

Denmark's national space strategy

Update of strategic objectives



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Preface by Minister for Higher Education and Science

Space-based infrastructure in support of green transition.

Every day, space technology and satellite services contribute to making life on Earth better, greener, and more secure. For man and society.

Satellite data help the IPCC - UN's Intergovernmental Panel on Climate Change predict climate development, and they support the global community in attaining the UN Sustainable Development Goals. Authorities use satellite data to protect our nature, climate, and the environment when monitoring emission targets and pollution, and when regulating agriculture and fishery. Cities use satellite data to design smart and sustainable cities capable of handling the increasing climate challenges. The business community uses satellite data to develop new digital solutions, the transport sector to optimise logistics and route planning, and the defence sector to communicate and get an awareness of our territory and possible risks.

With its global scope, high degree of digitalisation, and technological development opportunities, the space sector is particularly suitable for assisting Denmark and the world on the path towards green transition. When space is to unfold its potential in the green transition, research, innovation, and development are called for. These capabilities and competences are already present in Denmark, but they can and must be focused and enhanced even more.

Denmark got its first national space strategy in 2016. The strategy has helped us set a clear direction for the space sector, gather the national space environments, and support growth and public service. We



will now update the objectives of the strategy with a strong green profile in order to support the contribution from the space sector to an agenda with which the ability to aim for a green transition will be defining for our entire society and economy.

I would like to convey my thanks to all authorities, knowledge institutions, businesses, and others having created with their expertise, inputs, and ideas a broad foundation for the updated objectives.

Yours faithfully,
Ane-Halsboe Jørgensen

Executive summary

Five new objectives in Denmark's national space strategy will show how space-based technology and infrastructure contribute and support opportunities and potentials in relation to reduction and climate targets, smart cities, an efficient digital public sector, green value creation, as well as security and contingency preparedness.

Space-based data, information, and infrastructure today are of a quality that supports solutions within a large number of societal challenges. For a long time, satellites have supported our ability at the national and international levels to observe weather, climate, and climate change, communicate over large distances, and navigate safely afloat, ashore, and in the air. Increasingly, we use satellites to protect our nature, environment, and biodiversity, identify the best location of renewable energy sources, or monitor and control fishery, agriculture, forestry, and enforce the sustainable use of our natural resources.

More and more, satellite-based information will be important in attaining smarter and more sustainable communities and cities. In other words, how we handle increasing requirements for a circular and sustainable economy, but also how we warn about and handle extreme weather situations and climate change, avoiding loss of values and human life.

A large number of functions crucial to society depend increasingly on knowledge, data, and services from satellites, and these services are increasingly important to our economy, sustainable growth, and development. The security of supply of these systems, therefore, is a key aspect. The more integrated space-based services become in our everyday lives and economy, the more vulnerable we are to possible outages of these services.

Also, there is an increasing focus on the importance of space for the security of the Kingdom, its sovereignty and contingency preparedness, not least in the Arctic.

In combination with an increasingly digital society and an economy where the capacity for handling and reacting to large data quantities is decisive, space-based solutions contribute with relevant data, communication, along with timing and navigation. A contribution qualifying the data basis on which decisions are made. The space contributes in this way to knowledge about climate and climate change, optimisation and control of environment and resources, protection of values, and our common security.

Already back in 2016, Denmark's national space strategy captured the importance of satellites for a number of aspects of our societal development, but not all. The time has now come to look into the objectives of the strategy in order to adjust the framework for Danish exploitation of space in the coming years in a green, digital, sustainable, and security perspective.

To capture the opportunities of space to the benefit of Denmark, five new objectives have been identified to set the direction for Denmark's space initiatives in the future.



Space-based infrastructure and data will contribute to more and better knowledge about climate, environment, nature, and biodiversity

The space sector contributes with a significant part of the knowledge we have about the Earth's climate and state - and in the future it will contribute even more with data and digital infrastructure supporting researchers, businesses, and authorities in finding sustainable and cost-effective solutions to the challenges we are facing within climate, environment, nature, and biodiversity.



Space-based infrastructure and data will contribute to smarter and more sustainable cities

On a daily basis, space contributes with information and services supporting a smarter, better, and more digital daily life for cities and citizens. Space-based data and services in the future will to an even higher extent support the need of cities for smart solutions within transport, digitalisation, circular economy, climate adaptation, and environment.



Space-based infrastructure and data will contribute to better and more efficient public service

The use of data from satellites contributes to the digitalisation of public service at national, regional, and local levels. In the future, space-based information and services will further support the potential where satellite data are a substantial part of the solution for control and monitoring of the implementation of national and European targets within environment, climate, nature, and biodiversity.



Space-based infrastructure and data will contribute with further green value creation

Space-based technology and competences contribute with growth and value creation within the green transition, including climate adaptation and reduction targets. In the future, space-based technology and infrastructure will contribute further to increased use of green technologies and digital solutions in Danish industry to the benefit of Denmark and Danish exports.



Space-based infrastructure and data will contribute to higher and better security and contingency preparedness

Still more tasks of crucial importance to society depend today on space-based systems being accessible, resilient, and reliable, and in the future the systems will contribute to further security and contingency preparedness, not least in the Arctic. By using satellites, the Danish Defence and other authorities can become better at handling extreme weather and natural events, rescue operations, enforcing safety in the air and at sea, and enforcing the sovereignty of the Kingdom.

Five new strategic objectives

Five new objectives will create the impetus in the future for the contribution of space to the green transition, climate challenges, digitalisation, and the need for increased security and contingency preparedness.

To capture the opportunities of the space sector to the benefit of Denmark, five new objectives have been identified as a follow-up to Denmark's national space strategy from 2016 to set the direction for Denmark's space initiatives in the future.

New strategic objectives not only demonstrate the willingness to set a direction, but also the aim to opt for long-term opportunities and potentials. Opportunities and potentials, by nature, develop and change over time. For that reason, every objective will be followed up by a number of focus areas creating an opportunity for a concrete, but over time also flexible follow-up and action plan. The Interministerial Space Committee in its annual reports will follow up on objectives, focus areas, and derived initiatives, and the Committee will make current evaluations of these elements.

Common to all objectives is that they will only be attained through continuous development, research, and innovation efforts. Therefore, the objectives must be read and understood as a supplement to, for instance, the government's green research strategy, a national strategy for dynamic data based on satellite navigation, climate objectives, and other sector strategies, action plans, etc.

Traditional space research disciplines such as exploration of our solar system, including the Moon and Mars, manned space flights, astrophysics, and astronomy are not neglected and will continue to be an important and central part of the Danish membership of ESA. The update of the strategic objectives, however, will focus on the direct and immediate societal value of space-based systems that call for broad cross-sectoral backing.

Ministries in the Interministerial Space Committee





European space-based infrastructure

Many years of investments in development, establishment, and launch of space-based infrastructure by, among others, the EU, EUMETSAT, and ESA have created the framework for space today contributing to more green transition, sustainable economic development, and higher security. A large number of European and international satellite systems and services make data available against payment or for free. In the following the most important European actors and systems are presented in which Denmark as a member state plays an active role and has full access to data and services from these systems.

European space activities

In the EU financial period 2021-2027, most EU space activities are gathered in a new overarching space programme. The programme covers the existing programmes of Galileo, EGNOS, and Copernicus, but also new initiatives such as GOVSATCOM having focus on safe communication for authorities, and SSA dealing with the safe use of space. Generally, the use of European space systems is open and free in order to stimulate use and growth; however, a number of services are reserved for particularly safe and reliable use by authorities.

The ambition of the programme is to maintain the role of the EU as a global leader, stimulating

European research, innovation, technological development, and growth. In particular, there is a larger focus on start-ups and SMEs in view of diversifying the space economy in the EU Member States and over a broad spectre of applications.

The European Space Agency, ESA, has developed and designed EU's two space infrastructures: the Earth observation programme Copernicus and the navigation satellite system Galileo. Together, the two systems are assessed to cost more than DKK 125 billion. ESA also develops meteorological satellites for EUMETSAT, the European Organisation for the Exploitation of Meteorological Satellites giving access, among others, to weather and climate data to the Danish Meteorological Institute.

The EU assesses that more than 10% of the EU's total GDP is to some extent depending on satellite navigation. In 2019, London Economics assessed that 23% of Danish GDP is created in sectors dependent on global navigation satellite systems (GNSS).

Through our EU membership and Danish memberships of ESA and EUMETSAT, Denmark is therefore already contributing to the large shared infrastructure made up by the satellite systems. These systems will have to be updated and replaced regularly, but Denmark contributes proportionately through our memberships and will not have to pay separately for development, launch, and access.



Sentinel-5 under the Copernicus programme consists of a spectrometer carried by meteorological satellites of the type MetOp Second Generation. Sentinel-5 will supply data on the composition of the atmosphere from a polar orbit around 800 km above the surface of the Earth.





