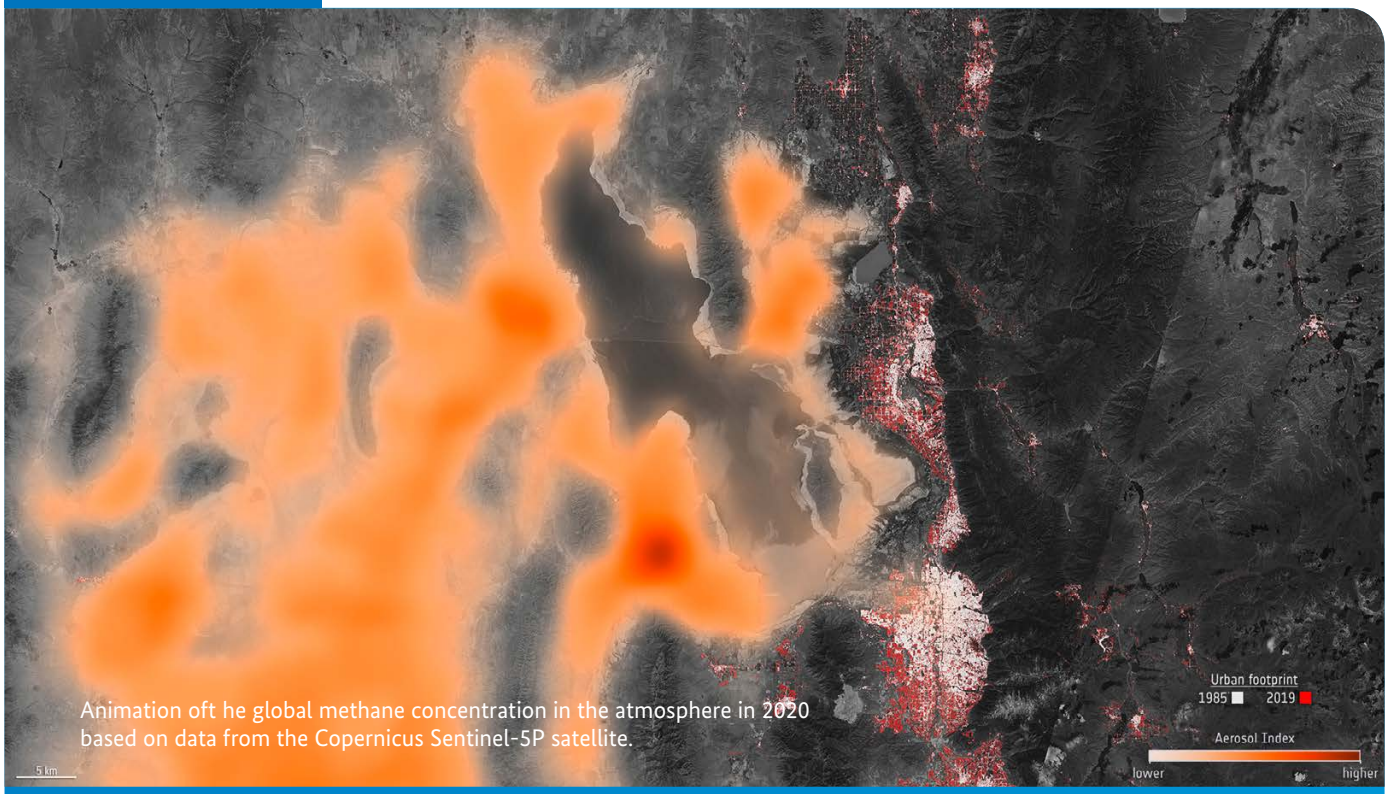
- **We are supporting providers and users of space technologies and services made in Germany**. In the process, we are helping companies to monitor the achievement of their own climate and sustainability goals more effectively, and to improve their own climate change adaptation. To this end, we are supporting efforts to improve the necessary sensors – such as sensors for high-precision monitoring of local emissions.

- The Federal Government is working to ensure that **government agencies at the Federal, Länder and municipal levels** are optimally informed about the potential inherent in Earth observation data – in areas such as agriculture, forestry and fisheries; city and state planning; climate change adaptation; nature conservation, environmental protection and coastal protection; health protection; water-resources management; transport; energy; and public services. Also, such agencies should have easy access to such data, should be trained in using it effectively, and should be able to use it actively and routinely in their own workflows.

- The Federal Government is working to improve **use of satellite data in connection with the energy system transformation**. In particular, such data can help identify "go-to areas" in this connection – specific locations, either on land or at sea, that are especially suitable for siting of renewable energy systems.

- Also, we are continuing to focus our space activities on Germany's contributions to the UN's Agenda 2030, to the EU's Green Deal, to the Paris **climate goals** and to bilateral climate cooperation.

KEY PROJECT:



Animation oft he global methane concentration in the atmosphere in 2020 based on data from the Copernicus Sentinel-5P satellite.

(5) Precise space-based measurement of emissions

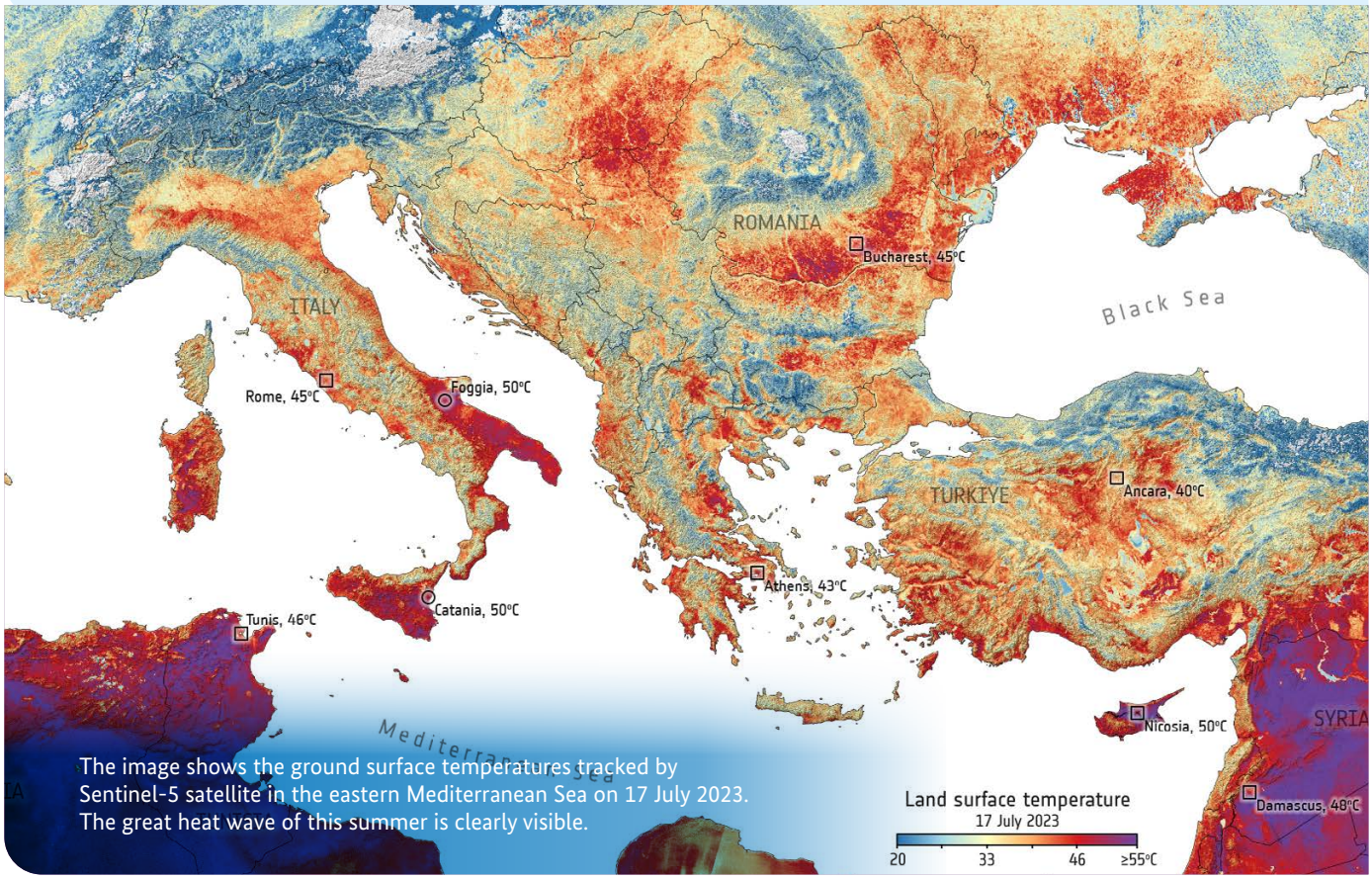
In the framework of the International Methane Emissions Observatory (IMEO) programme, and in cooperation with the United Nations Environment Programme (UNEP), Germany plans to work in the areas of Earth observation and sensing-data provision to help support efforts toward the "Methane Pledge" (COP-26, Glasgow). In the process, services for verification – and, ultimately, systematic reduction – of methane emissions are to be made available to national and European users.