European space organisations, agencies, and infrastructure



EUSPA

EUSPA - European Union Agency for the Space Programme - is the EU agency for the overarching space programme in the EU. In addition to Galileo and Copernicus, EUSPA will also be responsible for GOVSATCOM, developing safe communication for public authorities, and Space Surveillance and Tracking (SST), observing and tracking objects in Earth orbit. In the period 2021-2026 the EU space programme will have a total budget of more than DKK 108 billion.



Copernicus

Copernicus is one of the most sophisticated Earth observation systems in the world. Copernicus supports a large number of societal functions within, among others, climate, safety, transport, health, environment, agriculture, and fishery. Copernicus builds on a constellation of satellites taking advantage of a global network of thousands of land, air, and marine-based sensors to create the most detailed pictures of Earth. Copernicus is the largest space data provider in the world, currently delivering 12 terabytes per day.



Galileo & EGNOS

Galileo, comparable to the US GPS system, is the EU's global navigation satellite system (GNSS) giving exact information about position, navigation, and timing. Galileo is used in a broad range of applications: improving the quality of navigation data for vehicles, in the use of autonomous systems, optimisation of marine and land transport, and in mobile phones. Galileo is close to being finalised. The constellation today consists of 26 satellites, with four more on their way. Galileo will regularly provide new services paving the way for new applications. EGNOS, a sub-programme of Galileo, is used to improve the performance and reliability of GPS signals, for instance in connection with precision approach for aircrafts in controlled airspace, and in a longer-term perspective also to verify Galileo signals.



ESA – Den Europæiske Rumorganisation

In 1975, Denmark was a co-founder of the European Space Agency ESA that has focus on scientific exploration of space as well as development of space technology within all spheres of the space sector, including astronomy, astrophysics, human space flights, exploration of Mars, launchers, communication, navigation, and Earth observation. Denmark's contribution in 2021 amounts to DKK 238 million of the total ESA budget of some DKK 42 billion.



EUMETSAT – European Organisation for the Exploitation of Meteorological Satellites

Denmark is a member of the intergovernmental organisation EUMETSAT that assumes the operation of a system of meteorological satellites. Around the clock, the satellites provide weather and climate data to the meteorological services of the Member States, including the Danish Meteorological Institute. EUMETSAT participates in Copernicus with data from own satellites, and the organisation is also entrusted with the exploitation of those Copernicus satellites that monitor atmosphere, ocean, and climate. At present, EUMETSAT has 30 Member States. EUMETSAT has an annual budget of DKK 3.6 billion; in 2021 the Danish contribution amounts to DKK 63.5 million.



The picture has been taken by ESA astronaut Thomas Pesque on 27 March 2017 from the International Space Station, and on social media it was posted with this text: "We also have auroras in Europe (and they are the best auroras, it is true): a bit to the north, though. The big city in the foreground is Warsaw, and over there I see Copenhagen ".



With its global scope, high degree of digitalisation, and technological development opportunities, the space sector is particularly suitable for assisting Denmark and the world on the path towards the green transition. When space is to unfold its potential in the green transition, research, innovation, and development are called for.

- Ane Halsboe-Jørgensen, Minister for Higher Education and Science

Objective 1

Space-based infrastructure and data will contribute to more and better knowledge about climate, environment, nature, and biodiversity.

The space sector contributes with a significant part of the knowledge we have about the Earth's climate and state - and in the future it will contribute even more with knowledge and digital infrastructure supporting researchers, businesses, and authorities in finding sustainable and cost-effective solutions to the challenges we are facing within climate, environment, nature, and biodiversity.



A substantial part of the digital infrastructure of our society is provided by systems such as Galileo and Copernicus. Through research and innovation based on the daily monitoring of the state of the Earth and reception of precise positioning and time signals this infrastructure can be turned into green solutions for the challenges we are facing within climate, environment, nature, and biodiversity.

Satellites can designate the most suitable lowland soils in agriculture to be set aside

In 2030, agriculture will account for around one third of Denmark's emissions, unless mitigating measures are introduced. The most significant greenhouse gases within agriculture are nitrous oxide and methane. One of the most cost-effective instruments for the reduction of greenhouse gases within agriculture is setting aside and flooding lowland soils. However, the lack of knowledge about the water level in Danish lowland soils is a substantial barrier. Earth observations from satellites have the potential to survey and monitor the content of nutrients and water in soil along with its ability to bind carbon, thereby contributing to the identification of the most suitable lowland soils.

Satellites can provide the data basis for a holistic regulation of environment, nature, and climate

A more intensive use of Copernicus Earth observation data opens new opportunities for mapping soil and nature. Satellite data are generally suitable as a basis for data in a global and holistic regulation of natural resources, taking into account climate, environment, nature and biodiversity. By contrast to random sampling, which is manual, geographically limited, and relatively cost-intensive, satellite data are often free, large-scale, and often updated on a daily basis. Using Earth observation data from aircrafts and satellites as the basic input to the models, it will be possible in theory to establish a high-resolution monitoring model of all natural resources and ecosystems in Denmark. In a longer-term perspective, it will enable researchers and authorities, almost in real time, to provide input to decisions on expedient regulation and its effects on the government's targets within climate, nature, environment, and biodiversity.

Satellites are being put to use in agriculture, but their potential is far from being fully exploited

The use of satellites already contributes to the green transition and digitalisation in agriculture through development of precision farming. Digital satellite images from Copernicus in combination with Machine Learning and AI algorithms enable the farmer to monitor the state of his crops and to

precisely plan the real need for fertiliser, water, and pesticides on his fields. The use of these agents can be optimised and thereby reduced by using machines whose position on the field is established using navigation satellites. In the next few years, you can get access through Galileo to a so-called High Accuracy Service providing free of charge satellite navigation data with an accuracy of at least 20 cm. In addition, present and future satellites can also be used to evaluate the drought rate in soil and crop and to contribute to a prioritisation of, for instance, watering needs. Even if agriculture is starting to use this technology, still very few exploit its full potential, when Earth observations are combined with precision technology: While 24% of farms are using navigation satellites for more precise runs of tractors or harvesters, only 4% of farms are using satellite images to produce more precise maps as a basis for applying fertiliser and pesticides.¹

Satellites optimise transport routes and can build a bridge to the green fuels of the future

In Denmark and globally, transport activities are increasing and will do so for many years ahead. In Denmark, the transport sector is expected to account for around one third of Denmark's total greenhouse gas emissions in 2030. The development and dissemination of new fuel technologies are expected to last for many years, and therefore in a short-term perspective there is still a potential for exploiting space infrastructure to optimise logistics and energy consumption in the transport sector, thereby reducing greenhouse gas emissions. In the logistics sector, 64% are already using satellite-based positioning services². While in the longer-term perspective personal transport is expected to be dominated by electric vehicles, it is not possible in a foreseeable future to use electricity as a propellant in heavy road freight transport, nor for ships and aircraft for transport over long distances.

A preliminary estimate has shown that a national data sharing infrastructure in combination with algorithms and a precise real-time positioning through satellites holds the potential to reduce emissions from road freight transport by 20-30%, creating the basis for strengthening the international competitiveness of the Danish transport sector through digital innovation³.

The energy consumption of ships can also be reduced by up to 5%, if the sector improves in using satellite measurements of ocean currents, waves, wind, and water level/depths in the existing models for calculation of the most optimal routes. Within air transport there is also a potential for substantial optimisation of routes, thereby improving energy efficiency.



We can reduce emissions from trucks and light goods vehicles by 20-30% through the development and dissemination of intelligent route and freight planning models if we combine the latest digital technology with our space infrastructure⁴.

Satellites reduce costs for investments in renewable energy and energy efficiency

Wind and solar energy are expected to provide the largest contributions within renewable energy in the coming 30 years in Europe and at the global level. Satellite data can contribute to reducing the costs for this gigantic transition of the energy generation and consumption of the world. Today, for instance, the uncertainty is at 10-15% if you want to forecast the electricity generation of a wind turbine using mathematical models. Earth observations from satellites can better distinguish between different types of landscape, thereby designating more precisely the most promising locations of new wind farms ashore. The reason is that we do not have the right tools to distinguish between, for instance, surrounding forest lands and flat lands, so we assess the features of the landscape manually. At sea, satellite data can also be used to identify the best locations of new offshore wind farms, just as satellite data can be used to find the geologically optimal locations of geothermal facilities or safe underground storage of CO₂. In the future underground carbon storage, Earth observations can monitor surface movements, just as it has been done for gas storage and mining. Our entire energy consumption is increasingly based on renewable energy, but there will still be a potential for lowering costs of the green transition by exploiting energy more efficiently. High-resolution weather data from satellites can contribute, among others, to lower the costs of energy efficiency measures for new building projects and existing buildings, when more precise weather data allow for an adaptation to the local outdoor climate. Historic files with local weather data will also allow for the establishment of more precise assessments of the residual service life of building and construction structures.

Satellites develop our global climate models and will soon designate emission sources on the Earth

So far, total carbon in the atmosphere has been measured without experts being able to distinguish between natural and anthropogenic emissions. In 2025 we will see the launch of the first of three Copernicus satellites that make it possible to identify the sources of emissions of greenhouse gases; this will be an important supplement to national measurements of air pollution. In addition, satellite data and Earth observations can increase the quality of the existing data basis for Denmark's accounts of emissions and carbon sinks in soil and forests as a supplement to manual point measurements.

It is expected that actual emissions can be based on or at least be verified by precise satellite measurements. Thereby, international climate negotiations can rely on a better data foundation. The Paris agreement is based on climate model analyses of the future global temperature rises, and these analyses will continue to be dependent, among others, on Danish researchers' studies of e.g. sea ice melting in the Arctic and a large number of other critical climate variables in order to forecast climate change. Uncertainties associated with the climate models mean that there is also a need for new types of observations from satellites and space-based observatories, and these data are essential for, among others, the IPCC. To better understand developments in the Planet's climate there is a need, among others, for observing and studying the Earth's cloud cover, thunderstorms in the atmosphere, marine heatwaves, and not least developments in the polar regions. Knowledge about the atmosphere of other planets can furthermore contribute with important knowledge, for instance about how the greenhouse effect on Venus has run amok.



The world's first energy islands are to be built in Denmark to exploit our large wind resources in the North Sea and the Baltic Sea.

Satellites provide us with knowledge about how best and most cost-effectively to adapt to climate change

The development of climate models and their validation is decisive for our ability to forecast the magnitude and speed of climate change that may potentially lead to major destructions. Knowledge about the frequency of torrential rain, for instance, is decisive for the magnitude of investments in sewers and infiltration facilities in cities or the safeguarding of crops. This is essential knowledge that can also be used in countries with far more extreme weather events than Denmark.

To focus investments to local conditions it is necessary to supplement global climate models with satellite observations. For instance, there is a need for observations of water level and wave height in coastal areas to calculate which areas are at risk of flooding. Ashore, there is a need for observing topography changes and mapping the interaction between groundwater and surface water to better forecast flooding due to more frequent torrential rain events. Changes in slope and paving of the soil surface in addition have a large impact on the construction of facilities for local infiltration of rainwater or the construction of supply pipes and other major infrastructure

projects. In these cases, exact terrain models generated from aircraft and satellites are decisive. Earth observations can also provide new knowledge about coastal development, settlements, and rises of the sea level, where forecasts are crucial. More, better, and more frequent satellite observations will lead to a more efficient exploitation of the resources allocated in society to climate adaptation.

In addition to measuring the wind energy potential, Earth observations can support the EU objective of the establishment of 20 times more marine wind turbines by 2050. Satellites can support the allocation of new marine areas for the expected expansion in and outside Danish waters.





Focus areas

1

Prioritisation of green space programmes and missions in the EU, ESA, and EUMETSAT

Denmark primarily contributes to the space-based climate research and establishment of space infrastructure through contributions and appropriations to the EU, ESA, and EUMETSAT. It is expected over the next ten years that the number of satellites and missions - and thereby application opportunities - will increase significantly and give new and better opportunities for using satellites in the green transition in Denmark and in the climate monitoring of the Arctic. Therefore, Denmark will in the EU, ESA, and EUMETSAT work with focus to promote programmes and missions supporting directly or indirectly Danish interests, the green transition, and observations in the Arctic.

2

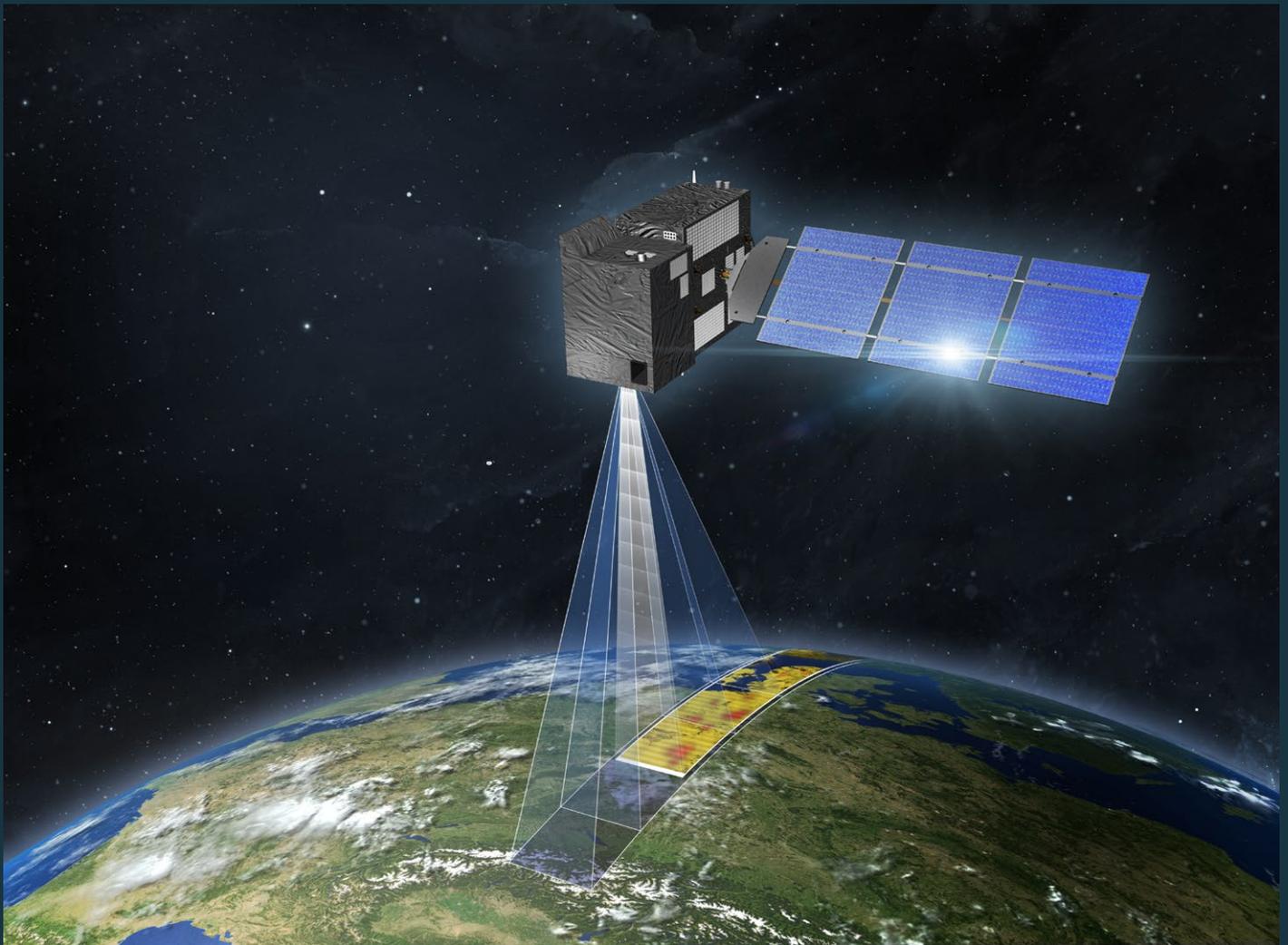
More knowledge about the importance of satellite data in the attainment of the government's climate, nature, environment, and biodiversity targets as well as the UN Sustainable Development Goals

To release the potential and other positive effects of the space sector in future green and digital strategies, including action plans and partnerships, a further uncovering of the sector's contribution in the attainment of the government's climate, nature, environment, and biodiversity targets as well as the UN Sustainable Development Goals is called for. Elements in question here are the documentation of reduction potentials and other green benefits through new analyses, mapping of data and data compilations needed, data already available, and how data can be made available and mature for contributing to new green solutions and cross-cutting measures.

3

Support to government's green research missions

The space sector has the potential to support the attainment of the government's green research missions, and for that reason, among others, it is decisive that data, technology, and research in the space sector are matured and brought into play in an efficient manner. This may be realised, for instance, through proposals for road maps and participation in the large green partnerships that are to be developed over the next years as part of the implementation of the government's green research strategy. It is an important precondition that actors in this field - be it researchers, businesses, or public authorities - can start cooperating early on regarding definition, description, and documentation of concrete proposals for space-based solutions in large scale. It may therefore be necessary to accelerate the decisive maturing and cooperation process; this can be done, for instance, together with the environments by investigating the opportunities for the establishment and by supporting small space-based partnerships that can build on knowledge in the field, contribute to the development of road maps and green partnerships, and work as development and discussion partners for authorities and funds. Opportunities may be found within, for instance, remote sensing, traffic management, fisheries and aquaculture, wind energy, energy efficiency in buildings, marine transport, CCS and geothermics, clean water, and clean air.