At the same time, the potential inherent in Earth observation data for support of conservation-based climate protection (for example, protection and renaturation of peatlands and riparian landscapes) is to be developed in Germany. To this end, an integrated Greenhouse Gas Monitoring System is being established for Germany. In this context, high-resolution satellite-based measurements of atmospheric greenhouse gas concentrations will make it possible to quantify emissions of local CO_2 and CH_4 sources, from space. In addition, the pertinent data streams will be improved, with a view to obtaining a data-assimilation and inversion system that can provide regular source-sink estimates of greenhouse gases on nationally relevant scales. Plans call for the Copernicus satellite fleet to be expanded through 2028, and beginning with a CO_2 Monitoring Mission starting in 2026. In the process, a total of six more Expansion Sentinel missions will be added. These missions will significantly support the European Green Deal, and efforts toward Europe's climate goals, and they will protect Europe's globally leading position in space-based Earth observation.

Copernicus

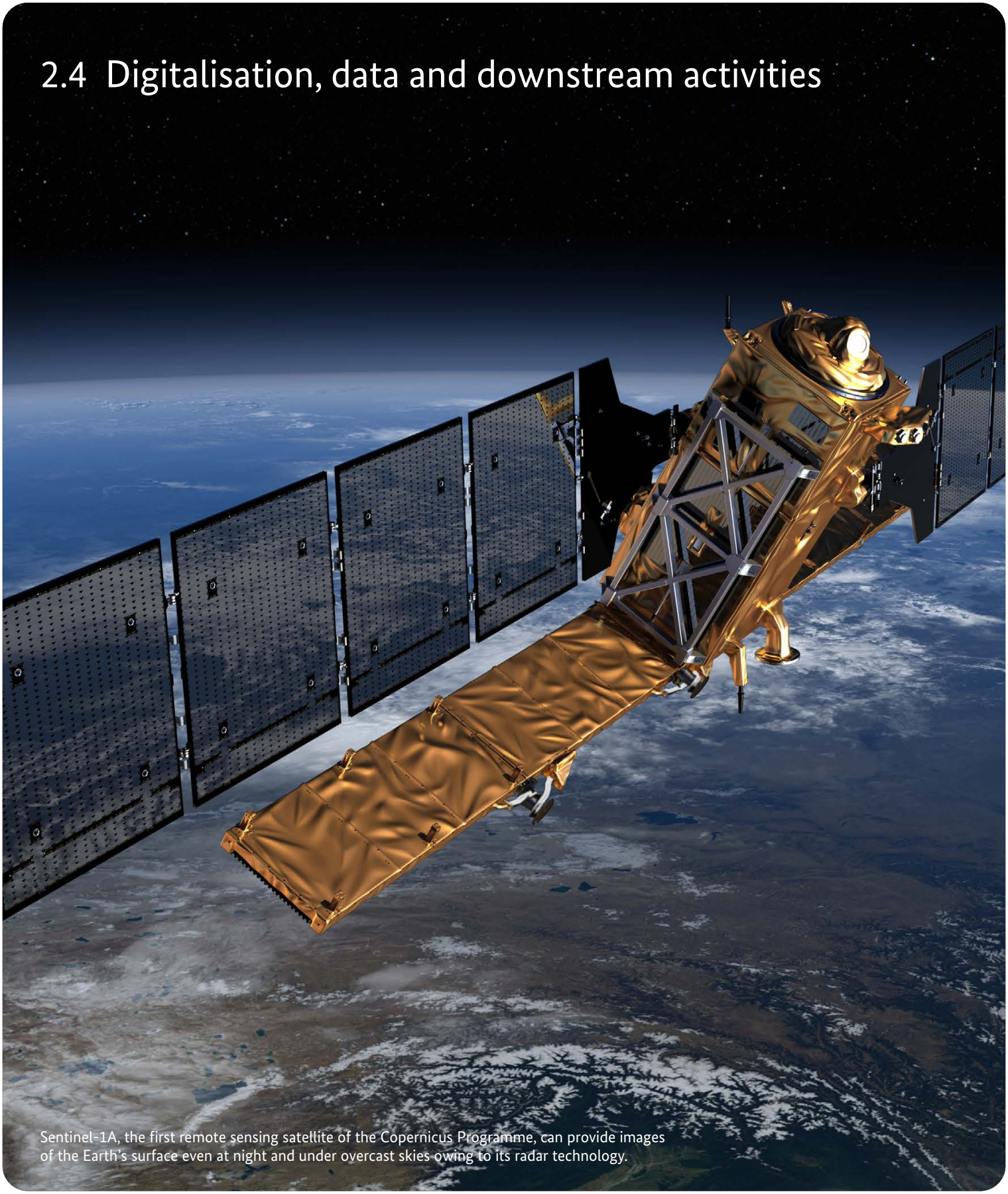
The European Copernicus programme, with its permanent Earth observation infrastructure, is providing continuity with regard to the Earth observation data needed in support of climate action. This programme, along with EUMETSAT's operational Earth observation missions (such as EPS-Aeolus) and various specially focussed scientific missions (such as GRACE), is monitoring climate change, supporting adaptation measures and monitoring the effectiveness of such measures – for example, in the framework of the European Green Deal. Data from the programme are also significantly furthering our understanding of central questions in climate science, environmental science and Earth system science that play a key role in forecasts and scenarios.

As a result, Copernicus is a powerful suite of satellite services that enables Germany to operate on the basis of objective data, in both planning frameworks and in urgent situations – such as disasters. Thanks to the Copernicus policy of free, open data access, the system serves as a basis for a wide range of user-friendly, cloud-based services for administrations, the business sector and private citizens. We are using it, for example, to support sustainable resources management, and transport safety on roads and waterways.



The image shows the ground surface temperatures tracked by Sentinel-5 satellite in the eastern Mediterranean Sea on 17 July 2023. The great heat wave of this summer is clearly visible.

2.4 Digitalisation, data and downstream activities



Sentinel-1A, the first remote sensing satellite of the Copernicus Programme, can provide images of the Earth's surface even at night and under overcast skies owing to its radar technology.

Space activities profit from digitalisation, and vice-versa. In its digital strategy, the Federal Government has defined ambitious goals, and identified the future availability and usability of data, data spaces, and applications derived from data and data spaces, as a strategic goal. Space activities are now relying on concepts for digitalisation and comprehensive data use, and doing so throughout their processes, including development and production of space technologies, ground and space-based operations, and data use throughout all space missions.

Hardware programming plays a special role in this connection, along with software development for space applications. To ensure that future missions can be executed efficiently, reliably and safely, expanded software capabilities are needed (for areas such as on-board updates of space systems and on-board data processing; in some cases, dedicated, hardened operating systems for space systems are needed). This is an area in which Germany can profit from its close involvement and experience with innovative methods for use of data-intensive, large-scale scientific equipment for basic research – especially since it is in competition with other countries that view software development as a key future technology and are investing heavily in it. In science, rapidly growing volumes of data, and the resulting need for powerful – yet sustainable – processing capacities, present the greatest challenges in using space data.

To date, digitalisation has been especially prominent in connection with state-of-the-art development and production methods for Industry 4.0. From the example of that sector, it is clear that while space industries can become both more capable and more cost-effective, they will increasingly need to protect themselves against cyber-attacks. Use of digital techniques and methods in satellite construction and operation, along with data-based collaboration throughout supply chains, opens up potential for efficiency improvements that can make (mega-)constellations such as IRIS² possible, and pave the way for new application and business areas.

As a result, satellites are becoming part of a three-dimensional communications infrastructure that supports broadband communications at any place on the globe. As this takes shape, development of innovative 5G- and future 6G communications technologies, and of application-oriented commercial solutions for integrated, secure satellite connectivity, will play an important role. The EU's IRIS² constellation is expected to play a central role in the infrastructure.

As new communications technologies are developed, the demand for broadband frequencies is growing. As a consequence, the international bodies responsible for managing the frequency spectrum will need to produce further agreements on management and use of the various frequency ranges, with a special emphasis on long-term assurance of uninterrupted Earth observation capabilities.

The new, highly precise services provided by the Galileo European civil satellite navigation system, which is located in a medium Earth orbit, will support decimetre-scale positioning, and give Europe an independent alternative to the other global satellite navigation systems in place – GPS (USA), GLONASS (Russia) and BeiDou (China). Satellite-constellation-based communications, in combination with satellite imaging data, open the way to range of different applications, both for mass markets and for special uses, such as (partly) autonomous vehicles, drones, smart cities/smart regions, precision farming and disaster prevention.

Data, services and products generated via space programmes are also driving digitalisation. The freely available navigation services and Earth

observation data provided by the European Galileo and Copernicus programmes provide the basis for many downstream-sector companies' digital business models. At the same time, the large quantities of data gathered by the Galileo satellites and by Earth observation satellites yield important information for the agriculture and forestry sectors, for atmospheric and climate monitoring and for crisis and disaster management. National remote-sensing services such as the satellite-based crisis and situation services (SKD) of the Federal Agency for Cartography and Geodesy (BKG) complement the aforementioned programmes, with analyses tailored to the needs of federal authorities.

The precision of satellite imaging data, and the speed at which it is provided, are constantly increasing. In addition, the global downstream market (data reception, data processing, services, ground equipment, etc.) is developing by leaps and bounds. In Germany, it is SMEs who especially profit from the data and services that are freely available via the European programmes. In spite of the markets' continual growth, the potential for value creation has not been exhausted. At the same time, the risks tied to inadequate protection against misuse and fraud are also growing.

The importance of space services for many areas of public administration – including services in the areas of mobility; logistics; agriculture, forestry and fisheries; weather forecasting, early warning, agricultural assistance; spatial planning; climate monitoring; climate reporting pursuant to the UN Framework Convention on Climate Change; and disaster management – is constantly increasing. In keeping with this insight, the Federal Ministry for Digital and Transport (BMDV), working in the context of the ministry's National Copernicus Integration Measure, is now supporting the implementation of pilot projects for demonstrating and evaluating Copernicus services in the context of German government agencies. A national application strategy will then outline the potential and strategic importance of operational satellite applications, and identify development scenarios for further use of the underlying infrastructures.

Rapid progress in satellite technology and data analysis – including progress involving artificial intelligence (AI) – is bringing use of satellite data to areas without any prior needs or concepts for such data. To enable federal authorities to profit from the new opportunities now available, transfer of research findings into the administrative realm is being facilitated. This is occurring, for example, via a framework agreement that the Federal Ministry of the Interior and Community (BMI) has concluded with the DLR. The agreement ("Innovative Remote Sensing for the German Federal Administration" – IF-Bund) is open to all federal authorities.

Government agencies' requirements in connection with use of satellite data include ease of access and supporting advising regarding the available services and training courses. In this regard, a first step in the right direction has been taken: the BKG, the central geoinformation-services provider for the entire federal administration, has arranged for central purchasing of data. Since 2022, the entire federal administration has enjoyed free access to commercial satellite imaging data, with the BKG's service centre for remote sensing serving as the central point of contact. This service has been very well-received; it is already being used by many government departments. The next important steps to be taken in the future will include further establishment of the service throughout the federal administration, with a view to meeting permanently growing, thematically diverse requirements.

Aims and measures:

- We are working to ensure that the **data services** provided via space-based systems, and the infrastructures needed for accessing such services, remain permanently, reliably and securely available to users, and that they remain sustainable in terms of the resources they use. We are supporting the further development of both international systems (ESA, EUMETSAT, ECMWF) and national platforms such as the Copernicus CODE-DE data platform.

- The Federal Government facilitates ongoing **dialogue between user departments and agencies**, with the aim of consolidating government **downstream requirements** for space-based services. This effort builds on the established Copernicus user-dialogue programme, which includes the interdepartmental Copernicus work programme. Ongoing networking, and the promotion of a better overall understanding of the system, on all government levels and among all participating partners, is expected to considerably improve the effectiveness of use of space services and open up new markets for space applications.

- The Federal Government is promoting an **investment-friendly climate** in Germany, relative to the procurement of space data and services, a climate that is optimal for services users and New-Space start-ups – and for sustainable business models.

- In implementing the **National Copernicus Strategy and the National Copernicus Integration Measure**, we are continuing Germany's commitment to establishing use of Copernicus data and services throughout all levels of public administration, and we are doing so by promoting development of innovative value-added services, along with their use for relevant specialised tasks.

- Also, we are encouraging intensified, cross-sectoral exchanges of digital technologies and methods between the space sector, data-intensive research infrastructures and the IT sector.

- With our ESA and EU commitments, we are ensuring that the German **Galileo Control Centre**, along with university and non-university centres for **quantum science** and their cooperating partners, remain one of the most important European competence clusters for statutory provision of navigation and communications data/services and for related research and development.

- The Federal Government plans to create the framework conditions needed in order to support German industry in making its contribution to the EU's Infrastructure for Resilience, Interconnectivity and Security by Satellite (**IRIS²**) programme. Implementation of competitive tendering, and inclusion of SMEs and start-ups in the programme, will ensure that the programme has a lasting impact on the entire European ecosystem. In addition to supporting the government services, the satellite constellation is expected to provide a boost for commercial services.

- We are aiming to ensure that satellite communication plays a significant role in the **6G communications standard**, as a complement to terrestrial networks – for example, for the Internet of Things (IoT), or for improved connectivity in the air, on land and at sea.

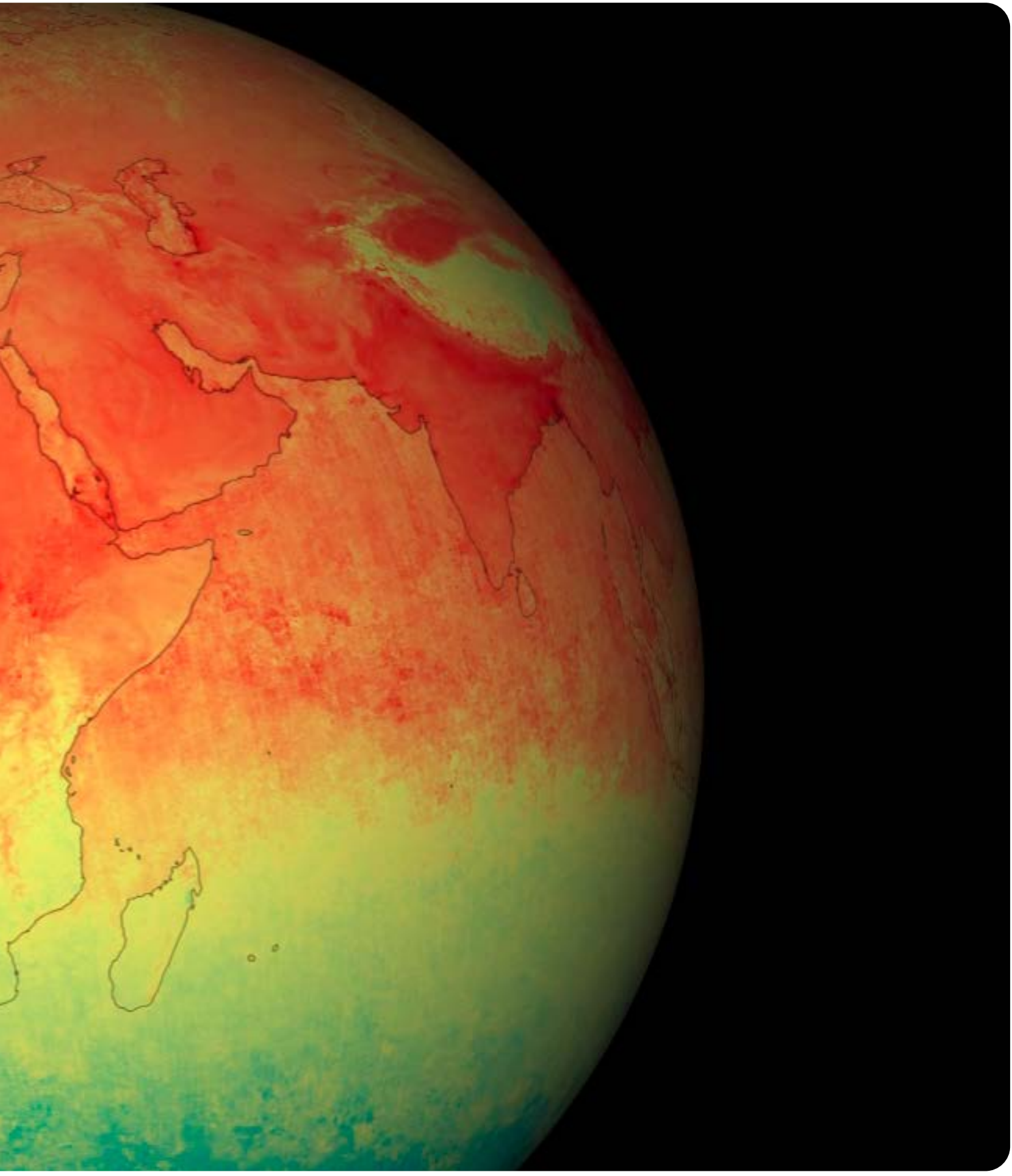
- In international bodies such as the International Telecommunication Union (ITU), and in our active cooperation with other countries, we are promoting the establishment of protected frequency bands.