ESA illustration of CO₂M measuring directly anthropogenic CO₂ emissions

Case Copernicus CO₂ missions (CO₂M)

In 2025, it is planned to launch the first of up to three Copernicus satellites that will make it possible to identify the sources of anthropogenic emissions of CO₂ from space. In pursuance of the Paris Agreement each country is to draw up national CO₂ accounts, and CO₂M is to provide data for this purpose. The missions will contribute to better climate monitoring and to the international climate negotiations relying on a better data foundation. Danish Terma supplies electronic components to the satellites in the form of a number of Remote Terminal Units - RTU that are used together with the on-board computer for monitoring and control of the satellite. The RTUs monitor and control, among other things, temperatures, sensors, valves, and many other functions onboard the satellite.

Objective 2

Space-based infrastructure and data will contribute to smarter and more sustainable cities

On a daily basis, space contributes with information and services supporting a smarter, better, and more digital daily life for cities and citizens. Space-based data and services in the future will to an even higher extent support the need of cities for smart solutions within transport, digitalisation, circular economy, climate adaptation, and environment.



Denmark is facing ambitious climate targets and growing challenges in the form of climate adaptation, demographic changes, and new shifts between rural and urban areas. This puts pressure on infrastructure and resources in an intersection between green transition, welfare, and development.

In the EU alone, 85% of the population in 2050 is expected to live in cities⁵; this sets enormous requirements for new smart solutions if cities are to develop in a healthy and sustainable manner. Furthermore, while cities only cover around 3% of the land, they emit up to two thirds of greenhouse gases⁶. Cities are also facing challenges such as climate adaptation, waste and wastewater management, health, housing, mobility, safety, air and noise pollution, as well as access to clean water, nature, and sustainable energy. Many cities are also located close to the sea, creating challenges during increasing sea water levels.

Satellites contribute with significant data for continuous digitalisation of cities

Satellites, drones, sensors, and IoT networks, etc. produce still more dynamic data and create new networks in the cities that can share information, among others, through 5G and satellites in real time. This paves the way for more resource efficient and innovative solutions through interdisciplinary, horizontal technologies such as quantum communication, digital twins, artificial intelligence, and block chain.

The access to data and knowledge about where mobile or dynamic objects are located at a given time will change our everyday lives significantly in the shape of more sustainable ways of solving tasks with new green business models and welfare solutions. This not only applies to scooters and shared cars in the expanding sharing and circular economy, but also to welfare products and products requiring authentication and certification, such as sustainable products and food.

Space-based technologies, such as the EU Galileo and Copernicus programmes and the ESA technology programmes, have a considerable application potential in the green digital economy ensuring the green transition of our urban spaces and concurrently creating a smarter and more sustainable development. Key technologies are monitoring, communication, navigation, and precise timing - they contribute continuously with relevant real-time data on weather, environment, climate, biodiversity, built-up areas, positioning, timing, authentication, geo data, and safe and reliable communication between units. The potential is found in the ability, in real time and through horizontal digital tools such

as digital twins, to combine, communicate, and act on this information to the benefit of sustainable development as well as citizens and authorities.

Already today, the space sector in the form of navigation and precise time indication is an integrated and necessary part of our society. The use of very precise timing, e.g. through the atomic clocks of the navigation satellites, is already a statutory requirement in some areas, such as time stamping of financial transactions. Timing is also used for the synchronisation of mobile networks and power transmissions. In 2019, London Economics assessed that 23% of Danish GDP is created in sectors dependent on global navigation satellite systems (GNSS). This share is expected to increase along with larger demand from new sectors and new challenges requiring the same accuracy and verification of time and place.

Satellite navigation is essential to sustainable transport and autonomous robots

Intelligent traffic management and logistics optimisation of goods in and around our cities will have a direct effect by reducing emissions, thereby also affecting air quality and our health.

In addition, congestion on the roads is an economic challenge for many cities. The Confederation of Danish Industry has assessed that congestion on Danish roads causes societal costs of DKK 25–27 billion a year⁷. In the same line of thoughts, the EU assesses that smart traffic navigation can lead to savings in the EU Member States of a total of EUR 20 billion a year⁸. Intelligent traffic optimisation, based among others on enhanced logistics processes, digital traffic simulation, and seamless public transportation in which satellite navigation is an essential element, can lead to a reduction in congestion on the roads and in the cities.

The possibility of accurate positioning indoors and in densely built-up areas where there is no direct coverage from navigation satellites is expected to hold a large potential.

One example of innovative use of precision positioning is found in the city of Aarhus where the Danish Agency for Data Supply and Efficiency in cooperation with DTU Space and the City of Aarhus have launched a research and development platform for precision positioning and autonomous systems (TAPAS⁹). TAPAS is a unique platform for accurate real-time positioning covering an entire city in real time, in which navigation signals from satellites combined with a number of local fix points give a very high accuracy. The platform can be used to test the opportunities and not least the limits

for, for instance, coupling positioning at centimetre level indoors and outdoors. Among others, this can support the further development of a technology that can support, in the longer-term perspective, autonomous drones and robots to deliver objects such as essential medicine etc. inside buildings.

Satellites create knowledge about essential climate adaptation and critical resources

Cities with their high degree of built-up and paved areas are particularly vulnerable to increasing precipitation, higher water level, and higher temperatures.

Satellite observations can help cities get the necessary overview in relation to meeting the most severe consequences of climate change and still comply with more stringent reduction targets for traffic and energy generation. A mapping of exposed areas helps cities in their risk mitigation by securing embankments, piers, ports, bridges, roads, and buildings so as to avoid loss and damage, for instance from flooding caused by climate change.

By an accurate mapping of critical, but also dynamic water resources, cities can better protect drinking water supply against environmental impacts from industrial activities, waste, and contamination from flooded sewers. In the same manner, knowledge about the dispersion of vegetation in the green oases of the cities is important in order to avoid so-called heat islands in the cities.

Even without climate change, satellite observations are beneficial to monitoring of built-up areas, roads, green fields, and underground infrastructure. Monitoring of land movements creates the opportunity to identify special areas with a special need for attention on underground pipeline networks. Current monitoring of infrastructure thereby saves resources since regular focused maintenance is cheaper than remediation of damages.

Denmark has more than 850 km² of reclaimed land of which large, low-lying areas are managed with a combination of embankments, drains, and regular adjustment of the water level. Urban areas, agriculture, and infrastructure located on reclaimed areas may see problems with land movements in or underground, which may cause heavy economic costs – also for maintenance.

By measurements based on InSAR data from the Copernicus satellites¹⁰ we can follow land movements (land uplift or subsidence) with an accuracy of millimetres.

This knowledge can be used in a large number of fields from area and urban planning, identification of lowland soils over planning of transport and utility infrastructure to research in geotechnical conditions in strata and foundation, and possible impacts on movements in periods of drought or torrential rain.

Detailed mapping of thermal discharge can identify a growing, and in some places obsolete building stock taking up much of the energy and heat consumption in the cities, while in a longer-term perspective the energy and heat distribution can be adapted to the city's peak loads based on real-time knowledge from satellites and IoT sensors.

Enhanced business potential for smart city solutions with space data

It is assessed that we have good export opportunities for green and smart urban solutions. The commercial market for new smart urban solutions was assessed in 2016 to be at US\$ 1.3 billion with an annual growth of 17 %¹¹.

In 2019, Denmark established ESA BIC Denmark, a Danish incubation centre associated with the Technical University of Denmark, Aarhus University, and Aalborg University; networking with other space environments and businesses all over Europe, ESA BIC will support new business opportunities based on space technology and applications, in particular the use of data from space. By coupling new applications of space technology with the ESA focus on strong business cases, a fertile soil is created for more sustainable start-ups and commercial opportunities. In addition, ESA BIC has the possibility to establish an 'ambassador role' matching, stimulating, and supporting the uptake of space-based knowledge and data in other sectors, including in the context of smart cities.