KEY PROJECT:

(6) Cloud platforms for climate and environmental data

Space services and international cooperation play essential roles in climate and environmental protection. For example, high-performance satellite-based Earth observation systems provide key support, such as climate and environmental monitoring, for efforts toward Paris Agreement goals, and for monitoring of relevant compliance. On the basis of the existing national and European platforms, we are facilitating reliable, efficient, user-friendly provision of satellite data and processing tools, so that users at public-sector institutions, along with researchers and services providers, can have fast, easy, efficient access to globally available Earth observation data, along with secure cloud-based processing services and the ability to integrate data within their own data structures. In the process, we are emphasising provision of integrated products that make use of data from a range of different sources, such as data from a diverse range of satellites, overflight data and terrestrial measurement data, within a systemic approach – for promotion of climate and environmental research.

Based on data from the Copernicus Sentinel-5 satellite, this animation shows the global methane concentration in the atmosphere in 2020.



2.5 Security, strategic options and global stability

Galileo satellites in Earth orbit

In its National Security Strategy, the Federal Government has highlighted its aims of giving intensified attention to the strategic dimension of space and of expanding its capabilities in this area. The EU and NATO, along with programmes for close cooperation with partner countries with space programmes, provide the central framework for addressing space security issues. In this context, space plays an important role in national security. Germany's civil and military capabilities in this area depend on our space infrastructure and on the data, services and products it makes possible. Russia's war of aggression against Ukraine, pursued in violation of international law, serves as a reminder of the important role that space-based systems play in crises and conflicts, as well as of the vulnerability of such systems.

Space programmes and space-based infrastructures are playing an increasingly role in national security. Military operational capacities depend centrally on secure, unhindered access to space, on satellite communications and navigation, and on Earth observation data. Germany's recently published National Security Strategy thus calls for the Federal Government to establish guidelines, in the framework of a space security strategy, for protection and defence in space, and for greater national resilience in this area. It also calls for the Federal Government to define measures for strengthening military capabilities via space-based systems, taking account of needed space technologies and potential for dual-use synergies. In 2023, the European Commission and the European External Action Service (EEAS) published a Space Strategy for Security and Defence (EU SSSD), in which they underscored a) the space sector's importance for the EU's security and defence policy and b) the need to protect access to space and space-based systems.

Space-based systems are continuously exposed to risks and threats. Along with risks from growing orbital-traffic densities, space debris and space weather, space-based systems face risks of disruptions and damage caused by other actors – either intentionally or unintentionally. Disruptions of and attacks against space infrastructures and their various segments can cause grave economic damage for entire countries and restrict governments' ability to act.

The Federal Government attaches central importance to the establishment of internationally binding rules and measures that support peaceful, sustainable use of space, reduce hazards for space activities and prevent arms races in space. In the framework of the United Nations, Germany and its close partners are participating in relevant negotiations and working groups. In this context, Germany rejects destructive tests of ground-based anti-satellite missiles, and it has obligated itself, in cooperation with the U.S. and other partner countries, to refraining from such tests in the future.

Cyberthreats are also a continually growing risk for space-based systems, including their ground-based segments and their data links. An international inventory of the vulnerabilities of space-based systems is needed, along with continual improvements of national and international standards and requirements for space programmes. Along with requirements pertaining to relevant technical and organisational measures, Germany's National Programme for Space and Innovation includes provisions for cybersecurity, with a view to protecting the security of space programmes, both on the ground and in space – and, thus, safeguarding the availability of space-based services. Also, at the international level, and in the framework of standardisation processes, requirements for all aspects of space activities are being developed and improved, with German participation.

As a high-tech nation, Germany depends on having free and unhindered access to space. For both

economic and security-policy reasons, we depend on having assured access to state-of-the-art space technologies and space-based services. In addition, space-based Earth observation and navigation services play an essential role in the future of our society, and its quality of life – including such aspects as food security. To carry out their work, security agencies depend on having reliable, space-based data, services and products. Germany needs to remain able to function in the space sector – either on its own or in cooperation with European and international partners – and in addition to fulfilling its obligations in European programmes, it has to be able to fulfil its own national requirements efficiently. For this reason, it is especially important for Germany to have capabilities that make it a competent, attractive partner for cooperation (partnership capabilities).

The Federal Government's space activities also serve purposes of national security and law enforcement. Because such purposes need to be addressed as efficiently and cost-effectively as possible, synergy-based dual use (civil/military) approaches play an important role in the development of new space technologies. Also, national and international processes for standardisation in the space sector play a key role in the safe operation and security of space systems in general. Economic aspects, such as protection and maintenance of key technologies and capabilities, and political and programmatic aspects of national and international cooperation in the space sector, are also highly relevant aspects to consider with regard to the issue of assured access to important space-based infrastructures.

In the interest of safeguarding the country's strategic options, it is also important to ensure that space infrastructures, and related services, for areas such as disaster prevention, crisis intervention, emergency response and criminal prosecution, are used efficiently. The availability of relevant capabilities and data provides a robust basis for decision-making in connection with disaster prevention and management, and security agencies' investigations. Via its Public Regulated Service (PRS), the Galileo system now provides an unprecedented, specially protected, encrypted navigation signal for state-authorised civil and military users, including rescue teams, emergency services and operators of critical infrastructures.

The National Security Strategy underscores the importance of acquisition of space-situation information, as a joint civil-military task. Since 2009, the German Space Situational Awareness Centre (GSSAC), which is operated by the German Armed Forces Space Command and the German Space Agency at DLR, has been making a decisive contribution to national security, by preparing situational views of space (with work such as cataloguing of space objects, and detecting and assessing space weather) and helping to protect civil and military space-based systems. In 2021, the German Armed Forces commissioned a Space Command. At the institutional level, this Command enshrines the increased importance of space-based systems with regard to security and defence, and it highlights the growing need to protect such systems.

Also, plans call for the growing risks in space to be addressed via the establishment of a Space Traffic Management (STM) system. Its basic operations will include observation and tracking of objects in Earth orbits, calculation of orbital-path data, and cataloguing of space objects (including via the Tracking and Imaging Radar (TIRA) and German Experimental Space Surveillance and Tracking Radar (GESTRA) systems). In this same context, the European Union has developed an approach to maintaining independent European capabilities that calls for use of high-performance sensors in preparation of situational views of space. The EU Space Surveillance and Tracking (EU SST) partnership, to which Germany is contributing national

funding and capabilities, is making a substantial contribution to this approach. EU SST has a key function in connection with the secure operation of the satellites of the European Copernicus and Galileo programmes.

With the Critical Entities Resilience Directive (CER), which entered into force on 16 January 2023, "space" has been included as one of eleven Critical Infrastructures (KRITIS) sectors. In addition, space activities can also play a role in other KRITIS sectors. As a result, space activities and space infrastructures are increasingly being seen as part of our critical infrastructure, and they play a role in the operation of other critical infrastructures. Under the CER Directive, the space sector currently includes state and private operators of ground-based infrastructures that are needed for the operation of space-based services. This CER-mandated framework is taken into account in the planned KRITIS umbrella law with which the CER Directive is to be implemented.

In our digitalised world, large quantities of data need to be transmitted securely. This is why the EU has launched the satellite communications constellation "Infrastructure for Resilience, Interconnectivity and Security by Satellite" (IRIS²), as the third pillar of its space programme. IRIS² will provide Europe with independent access to resilient, satellite-based broadband communication capabilities. In these strategic areas, Germany wants to be able to operate on its own, in cooperation with its European partners. German companies and research institutions have developed cutting-edge solutions in the areas of laser communications and quantum cryptography, and we view such solutions as possible national contributions in this context.

Aims and measures:

- The Federal Government is aiming to ensure the permanent, reliable **availability of space-based data, services and products**, for the German government, economy and society. In light of new global challenges, efforts toward this aim will depend on the ability to adequately protect all segments of the relevant infrastructures, as well as the technologies they require.

- We are calling for **use of space to be based on rules, and to be secure**. To this end, we are strengthening our interdepartmental coordination, as well as our cooperation with European and international partners and organisations. Also in this context, the Federal Government supports networking with non-state actors.