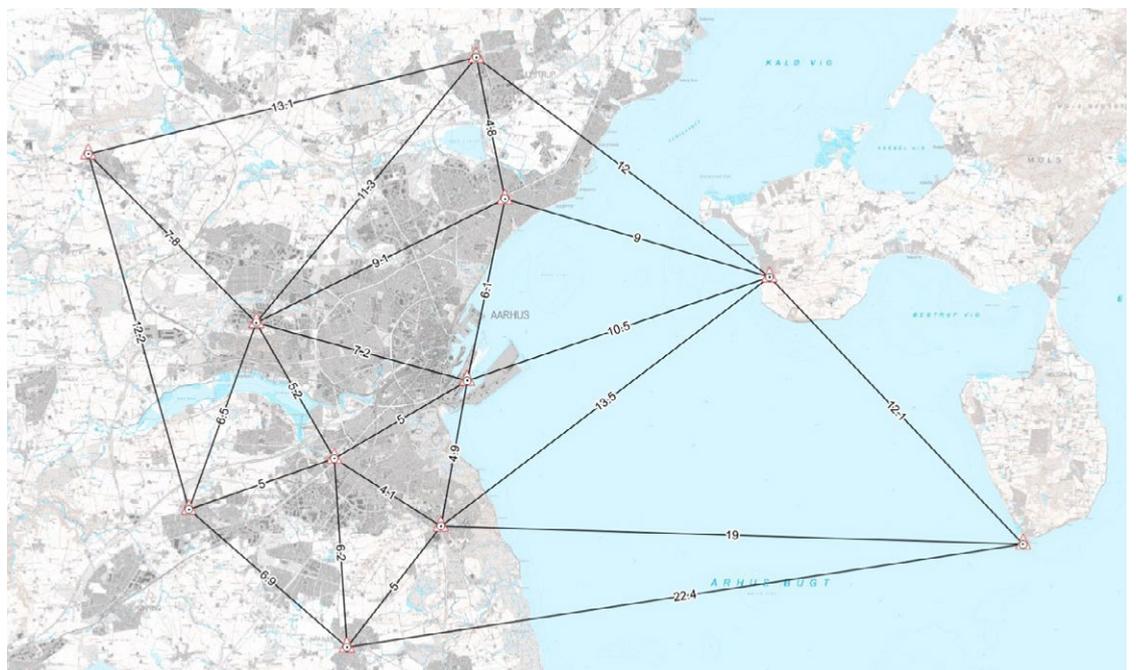


Smart cities and communities (i.e. both larger and smaller cities) are promising places for implementing the Green Deal objectives, as they strive for reducing resource consumption and pollution, adapting to climate change, and improving people's quality of life, using digital technologies and intelligent solutions.

- EU Green Deal



The TAPAS platform consists of a network of eleven reference stations improving data from global satellite-based navigation systems such as GPS and Galileo etc. (GNSS). With TAPAS the user will get an accuracy of a few centimetres in real time. This also applies to objects in motion. TAPAS offers the largest possible flexibility for the research and development of the next generation of networks of positioning technologies.



Focus areas

1

Supporting the uptake and integration of space-based data in smart sustainable solutions.

The space sector has the potential to support a smarter and more sustainable and digital development in all spheres of society, especially in cities where challenges and potentials in relation to reductions, resources, transport, and climate change adaptation are particularly large. In particular, the intersection between positioning technologies and Earth observation data in combination with sensors, timing, and IoT seems to hold a large potential. Instruments may be through increased knowledge and dissemination of technological and digital opportunities and potentials as well as mapping of key actors such as clusters, businesses, universities, and authorities.

2

Closer dialogue with key purchasers of data driven solutions.

Dialogue, awareness-raising activities, match-making, case catalogues, and projects between suppliers and purchasers can support this field and identify, among others, new commercial opportunities and solutions. The uptake of satellite-based information with key purchasers in the cities will be a significant contribution to a higher Danish digitalisation readiness.

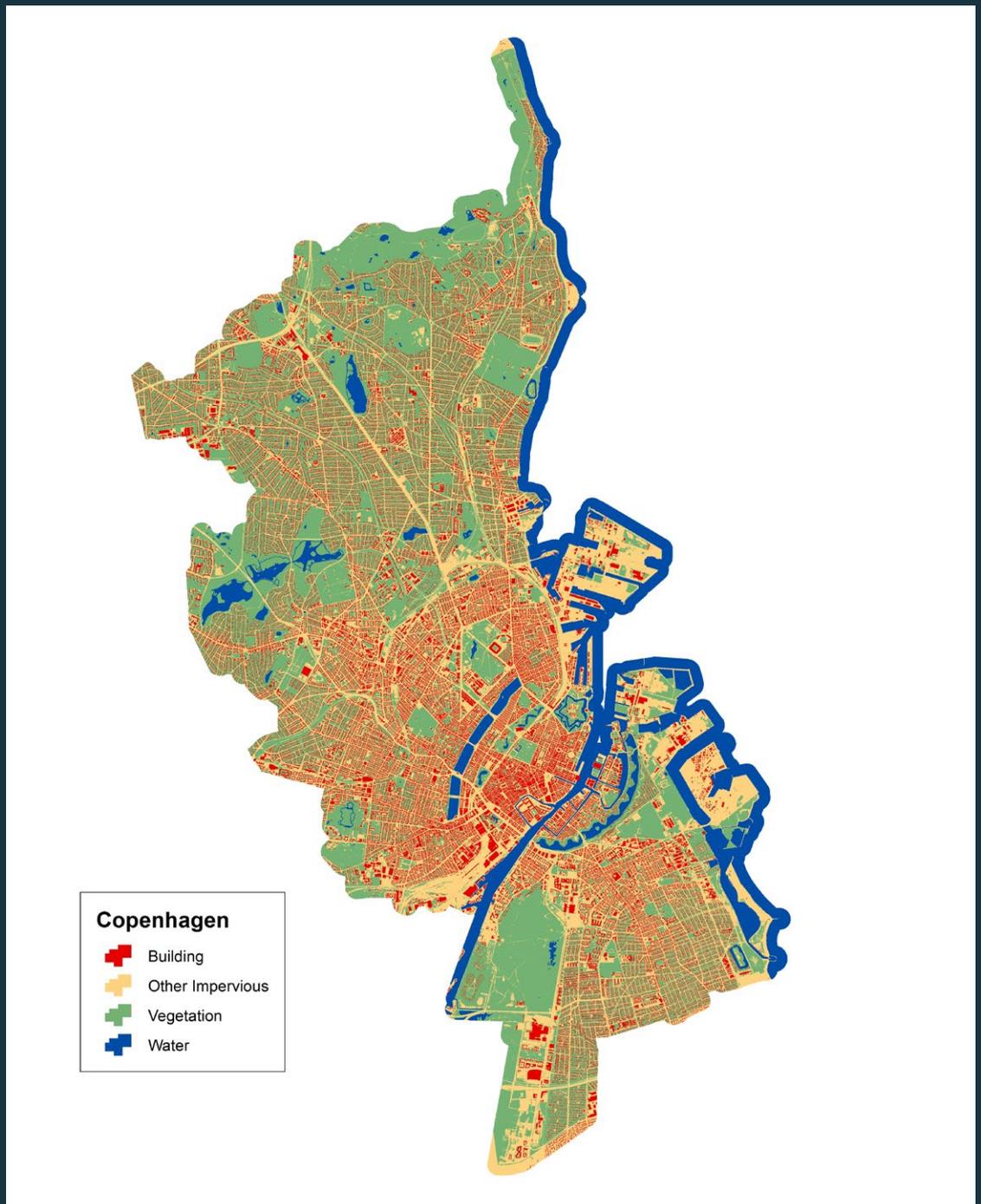
3

Supporting smart social solutions in the European space cooperation.

The space sector has the potential to support the attainment of the government's green research missions, and for that reason, among others, it is decisive that data, technology, and research in the space sector are matured and brought into play in an efficient manner. This may be realised, for instance, through proposals for road maps and participation in the large green partnerships that are to be developed over the next years as part of the implementation of the government's green research strategy. It is an important precondition that actors in this field - be it researchers, businesses, or public authorities - can start cooperating early on regarding definition, description, and documentation of concrete proposals for space-based solutions in large scale. It may therefore be necessary to accelerate the decisive maturing and cooperation process; this can be done, for instance, together with the communities by investigating the opportunities for the establishment and by supporting small space-based partnerships that can build on knowledge in the field, contribute to the development of road maps and green partnerships, and work as development and discussion partners for authorities and funds. Opportunities may be found within, for instance, remote sensing, traffic management, fisheries and aquaculture, wind energy, energy efficiency in buildings, marine transport, CCS and geothermics, clean water, and clean air.



Illustration by DHI Gras for the City of Copenhagen; built-up and paved areas in a section of Greater Copenhagen. Red areas are buildings and yellow areas are other types of paving. An updated overview of the degree of paving in urban areas and the composition of the city's areas is a key input in hydrological models.



Case Paving in urban areas

Paved areas are one of the critical parameters affecting the quality of water resources. Urbanisation has resulted in a higher share of paved areas. Roads, roofs, parking areas, pavements, etc. are a barrier for water infiltration and cause a higher runoff of rainwater; this changes the hydrological balance, the structure of critical habitats, water quality, and biodiversity in the water-based ecosystems.