- We plan to intensify our **strategic cooperation with our partners**, with the aim of protecting the space industry's global supply chains against unlawful influence, espionage, unauthorised leading of knowledge, and sabotage. In our R&D cooperation in the area of critical and emerging space technologies, we are giving special priority to safeguarding such technologies, in the interest of international security and of preventing abuse of the technologies.

- Germany needs to have its own, **independent access to space, along with independent, reliable access to strategically relevant space-sector capabilities and space-based infrastructures**, in areas such as satellite communications, satellite navigation and Earth observation. These requirements are of essential importance for Germany. Together with our European partners, we are working to ensure that we remain able to operate independently and effectively in these strategically important areas.

- In the interest of maintaining **our capacity** to act in these areas, we are identifying critical space infrastructures, of both state and private actors, that are particularly worthy of protection, and helping to strengthen their **resilience**. This includes the area of cybersecurity, which continues to grow in importance. Wherever possible, we are making preparations that will enable us to quickly replace failed systems, and we are maintaining alternatives to space-based data links.

- We want to improve the **framework conditions for business and research**, with a view to expanding Germany's and Europe's space-technology base for strategically important key technologies, and thereby reduce critical dependencies. Wherever possible, such as in the area of dual-use technologies, we are making use of potential synergies.

- To counter **uncontrolled access** to security-relevant key technologies, we are continuing to apply restrictive export controls, on the basis of existing international export-control regimes and national foreign-trade law.

- The Federal Government plans to promote the **development and expansion of additional capabilities for space situational awareness**, including capabilities for monitoring and assessment of space objects and space weather, at the interdepartmentally operated GSSAC. Also, it plans to work with international partners to establish a permanent sensor network with full global coverage.

- In cooperation with our European partners, we plan to continue taking an active role in the **EU SST programme**, and we have assumed lead responsibility for the establishment and operation of a European catalogue of space objects.

- The availability of space-based sensors, and of the data, services and products that can be generated with them, is a **key element of robust support for decisions** in connection with emergency preparedness and response. In certain types of cases, such availability provides the basis for state options for action. Therefore, we are intensifying the use of space technologies and data in the interest of our national security and law enforcement.

- In the UN framework, Germany is promoting **peaceful exploration of space, and safe, sustainable use of space**, and it is reinforcing relevant international cooperation and space-sector diplomacy. Also, Germany is promoting dialogue on the relevance of space with regard to security and defence policy. In the UN framework, it is helping to develop politically binding principles and standards for responsible space-based behaviour by state actors – i.e. principles and standards that, in the long term, could lead to legally binding instruments in this area.

- The Federal Government is ensuring that it has **independent access to the Galileo Public Regulated Service (PRS)**. In so doing, it is also seeking to support use of the improved security features of the future Galileo services. The PRS authority's operations are being set up at the Uedem facility that also houses the German Space Situational Awareness Centre (GSSAC) and the German Armed Forces Space Command.

- Germany is supporting the **establishment of PRS technology**. It is doing so via a national funding programme for development of PRS technology and of applications for protecting its own independent access to the Galileo PRS, a programme focussed especially on development of proprietary, independent PRS receivers.

KEY PROJECT:

(7) Establishment and expansion of national capabilities for space situational awareness

Capabilities for space situational awareness play a key role in development and implementation of measures to protect space-based systems. They are of fundamental importance with regard to the protection of such systems – and, thus, of national actions in space. The National Security Strategy underscores the importance of acquisition of space-situation information, as a joint civil-military task. To ensure the availability of operational capabilities for real-time, independent space-situational awareness, we are establishing and expanding our national resources in this area through 2030, with focuses that include sensors and the interdepartmentally operated German Space Situational Awareness Centre (GSSAC). In the process, we are also building on competencies already in place at research institutions and various federal institutions. Germany plans to continue playing a leading role in the EU SST partnership, and it plans to support establishment of a catalogue of space objects that will serve as a basis for the provision of services relative to monitoring of all relevant Earth orbits.

GESTRA

The German Experimental Space Surveillance and Tracking Radar (GESTRA) is a ground-based radar system that was developed for monitoring of space objects in low Earth orbits. In 2015, the German Space Agency, sited at DLR, commissioned the Fraunhofer Institute for High Frequency Physics and Radar Techniques FHR with the development and construction of this space radar, with a view to improving monitoring of space debris. The radar system, which is partly mobile, consists of separate transmission and reception systems. It is located at the Federal Armed Forces' Koblenz-Schmidtenhöhe facility. Since 2020, the German Space Situational Awareness Centre (GSSAC) has operated the system is a test mode, and has already discovered a first group of objects in Earth orbits. Currently, project handover and acceptance are scheduled for the end of 2023.

GESTRA shelter on the Schmidtenhöhe near Coblenz

GESTRA provides valuable data that are to be used for the preparation of a German catalogue of space debris. The resulting catalogue will complement the existing catalogues of the U.S. and the EU.

2.6 Sustainable, safe use of space

Around 11,000 objects larger than ten centimetres are currently orbiting the Earth.
The number of smaller particles is estimated at several million.

Germany attaches high priority to the sustainable, safe use of space. Access to space, a common global resource, needs to be protected and kept available for future generations. We want to establish sustainable practices for use of space, on the basis of the UN Sustainable Development Goals, and thereby promote a long-term scenario in which space activities have as few adverse impacts as possible. The focus in this connection must be on preventing both environmental damage in space and any adverse repercussions for the Earth. Funding for this effort is also oriented to the project's benefits for society.

Because human activity in space continues to intensify, the need for regulation is growing. The task of strengthening and enhancing the international framework for use of space, on the basis of international law, is a task for the international community. In the United Nations framework, as well as in bilateral and multilateral frameworks, Germany is addressing this responsibility and working for its fulfilment.

Low Earth orbits, in particular, make up a limited resource that is being used by more and more institutional and private actors. And as space activities continue to increase, the frequency spectra used by space-based systems are proving to be a limited resource as well. In the interest of our everyday access to space-based infrastructures, and to the services generated with them, it is essential that such resources be used sustainably.

Furthermore, it is vitally important that the impacts of increasing space activities – in both space and on the ground – be addressed via sustainable use. In the interest of achieving the relevant SDGs, a holistic sustainability approach needs to be applied, taking account of the ground-based and operational infrastructures needed for space activities, as well as of any possible smart concepts for resource-saving usage, throughout the entire value chain. A better understanding of the impacts of rocket launches, and of satellite re-entries, on our planet and its atmosphere (especially its ozone layer) is needed, with a view to minimising any adverse effects. Far-sighted, precautionary prevention of unnecessary light and radio emissions from manmade satellites helps to keep the night sky dark, and to protect access for radioastronomy.

An understanding of space weather and its potential impacts plays a decisive role in the safe use of space. "Space weather" refers to a range of phenomena, including solar storms, radiation bursts and charged particles that interact with the Earth's magnetic field. Such phenomena can endanger astronauts, and they can have major impacts on satellites, spacecraft, space-based infrastructure, ground systems (such as electricity networks) and radio links. With a proper understanding of space weather, we can take timely measures to prevent hazardous situations. Such measures can include suitable mission planning; shielding of sensitive devices; and hazardous-event forecasts aimed at minimising damages. Measures taken in this context can improve the safety of space missions and enhance the reliability of our communications systems and other space-based technologies. The Federal Agency for Cartography and Geodesy (BKG) is establishing a ground-based system for monitoring space weather, as a complement to existing satellite-based observation systems. In future, the relevant operational data and products will also be available from the German Space Situational Awareness Centre (GSSAC).

In the interest of safe, sustainable use of space, it is urgently important to prevent space debris and reduce the quantities of space debris in orbit. Space activities have increased sharply in recent years. As a result, the risks that space debris presents to space-based systems have increased sharply as well. The quantity of space debris in orbit has more than doubled over the past 20

years. In addition, intentional destruction of objects in space, in tests of ground-based, destructive anti-satellite weapons, has also added to the debris. To counter this trend, Germany and several partner countries have committed themselves, in the framework of the United Nations, to refraining from conducting such tests. We are working actively in the UN framework to encourage additional countries to join these voluntary commitments.

Growing volumes of space traffic also now present enormous challenges for the safe operation of spacecraft. Within the space of 10 years, and as a result of the launching of mega-constellations, the number of active satellites in orbit has more than doubled, and it will continue to increase rapidly. As a result, the need for a Space Traffic Management (STM) system, and for coordination of orbit and frequency use, is growing continually.

The following two approaches to making space activities more sustainable complement one another: Avoidance of new space debris, and active removal of existing space debris.

The creation of new space debris should be avoided whenever possible. To this end, collision-avoidance capabilities need to be enhanced – for example, with the help of suitable algorithms and methods for assessing collision risks. Also, satellite and spacecraft operations need to be suitably coordinated, and satellite and spacecraft need to be disposed of properly when they reach the end of their operational lives. A first group of internationally coordinated measures for limiting the time periods that decommissioned satellites remain in relevant orbital regions is now in place. They include the guidelines on avoidance of space debris issued by the Inter-Agency Space Debris Coordination Committee (IADC) and the UN Committee on the Peaceful Uses of Outer Space (UNCOPUOS), and the latter committee's Guidelines for the Long-term Sustainability of Outer Space Activities (LTS Guidelines). Another important step toward the avoidance of space debris is to develop innovative, relevant new solutions for the design of satellites and spacecraft, ultimately with the aim of developing maintainable, smart and adaptive systems. Modularity and standardisation play a key role in efforts to develop such forward-looking space technologies.

For the active removal of space debris, highly reliable robotic systems are needed that can safely remove objects from relevant orbital regions (active debris removal). In the interest of preventing misunderstandings, such robotic resources must be used in a predictable, transparent manner.

A national Space Act (Weltraumgesetz), including provisions for Germany's fulfillment of its legal obligations under the Outer Space Treaty, will help prevent the creation of space debris and contribute to the sustainable, safe use of space.

Aims and measures:

- Germany is pursuing the aims of promoting **a holistic approach to the use of space, within the meaning of sustainable development**, of actively protecting orbital space and of ensuring that orbital space remains available in the long term. Internationally, we are thus urging the adoption of sustainability standards and best-practice rules. In the United Nations

framework, we are urging that the time periods that decommissioned satellites be allowed to remain in orbit be considerably shortened. Also, we are calling for more-effective use of orbital and frequency resources; for precautionary avoidance of unnecessary light and radio emissions; for environmentally friendly design of all ground infrastructure; for resource-saving, emissions-free production and operation of relevant technical systems; and for usage practices oriented to sustainability goals. Germany supports the guidelines on avoidance of space debris. Also, it has enhanced the guidelines and is implementing them in its own national space programme, also with the help of supporting research.

- In addition, we are actively supporting the further development of an EU approach for a **Space Traffic Management** (STM) system, and in the UN framework we are calling for joint efforts to design an international STM system in the medium term.

- Germany attaches great importance to the **avoidance of space debris**, and it is working to prevent light pollution of the dark night sky and to protect observational conditions for radioastronomy. In cooperation with our European and international partners, we want to keep satellites from becoming space debris – either as the result of intentional actions or simply at the end of their service lives. Satellites should be equipped with the technological means necessary to prevent a transition to space-debris status.

- In the interest of sustainable use, development of new satellites should emphasise **maintainability and modernisability** and the **establishment of collision-avoidance capabilities**. We are working toward these aims at the international level.

- In the interest of **reducing space debris**, we are promoting development of technological capabilities for reliable, active removal of decommissioned spacecraft and of space debris.

- Also, we are promoting **life-cycle analyses for space missions**. Such analyses are needed especially with regard to the atmospheric impacts of launches and of re-entry of objects from space.

KEY PROJECTS:

(8) Space Traffic Management (STM)

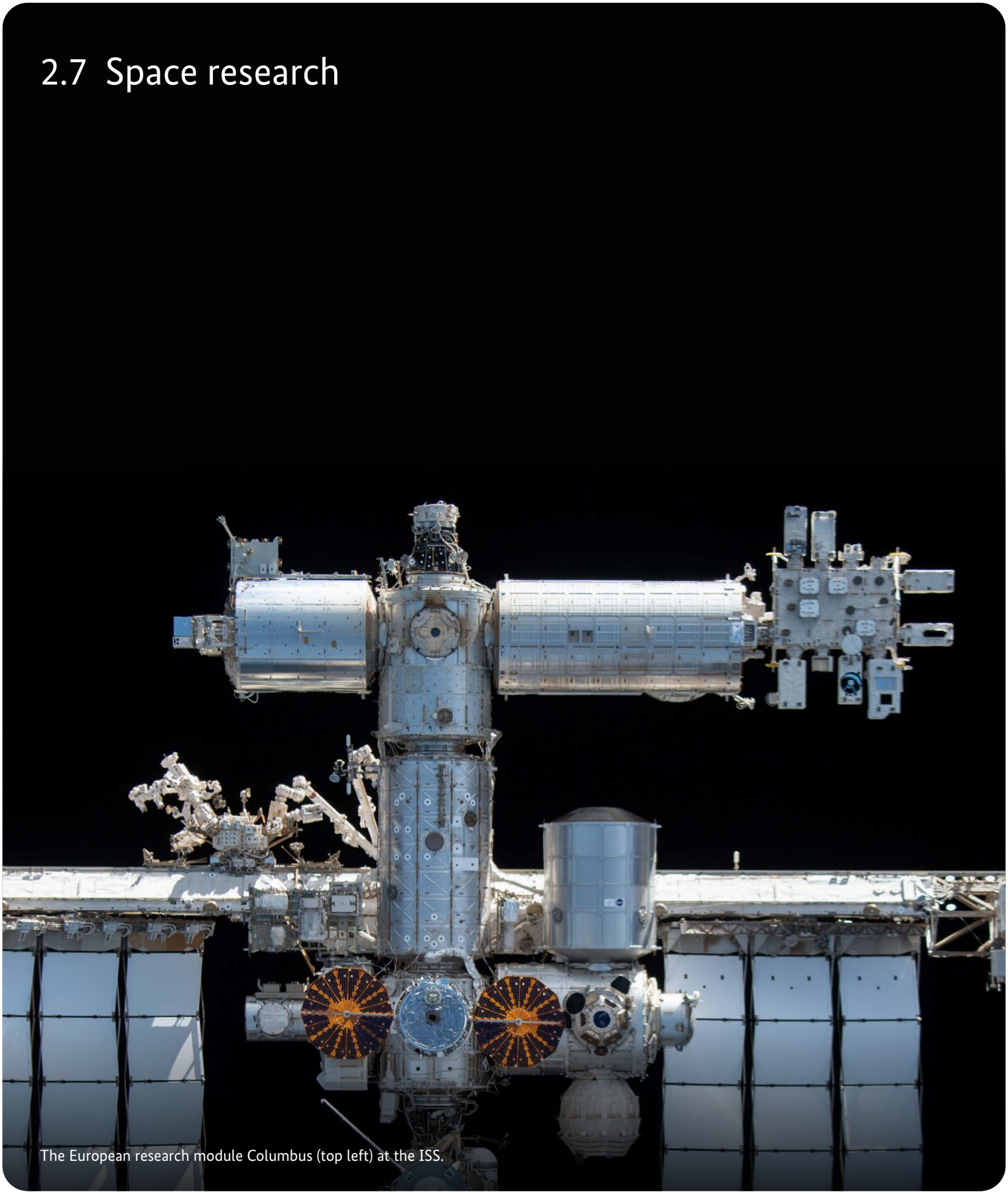
The number of objects in space continues to grow sharply. In contrast to the aviation sector, in which air traffic control ensures that aircraft always remain at a safe distance from each other, the space sector still lacks a traffic control system. In light of the physical differences involved, approaches used in aviation cannot necessarily be directly applied to space traffic. In the interest of preventing collisions in space, the European Union has developed a political approach for space traffic management that takes account of the efforts of the EU Member States working together within the EU SST partnership, efforts which are enhancing the EU's independence in the area of monitoring and tracking of space objects. The services that the EU SST provides to satellite operators worldwide, free of charge, make it possible to detect collision risks and carry out avoidance manoeuvres. In addition, we are actively supporting the implementation and international promulgation of an EU approach for a Space Traffic STM system, and in the UN framework we are calling for the establishment of an international STM system. To support its position in this area, Germany needs to enhance its national capabilities, and it needs to expand its bilateral and multilateral cooperation with civil and military partners in the area of space monitoring. To these ends, we are aiming, in close consultation with France, to continue in our lead role in the EU SST. On an operational level, we are supporting this role with national capacities such as the GSSAC and with various technologies, such as technologies for space monitoring. Networking, via the EU SST, with additional sensors for space-situation evaluation is now facilitating the first globally coordinated operation of multinational sensors for space-situation evaluation, along with multilateral data exchange. It thus represents a first step toward a global STM.

(9) Space Act

The Federal Government is aiming to enact a national Space Act (Weltraumgesetz) that would enhance sustainability in the space sector by establishing permit and monitoring requirements for space activities. Legal provisions should provide a reliable framework, and they should be conducive to innovation and competition among space companies. In preparing the Space Act, we will also consider the possibility of including security-relevant aspects.

A piece of space debris has punshed through NASA's SolarMax-Experiment.

2.7 Space research



The European research module Columbus (top left) at the ISS.