Urban environments will continue to grow to make room for a growing population; this will lead to substantial changes of natural processes and the quality of the environment. Data from satellite-based analyses are essential to meet this challenge.

Objective 3

Space-based infrastructure and data will contribute to better and more efficient public service

The use of data from satellites contributes to the digitalisation of public service at national, regional, and local levels. In the future, space-based information and services will further support the potential in the field of environment and nature where satellite data can be a substantial part of the solution for control and monitoring of the implementation of national and European targets within environment, climate, nature, and biodiversity.



Digitalisation of the public sector in Denmark is a world leader according to the UN¹². Today, satellite data play a small, yet increasing role in the public digitalisation within control and monitoring of, among others, coastal protection, raw material extraction, agriculture, forestry, and fishery¹³. There is a particularly high potential for using satellite data to make control and monitoring measures in the green field more efficient.

Denmark as a frontrunner in the EU

Already today, satellite data contribute to the improvement and efficiency of a number of assignments for authorities, especially within control and monitoring of the environment, agriculture, fishery, sea farming, forestry, and raw materials. Satellites are used, among others, for the control of environmental permits for large installations and landfills, subsidy schemes within agriculture and forest plantation, fishery control, control of coastal protection, and increasingly also for environmental and nature monitoring. The Danish Environmental Protection Agency uses satellites today to monitor the state of the aquatic environment, when chlorophyll production is measured, and eelgrass is surveyed. The Danish Nature Agency uses satellites for monitoring of forest plantation, among others.

In its report from 2018¹⁴, the Interministerial Space Committee assessed that the positive development will continue along with the adaptation by Danish authorities to new EU requirements for satellite monitoring. Within agriculture and fishery, Denmark has been a technological frontrunner in the introduction of satellite-based monitoring and control. The Danish Agricultural Agency, controlling payments of EU farm subsidies, has increasingly

used satellite data over the last five years in their control; since 2019 the agency has operated a sophisticated nationwide satellite-based control of Danish agricultural land. Now the Agency is investigating how neural networks can be used for sophisticated image analysis to be used in the control of, for instance, small habitats and sub-fields.

We also see a growing interest from the utilities sector and local authorities in using satellite data to improve public service and make it cheaper. For example, Lemvig Water Utility in cooperation with the Municipality of Lemvig on the North Sea coast and the Coastal Authority has shown how satellite data can considerably reduce maintenance costs. The Municipality of Lemvig used satellite data in correlation with measuring stations on land to assess how and where land movements can stress underground pipes, so they break. This new knowledge has radically changed the way the utility maintains its pipes. Instead of replacing entire pipes in stretches where they often break, the pipes are now repaired on the spot, resulting in major savings. In the future, it is expected that it will be possible to prevent pipe damage caused by land movements thanks to the accurate designation of areas affected by such movement.

A green case for use of satellites in nature and environment administration

It is assessed that there is a particularly high potential for using satellite data to make control and monitoring measures in the green field more efficient. Compliance with the political objectives for a better protection of nature, environment, biodiversity, and climate not only calls for new regulation. Subsequently, Danish authorities will need to

Control and monitoring are key tasks for many Danish authorities at local, regional, and national levels. Authorities' monitoring and control takes place in many cases in the form of limited physical controls. This is often relatively expensive and inefficient, for authorities and businesses alike. A digital and automatic control using satellites can in many cases be a better and cheaper solution.

conduct an efficient control and documentation of Denmark's compliance with national and European targets within climate, environment, and nature.

The use of satellite data from the Copernicus programme in the EU - in combination with artificial intelligence and machine learning tools ensuring automated recognition of species and nature - can be a substantial part of the solution for Danish authorities. Denmark has access to large quantities of geographical information on, among others, land cover, land use, vegetation state, and water cycle. Subsequently, the same data can be used to focus the regulation and contribute to a better and more efficient target achievement.

In Greenland, satellite data constitute the main basis for new data and maps produced. These are applied broadly, not least as a modern, joint digital administration basis for authorities. Satellite data require accurate in-situ and reference data to be applicable, and satellite systems are also a source of new reference data. This is particularly the case in Greenland and the Arctic, where mapping bases, images, and geodata are often less accurate. The Greenlandic basic data programme is being established now, and it is totally dependent on accurate and up-to-date geodata, which can only be provided over large areas with satellite data.

If Danish businesses and knowledge institutions develop the right solutions, they can subsequently find a market globally. The market for satellite data is developing rapidly and is expected in 2023 to have a turnover of more than USD 86,000¹⁵. A large and growing part of this market will lie within the use of satellite observations to mitigate the problems we are facing within climate, environment, nature, and biodiversity. The EU is expected to invest massively over the next years in climate and environment as well as monitoring of nature and biodiversity. If Danish businesses are to attract these assignments, it is important that they get the opportunity to enter development projects with Danish knowledge institutions and authorities.

Barriers for more extensive use in public administration

A number of barriers have been identified for more extensive use of satellite data in public administration, where there is still room for a more efficient use of competences and resources across the remits of the authorities:

- Questions relating to access, quality, frequency, and accuracy of satellite data are treated in international organisations such as the EU and ESA.
- The use of satellite data in public administration calls for further education and/or hiring of competent staff with the right knowledge and understanding of the use of satellite data.
- Data and competences are dispersed over different authorities, and it is difficult to share them with other authorities.

“

Exact and continuously updated Earth observation satellite data provided by the Copernicus missions serve to improve and deepen our understanding of coastal change, for instance in relation to storm erosion, and it helps optimising measures for coastal protection and improved environmental monitoring.”

- Carlo Sørensen, Senior Advisor, Coastal Authority



“

In the Danish Agricultural Agency, we got the opportunity to rethink one of our key functions: control of the annual agricultural activity on the fields. We have made a paradigm shift from a very detail-oriented physical control of 5% of the fields to a satellite-based holistic view of 100% of the fields. The new control method is based on time series of images provided by satellites, and thanks to this almost the entire process has been automated, leading to major gains in efficiency¹⁶."

– Peter Ritzau Eigaard, Head of Unit, Danish Agricultural Agency





Focus areas

1

More and better knowledge about the value of digitalisation through satellite data

Through joint competence-building it is possible to lift and disseminate knowledge about the application opportunities in the Danish public administration and base tenders for solutions on experience from this new knowledge. Deeper knowledge about application opportunities across Europe may also inspire Danish decision-makers. Instruments may be pilot projects, publications, workshops, and courses for national and local authorities.

2

Cooperation with Danish businesses and knowledge institutions

To harvest the full potential of using satellite data as a constant significant part of the administration basis in Danish public administration, the future needs of authorities must be subject to development projects in which businesses, clusters, and knowledge institutions cooperate on demonstrating and developing solutions for how to combine, for instance, machine learning techniques with the huge data quantities available under the Copernicus programme. Instruments may be the active participation of authorities in projects in Innovation Fund Denmark and participation in green space partnerships.

3

Focused and active Danish influence in ESA and the EU

When Danish authorities use satellite data in their administration access to relevant satellite data is a precondition. Thanks to our membership of ESA and the EU Danish authorities are in a position to affect what kind of satellite data are made available in a longer-term perspective. To secure the access for Danish authorities to relevant satellite data of sufficiently high quality, it is necessary regularly to collect and organise Danish requests for data in order to table them in relevant international fora. This coordination work takes place in the Interministerial Space Committee and the relevant committees for Copernicus and Galileo.



Section of the Danish Agricultural Agency's webGIS; the traffic light shows the farmer which fields have no registered activities. Not only the Danish Agricultural Agency, but also the farmers have access to this traffic light.

Case WebGIS of the Danish Agricultural Agency

In 2019, the Danish Agricultural Agency replaced the physical control of the largest subsidy scheme in Denmark with satellite-based monitoring of all fields. This opportunity came up with the Copernicus programme, and Sentinel 1 and 2 are now the driving forces behind the control. Time series of satellite observations from the two satellites are now behind the control, in which agricultural activities such as ploughing and cultivation of various crops are detected.

If an activity is detected, the field is approved, and the farm subsidy is paid without further control. If the satellite analyses indicate that the requirements for agricultural activity are not met, the subsidy is withheld for the area in question until the farmer has been consulted. In the consultation period it is possible through the Danish Agricultural Agency's app to submit an opinion in the form of a geo-tagged photo of the field.

The result of the satellite analyses is shown to farmers in the form of a traffic light map with green, amber, and red fields. The map provides transparency and guides the farmers into focusing on the fields where no activities have been detected yet (amber). In this way the Danish Agricultural Agency has focus on increasing compliance with the rules while saving time, for the Agency and farmers, spent on physical control visits.