In space research, which takes place both in space and on the ground, with ground-based systems, researchers study fundamental scientific questions and seek to understand humanity's real position within the universe. In doing so, space research, carried out with the help of satellites and space probes, often draws on findings from research disciplines and areas outside of the space sector – areas such as ground-based astronomy and astrophysics, with which it fruitfully interacts. To be able to operate reliably in the extreme conditions prevailing in space, space research often requires high-tech equipment that pushes the limits of what is technically possible. In the process, it triggers innovation in, and technology transfer to, a range of economic and life areas. Exploration of space and its phenomena is thus an important field for the future of science – and this applies throughout the range from basic research to application-oriented development of cutting-edge space systems.

Much of Germany's space exploration with satellites and space probes takes place via the ESA Science Programme, in which Germany is currently the largest contributor. National and bilateral projects, such as Germany's cooperation with Japan in asteroid exploration, are another pillar of German space research. Scientific instruments for relevant missions are developed by research institutions, with the support of German industry, and financed via the National Space Programme. The institutionally funded research infrastructures supported by the Federal Government, such as the Helmholtz Association (HGF), and including DLR, use their unique capabilities to make important contributions for preparing missions for the harsh conditions of space. For example, the GSI Helmholtzzentrum for Schwerionenforschung and ESA are cooperating on the development of a cosmic ray simulator that can be used to study the impacts of cosmic rays on people, electronics and various materials.

Satellite and space probes are built by industry, under contract to ESA. Germany has a high level of scientific expertise in all relevant subject areas. Also, its research institutions, which attract considerable funding via the Federal Government's institutional support and via third parties, and which receive additional support from the National Programme for Space and Innovation, also have extensive engineering expertise, including software engineering.

In recent years, German research institutions, along with German industry, have made key contributions to ESA missions. In various missions, they have also taken on leadership roles – examples include the highly successful GAIA astrometry mission, and the Jupiter Icy Moons Explorer (JUICE) mission, which was recently launched, and for which DLR, in cooperation with partners, has contributed a highly complex instrument for surveying the Jupiter moon Ganymede. German research institutions are also making important scientific contributions to missions that are currently being developed, such as the innovative Planetary Transits and Oscillations of Stars (PLATO) mission for study of exoplanets, and the Laser Interferometer Space Antenna (LISA) mission for study of gravitational waves. German research institutions plan to continue providing scientific payloads, and to continue taking responsible roles in the extensive data analysis required for ESA missions. We want German industry to take leading roles in preparing and executing such missions.

A strong demand is emerging for small satellites that are sustainably designed, produced and used, and this is also the case in the science sector; it needs small satellites for cost-effective scientific study that complements the ESA Science Programme, as well as for efforts in preparation for German participation in major missions.

For research under space conditions, the German Space Agency offers a spectrum of flight opportunities with weightlessness periods of various durations, including stays at the International Space Station (ISS). With the resolution taken at the last ESA Ministerial Council meeting (held in 2022), providing for extension of the ISS programme until at least 2030, Europe – and Germany in particular – are supporting the continuity of the ISS programme and the research it is carrying out.

Following the decommissioning of the ISS, the U.S. government plans to rely on commercial space stations for both manned and unmanned research in orbit. In the changing environment that then results, cooperation between agencies, users and industry, with regard to research in low Earth orbits, will have to be redefined. The relevant options range from the establishment of a new European infrastructure, to partnership-based use of new national platforms and to the purchase of services on commercial infrastructures. For Germany, it will be important to act early in helping to prepare the transition from the ISS to new opportunities for research and technology demonstration in low Earth orbit, to ensure that German scientists continue to have access to a space-based platform after the termination of the ISS programme.

Aims and measures:

- Germany continues to pursue **excellent space research**, and it supports the production and use of research findings, also within the meaning of sustainable development.
- We continue to support effective work-sharing between science and the space industry in the **development and construction of instruments** for space-based telescopes, detectors and scientific probes, work-sharing that takes equal account of both scientific aims and cost aspects. With this approach, we are seeking to make an important European and international contribution to space exploration.
- In the future, we want to develop the potential inherent in sustainably usable **small satellites**, and do so also for the purposes of space exploration.
- We want to ensure that the thematic structure of ESA's new **Voyage 2050 Science Programme** takes account of the interests of German science. In addition, we want to continue playing a leading role in the development of scientific instruments.
- We want to pursue successful research, under space conditions, in the areas of biology, medicine, human physiology, physics and materials research, and we are seeking to produce **excellent results in both basic and applied research**.
- We plan to use the **ISS** until at least 2030, in cooperation with international partners.

KEY PROJECT:

(10) Excellent research in low Earth orbits, following the termination of the ISS

When the ISS programme ends (and the post-ISS period begins), we want German science to continue to have access to experiment time in low Earth orbits. To this end, we are establishing an expert group that will develop the various German options for the post-ISS scenario, in preparation for decisions to be taken by ESA. To ensure that the interests of future users are suitably considered, the expert group will identify the development phases, of various alternative scenarios, in which the Federal Government can participate and create opportunities for German industry and research.

Technology transfer from DLR research

One of DLR's strengths is that it transfers technologies originally developed for research purposes into industry applications.

The Hugo™ robotic-assisted surgery system, for example, is based on a technology that is licensed by DLR and that was developed by the DLR Institute of Robotics and Mechatronics for use in space – for ground-based remote control of robots on the ISS.

With the help of its MiroSurge system, the institute turned this development into a useful option for medical applications. The successful technology transfer for this system was carried out and completed in cooperation with a globally leading medical technology company based in Wessling, Bavaria, in partnership with DLR.

The system puts research findings developed by DLR to practical use. In cooperation with industry partners, an exemplary innovation was achieved with the help of technology transfer.

Along with licensing arrangements and cooperation with industry, spin-offs are an important means by which DLR entrepreneurially commercialises transfer-capable ideas. On average over the past 10 years, one company per year has been spun off from the DLR Institute of Robotics and Mechatronics.

2.8 International space exploration

The European service module orbits the Moon on the Artemis I mission.

The Federal Government understands "exploration" to refer to all activities carried out for preparation and execution of missions to the moon and to Mars. The aim of such missions is to expand humanity's radius of action, and its knowledge horizon, beyond the boundaries of the Earth and, in the process, to develop innovative technologies for activities in space and on the Earth. For exploration of celestial bodies near Earth, both manned and robotic systems are used.

In recent years, international attention has been turning especially to the moon. The moon is of interest also as a stepping-stone for preparation of missions to more-distant bodies, such as Mars or asteroids. The focus of interest with regard to Mars is on searching for traces of life, as well as on robotic preparation of future long-term missions involving astronauts.

As a result of their costs, complexity and scientific breadth, exploration missions are possible only in the framework of cooperation and international work-sharing. Germany is in a position to contribute outstanding technologies, and it has extensive expertise at systems levels. Via the European Service Module (ESM), which was built in Bremen, under the responsibility of German industry, Europe has a system-critical element within the U.S.-led Artemis programme. The ESM is part of the Orion spacecraft for the Artemis programme. Artemis is expected to return humans to the moon by 2025, after an absence dating from 1972.

The German space industry and German research institutions are participating in the exploration programme's ESA missions, to a degree in keeping with Germany's large share of the programme. Among the European participant countries, Germany is making the largest relevant contributions for ISS operations and for the ESMs, with a financing share of over 50% for both categories. In many cooperative efforts, Germany is functioning as a developer, system integrator and operator, in cooperation with many highly specialised SMEs that serve as reliable partners. The many activities and missions planned are opening new opportunities for SME participation in lunar exploration in the coming years.

The International Space Station (ISS) continues to serve as the basis for astronautics and international space exploration. In addition to their potential for technology transfer and applications on Earth, research and technology development under space conditions are playing an increasingly important role in addressing numerous questions that relate directly to the feasibility (including commercial feasibility) of manned and robotic exploration. This applies especially to the study of the health impacts of astronaut missions (for example, via cosmic radiation and micro-gravity); such study enhances our ability to assess such risks and protect astronauts against them more effectively. Other examples include combustion research (fire safety), life support systems, non-invasive medical diagnostics, in-situ resources use (ISRU), in-orbit refuelling, energy-storage systems, autonomous control of experiments and vehicles, and dust control.

All of these areas involve technologies that could be used on the future Lunar Gateway. The Lunar Gateway space station, which is being jointly planned by the U.S., Japan, Canada and Europe, is to be placed in a lunar orbit, where it will serve as a logistics hub for the further exploration and development of the moon and beyond. The companies that will share in development of the space station modules, via Germany's commitment, will mainly be SMEs.