Objective 4

Space-based infrastructure and data will contribute with further green value creation.

Space-based technology and competences contribute with growth and value creation within the green transition, including climate adaptation and reduction targets. In the future, space-based technology and infrastructure will contribute further to increased use of green technologies and digital solutions in the Danish business community to the benefit of Denmark and Danish exports.



The commercial benefit to be harvested from the space sector is a focal area in Denmark's national space strategy. According to an OECD study¹⁷, investments in the space sector often lead to higher productivity and efficiency, savings, and new products and services in many sectors. Concurrently, satellite data play an increasing role for the economic development of society and for a wide range of societal functions¹⁸.

Analyses conducted in Denmark¹⁹ and by the EU Commission²⁰ have established that global navigation satellite systems (GNSS) contribute substantially to growth and value creation. Integration of space-based solutions in our daily lives, therefore, is no longer just a matter of convenience, for instance when looking for the shortest route, but it is an essential and integrated part of the ever-increasing digitalisation of economy and society.

Focus on green space technology

The terms 'green space technology' and 'green value creation' are to be understood not only as instruments and technologies for satellites and ground control systems (upstream), but also as a user basis in which data and signals from satellites are used in different applications (downstream). Denmark's national strategy for space defined and aligned these two notions, and this still applies.

Traditionally, the space sector has always developed new cutting-edge technologies based on extremely high requirements for performance, durability, reliability, and low energy consumption. For instance, Danish businesses already develop and produce instruments, components, testing equipment, software, and entire satellites for European and international satellite systems. Technological competences are necessary in order to contribute to and establish the relevant satellite systems. The European space systems are furthermore established in a solidaric approach where everybody contributes to the establishment through contributions to, for instance, the EU, so Danish businesses can only participate in the satellite consortia if they have the requested competences. These competences are primarily gained through participation in the ESA development and technology programmes.

Green space-based value creation and technology, however, is also about contributing with the technology and knowledge that enables the use of data and information from the satellites. Green space technology, therefore, also covers all the professional competences required to understand, combine, and derive knowledge from the huge

The objective encompasses a continuation of key elements from Denmark's original space strategy relating to increased growth in the private space sector and better funding success rates from the EU research programmes.

quantities of data produced and made available every day by satellites. And green space technology is not least the ability to transform these competences and knowledge into products and exports of benefit to the Danish society.

Denmark continues to support the commercial exploitation and value creation in the space sector through, for instance, Innovation Fund Denmark and our membership of ESA; here, especially the technology-intensive development programmes and the Earth observation programme contribute to our green strategic objectives.

Participation in programmes about security in and from space as well as exploration of space also have an impact on Danish competences within research and business. Knowledge about the climate on other planets, for instance, can contribute to digital simulations - the so-called digital twins - of climate developments on Earth; and resource-optimising technologies, for instance from the International Space Station, can have an impact on optimisation of water resources and the use of hydrogen in fuel cells on Earth.

Development of long-term green and digital competences in Denmark based on space data

The ability to understand, develop, and disseminate knowledge based on Earth observation and positioning data is expected to gain in commercial importance in the future. The potentials seen in the exploitation of new technology and digitalisation rest widely on the digital transformation gaining ground among authorities, businesses, and in our daily lives. In addition, many satellite-based data



Around 80% of Danish commitments to ESA comes back to Denmark in the form of development contracts to businesses and universities. The remaining around 20% are used for the operation of ESA. In the period 2015-2020, Denmark has won contracts amounting to a total of DKK 940 million, of which 73% was allocated to industry, 25% to universities, and 2% to public authorities.”²¹

– **Space moving closer. Annual report from the Interministerial Space Committee**

are open and freely accessible, thereby creating new commercial opportunities just from the ability to think analytically and creatively.

The amount of data is expected to continue growing steeply. Concurrently, the way we use and work with data is pushed forward with horizontal technology leaps such as Cloud Computing that moves data processing from local units to the cloud, and developments within Artificial Intelligence and Machine Learning. This agenda is supported, among others, by the EU High Performance Computing under Digital Europe. This creates new opportunities opening new doors for more resource efficient and innovative solutions not only in public administration, but also within new fields and businesses that can use space-based technologies and solutions in areas such as transport and logistics, building and construction, sharing economy, or the utilities sector.

It sets high professional requirements for researchers, authorities, and businesses wishing to use and develop new digital solutions based on large data quantities. Being a competent buyer and user of these new opportunities also calls for new qualifications - ultimately also among local and regional authorities.

Focused effort to increase participation in relevant EU programmes and policy fields

A special element of continued value creation and growth is related to international cooperation and participation in programmes. Already today, Denmark's participation in ESA programmes reflects a strong focus on technological development within a number of key areas such as Earth observation and communication, but it can be strengthened, for instance, in relation to the EU space programmes and EUMESAT - and in the coordination of these aspects.

An evaluation of the objectives of the space strategy so far has shown that there is still a need for a focused effort within Danish participation in the EU. This applies to the EU space activities under Horizon Europe and to the new overarching space programme under the EU, but it is also assessed that we have a large potential in other EU programme and policy fields since space is gaining in importance also here. Therefore, Danish actors must be encouraged even more to have focus on participation in EU initiatives and relevant programme fields such as the Green Deal, Digital Transformation, partnerships and missions of Horizon Europe, agriculture and food, the transport sector including air and ship freight and goods transport, communication, and security where space competences are a natural part of the solutions.



Focus areas

1

Optimal framework for programme participation and technological development in ESA

The framework for the participation in and benefit from joint European space programmes by Danish businesses, knowledge institutions, and authorities widely depends on the opportunities for participation in the ESA development programmes. This framework must be evaluated, developed, and adjusted regularly to best meet the needs in relation to the green transition along with research, development, and competences across the objectives of the strategy.

2

Enhanced focus on interdisciplinary competences in the exploitation of space-based information and data

Digital competences and welfare technologies are key areas for a continuous sustainable development in which digital competences are decisive for the optimal resource use and sustainable development within environment, nature, and climate. There are high requirements for researchers, authorities, and businesses wishing to use and develop new digital solutions based on large data quantities and seeking to be a competent buyer and user of those solutions. By furthering dialogue and awareness among education and research institutions, business clusters, and buyers of space-based information about competences and post-education needed to fully exploit space-based information and data, the benefit can be optimised.

3

Strengthening of authority coordination of Danish participation in joint European activities

We wish to support a broad Danish participation in European programme activities where the uptake of space-based solutions contributes with relevant solutions to different policy fields. In addition to participating in the EU research programme, partnership programme, and missions it would be beneficial to take a general and coordinated view on Danish business opportunities in the EU digital and green transition as well as other policy fields such as agriculture, fishery, climate, environment, the marine and security fields. This can be done in dialogue and cooperation between relevant ministries, clusters, sector and business organisations.

4

More focus on export of applications and uptake of space-based services in the Danish business community

Solutions developed by Danish businesses, authorities, and researchers all have an export potential, since challenges in other countries are comparable to what we see in Denmark - and sometimes even larger. All objectives widely support the UN Sustainable Development Goals and can naturally be part of development projects. Therefore, one of the key elements of higher green growth within space infrastructure is therefore the support to Danish export opportunities through dialogue and cooperation with, for instance, the Innovation centres, the Trade Council, bilateral agreements and relevant clusters, sector and business organisations.



ESA illustration of Arctic Weather Satellite (AWS)

Case Arctic Weather Satellite (AWS)

The AWS satellite is smaller than traditional weather satellites. It will be launched into a so-called polar orbit 600 km above the surface of the Earth, and it can cover the polar areas several times a day.

The Danish Meteorological Institute participates together with the other Nordic meteorological institutes in the analysis of data from AWS, while DTU Space and the Danish businesses Space Composite Structures DENMARK from the city of Odense and GomSpace from the city of Aalborg contribute with technology and know-how to the mission.



AWS is a relatively cheap prototype satellite, but its contribution will mean a great difference to weather models and meteorologists. AWS will, among others, measure temperature, water steam, clouds, and ice in the atmosphere and on the surface of the Earth. Such observations are used in our weather models and are essential for us to make accurate weather forecasts, for instance for Greenland, but also for Europe. If AWS becomes a success, it will be evident to expand the number of satellites. In this way it will be possible to obtain a very frequent coverage of any point in the Arctic, quite like the coverage provided by geo-stationary satellites at our latitudes.”

– **Ole Krarup Leth, Deputy Head of Division of Research and Development, Danish Meteorological Institute.**

Objective 5

Space-based infrastructure and data will contribute to higher and better security and contingency preparedness

Still more tasks of crucial importance to society depend today on space-based systems being accessible, resilient, and reliable, and in the future the systems will contribute to further security and contingency preparedness, not least in the Arctic. By using satellites, the Danish Defence and other authorities can become better at handling extreme weather and natural events, rescue operations, enforcing safety in the air and at sea, and enforcing the sovereignty of the Kingdom.