In addition to participating in the Gateway, Europe plans to play an important role in the ongoing exploration of the moon and its surface. Germany and Italy are the two countries with far

and away the largest shares of the newly initiated European Large Logistics Lander (EL3), which is known as the "Argonaut." The lander's first mission is to take place by 2030. The lunar lander system is supporting Europe's strategic sovereignty in connection with its lunar exploration activities, while also strengthening its international partnerships. In the framework of these international partnerships, an opportunity is seen to put a European astronaut on the moon, and this provides an exciting and inspiring perspective for German astronauts.

In exploration of Mars, robotic missions will first prepare the technological capabilities and scientific studies needed for possible European participation in manned exploration of Mars. These missions include the Japan-led MMX mission, which will explore the Martian moons; the Rosalind Franklin Rover mission being planned via ESA; and the joint NASA/ESA Mars Sample Return mission, which is scheduled for the second half of this decade, and to which Germany will contribute scientific payloads and robotic technologies.

In the new lunar missions, and in missions to other celestial bodies, exploration and use of space resources (regolith, water, strategically favourable locations) will begin to play an important role. In general, all such resources are available only in limited quantities, and this holds the potential for conflicts between different forms of use and between various actors. Since space and the relevant celestial bodies are seen as a common space belonging to the international community as a whole, and as a space beyond any national laws, exploration and usage of resources in that space can only be governed by international law. To study this issue, the UN COPUOS legal subcommittee, acting with key input from Germany, established a "Space Resources" working group. A supporting international conference on space resources is planned for 2024.

Aims and measures:

- With its significant participation in exploration activities, Germany is pursuing four aims: **International cooperation**, development and use of **cutting-edge technologies**, **scientific research** and **human inspiration**.

- We want to promote the further development of robotic lander systems and of innovative methods and mobility concepts for **in-situ exploration** of planetary bodies – primarily the moon and Mars. Germany is seeking to play a leading role especially in connection with the robotic logistics for lunar exploration with the EL3 Argonaut lander system.

- We want to use the **European Service Module (ESM)**, for which Germany is taking responsibility, as our contribution to manned exploration of the moon.

- We are supporting our **German ESA reserve astronauts** as they make their way into the ESA Astronaut Corps.

- To position Germany as an attractive partner in space exploration, we are concentrating on selected, promising **key technologies**, such as robotics and artificial intelligence.

- In the United Nations framework, we are supporting efforts to bring about suitable international **regulation of activities on other celestial bodies**. For example, we want to work with our international partners to establish a legally watertight basis for sustainable, ethical use of space resources and for mining in space.

KEY PROJECT:

(11) A return to the moon, via international partnership

With the European Service Modules being built in Bremen, Germany is making an essential contribution to the Artemis missions, via which humans will return to the moon's surface for the first time since the 1970s. Also, Germany is participating intensively in the robotic logistics for lunar exploration, and it plans to play an important role in connection with the EL3 Argonaut lander system. With these efforts, we want to promote robotic lander systems at the ESA level, strengthen German space robotics and its potential for transfer into other industrial sectors, and reinforce our partnerships in international exploration.

2.9 Space activities in the context of recruiting and attracting talent

Every year, student competitions such as the REXUS/BEXUS competition of the German Space Agency at the German Aerospace Center (DLR) bring out young, dedicated talents who work day and night on their experiments.

Perspectives on space activities have changed profoundly in recent decades. During the Cold War, space programmes were seen as a battle for supremacy between the U.S. and the USSR. Now, the space sector comprises an infrastructure that is constantly in everyday use, and it has become a dynamic economic sector.

The growing importance of space activities is also apparent in the increasing number of public-sector agencies involved in them in one way or another. The importance of systematically good communication between the various government departments, and between the Federal Government and the Länder – as is already practiced in the area of the basic Federal/Länder support provided for DLR – continues to increase, especially in connection with use of suitable instruments to address overarching interests.

Space activities and space exploration deserve greater public attention. Communication to the public needs to be transparent, and it should highlight the benefits of space programmes for society. In addition, targeted funding needs to be provided for vocational and academic education and for research. In light of demographic trends, and of the worsening shortages of skilled labour, the fascination that space programmes, the universe and space exploration can trigger must be seen as a valuable means of interesting young people in careers in STEM (science, technology, engineering, mathematics) subjects. In the process, we need to build on experience gained in public relations and in measures such as "Science Year 2023 – Our Universe." Increasingly, space programmes, and especially the NewSpace sector, are attracting graduates of programmes in unrelated areas, and thereby creating a need for continuing education and training. In the process, a new pool of interested young people is emerging that has the potential to increase diversity in the space sector.

If more people become interested in, and excited by, space programmes and space exploration, urgently needed new talents can be recruited for the task of moving future developments forward and facilitating the further growth of Germany's space sector.

It is time for the space sector to gain greater public attention, to highlight its own added value – and, thereby, to create excitement. Civil society and the many different interest groups it contains can contribute – and want to contribute – input and ideas. In general, there needs to be an open, constructive dialogue involving all stakeholders. When more people are fascinated by space, more people will support the sector, and better use can be made of the space sector's potential to address our shortages of skilled labour.

Aims and measures:

- We want **to raise public awareness of the space sector's importance** and, in our public communications, highlight the space sector's value for humanity and our planet. The challenges that the space sector will face in the coming years – such as balancing the need for greater sustainability with the need for sectoral growth – need to be discussed, along with the reasons why the sector is now so indispensable.

- To reach as many people as possible, we are working with media multipliers, supporting programmes such as DLR_School_Labs, which provides locations at which school pupils can carry out their own experiments and discover many exciting aspects of space exploration, and making use of a broad range of communications channels and formats, such as the Space Agency's Space2School.de schools portal.

- We plan to make **decision-making processes** relative to German space activities more transparent and participatory. To that end, we are strengthening dialogue with users in the space sector's downstream application areas – for example, via programmes such as the Copernicus network offices for the areas of transport, municipalities and forests, which complement the established channels for involvement by space-sector stakeholders.

- With the expertise of the Space Agency at the DLR, we are supporting establishment of **formats for exchanges** between space-sector actors – especially between the NewSpace sector and young researchers, and between space-sector policymakers and space-sector actors.

- We want to increase the participation of **women in the space sector**, on all levels. We are doing this via a holistic parity and diversity concept that addresses the needs of stakeholders in science and industry, consolidates existing measures (such as Girls' Day, Networks, Cascade Model) and develops new measures (such as measures for reaching out to girls and young women regarding the space sector and efforts to increase the visibility of women in the sector). In this context, female role models, such as Nicola Winter and Amelie Schoenenwald, the first German women to enter the ESA Astronaut Reserve, play a central role, especially in light of the need to do away with all stereotypes in career choices for girls and young women.

- We are participating extensively in measures to **address shortages of skilled labour**, with a view to highlighting the attractiveness of the German space sector. Also, we are addressing short-term shortages of qualified personnel by supporting measures for immigration of skilled people. In addition, via its STEM Action Plan 2.0 (MINT-Aktionsplan 2.0), the Federal Government is strengthening **STEM education** throughout the entire educational chain (STEM – science, technology, engineering, mathematics). The Federal Government is also supporting **training and further training** in this area, and in applications based on the space sector, for all age groups. The space sector is expected to profit from the Federal Government's cross-sectoral measures in this area (the Federal Government's skilled-labour strategy, amendment of the Skilled Immigration Act (Fachkräfteeinwanderungsgesetz), Alliance for Initial and Further Training).

KEY PROJECTS:

(12) Explaining the space sector

(a) Via dialogue with schools of journalism, universities, editorial staffs and institutes for continuing education in journalism, we are developing options for raising awareness about the space sector.

(b) Via the Space Agency, and in cooperation with it, we are intensifying public relations regarding the space sector. In the future, a fixed share of funding for space projects will go to outreach activities and science communication.

(c) We continue to support school and university programmes (such as SchoolLabs, REXUS/BEXUS, STERN, Überflieger ("high achievers") and the small-satellite programme for universities ("Kleinsatellitenprogramm")) that give young researchers practical, hands-on access to the space sector.

(13) Experiencing the space sector

At numerous locations throughout Germany, visitors receive the opportunity to become acquainted with the space sector and its value for society. These places for encounters include the following: research institutions, locations of ESA, EUMETSAT and DLR, industry companies, trade fairs and science centres. We are aiming to make such places for encounters even more visible and accessible for the general public.

(a) To this end, the Federal Government plans to sponsor a German Space Day in 2025: All space sector locations in Germany will open their doors to the public for a day, to give an idea of the diversity and broad regional distribution of German space-sector locations throughout all German Länder.

(b) Also, the INNOspaceEXPO "ALL.täglich!" exhibit will be expanded, and presented at publicly accessible locations.