Being one of the most digitalised societies of the world, Denmark uses satellite data for everything from weather monitoring, environment, and agriculture, to transport, communication, and bank transactions. In short, space-based systems are decisive for our society working as we know it.

Space-based systems increasingly gain in importance in our defence and security policy. Several countries have presented defence strategies for space and established space commands. In 2019, NATO declared space to be an operative domain in line with existing domains for land, water, air, and cyber; this places concrete requirements for Denmark in the fields of organisation, education, and capacities²². In crisis and emergency situations space-based systems can create an overview of the situation and contribute, for instance, with communications solutions, if ground-based systems fail.

Security of supply and accessibility of space-based systems

With our increasing dependency on space-based systems come new vulnerabilities and potential threats,

not least for the satellite-based services contributing today to solving important societal tasks. Threats may be everything from sun bursts over unplanned collisions in space to actual hostile acts.

Solar storms can have serious consequences for a high-technological society like Denmark. They may cause damage to satellites, power failures, disturbances in communications infrastructure, and breakdowns of other electrical equipment. More knowledge and better measurements can enable us to forecast space weather and thereby mitigate the effects on our infrastructure. Today, Denmark is already involved in space weather activities in ESA.

Space debris²³ is an increasing problem; if quantities continue to rise, we ultimately risk that the most commonly used satellite orbits will become unusable for future generations. In the EU, a network is being established of sensors monitoring and tracking objects in space, for instance in order to warn about collision risks in space. In addition, there are several international efforts to enhance coordination, share information, and formulate guidelines ensuring a sustainable use of Earth orbits.



Space Situational Awareness

Space Situational Awareness covers monitoring of conditions in space that constitute a risk for human activity in space and for infrastructure on the ground. In addition to space weather, it covers monitoring and tracking of space debris, satellites, and asteroids getting too close to the Earth.

→ Illustration of space debris in Earth orbit



In Denmark, we depend on satellite services, and together with the other EU Member States we have invested in Copernicus and Galileo. Therefore, it is in our interest that the satellite orbits around Earth are used in a way where we also in the future can benefit from those satellite services.

A higher and more sophisticated threat landscape places high requirements for security and resilience of satellites, the associated Earth stations, users' receiving equipment, and the signals passing between them - also when systems are civil. The threat landscape also covers cyber attacks, jamming (disturbance of signal), and spoofing (transmission of fake signals)²⁴. As a co-owner of the Copernicus and Galileo satellites, Denmark is obliged to contribute to the security of the programmes, just as a higher Danish commitment will strengthen Danish authorities' competences within the security of space-based systems.

Research activities have been launched in the DFM²⁵ relating to the establishment of an independent Danish time reference based on atomic clocks that may bring about in a longer-term perspective an official Danish time scale linked to the international UTC time. Atomic clocks can increase the level of security and reliability for critical functions such as bank transfers, power transmissions, and 5G networks since Denmark will be less dependent on communication of the time reference from atomic clocks in navigation satellites.

Defence and security

Satellite communication and data are decisive for the Danish Defence to be able effectively to react to crises and conduct military operations. Especially in the Arctic, the Danish Defence meets an increasing need for satellite data to be able to monitor movements in the air and at sea in the large and very thinly populated area, thereby enforcing the sovereignty of the Kingdom. The need of the Danish Defence for increased presence in the Arctic also places new requirements for being able to navigate and communicate, be it regarding navigation in ice-filled waters, rescue operations, or general communication in the area. Access to and use of space today is no longer reserved to large nations capable of setting up sophisticated space programmes. It has become significantly cheaper to develop space technology, which has enabled small countries such as Denmark to develop own satellites. In 2018, the Danish Defence sent its first satellite into space, and with the agreement on the capacity package for the Arctic monitoring and presence in the Arctic are strengthened, among others through satellites.

Support to search and rescue operations in the Kingdom of Denmark

There is a potential for better exploiting satellite data in the civil contingency preparedness. For example, satellite data can be used to forecast and detect extreme weather and to monitor areas at risk of rockslides, coastal erosion, embankment breaches, and flooding, which authorities can use to draw up contingency plans. At sea, there is a potential from using satellite data in the monitoring of oil spills and in forecasting the movement of the spilled oil. Copernicus and Galileo already have services that can be used for safety and security operations. In addition to a particularly reliable and accurate service, the Galileo system can support rescue operations in desolate areas by a simple reply function telling the distressed persons that their distress call has been received, and rescue is on its way.

In the EU, a secure satellite communications service is being established where Danish contingency authorities and the police can get access in crises, where other communications systems fail or are overloaded. The Danish Ministry of Defence Acquisition and Logistics Organisation is establishing the necessary contact point for Denmark to get access to the encrypted and specially robust service of the Galileo programme, the Public Regulated Service (PRS). The PRS is reserved for public authorities assuming societal tasks where the maintenance of a robust and safe navigation and positioning signal is crucial. In other EU countries, the PRS service is used by the police, the contingency authorities, and the defence. In case of disasters, contingency authorities and aid organisations can get quick access to Earth observation data through the International Charter on Space and Major Disasters, where a number of space agencies make their satellites available in case of accidents and disasters.

Safe navigation and identification ashore, afloat, and in the air

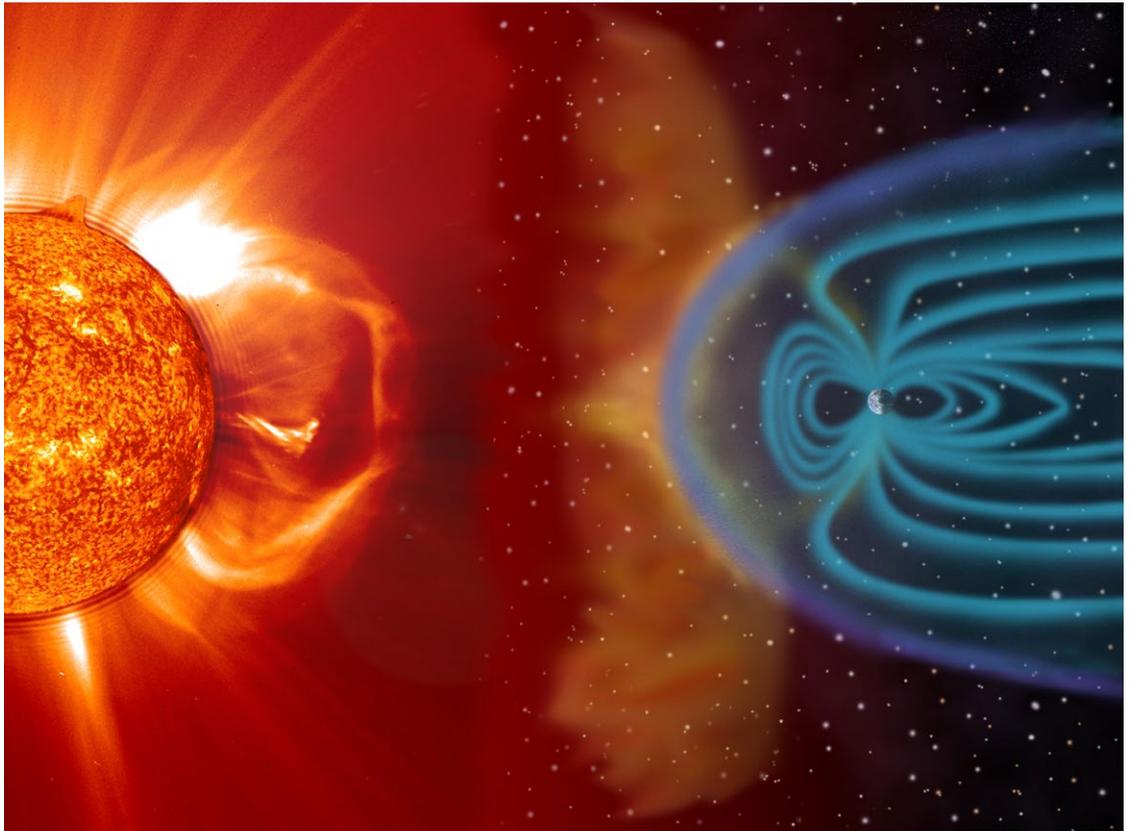
The rapid development within drones, autonomous ships, and self-driving cars along with an expected increase in traffic density enhances the requirements for accurate and reliable navigation data and for the traffic monitoring systems that are to prevent accidents, breakdowns, and in the worst-case scenario the loss of human life. In line with the other global satellite-based navigation systems such as the American (GPS), the Russian (Glonass), and the Chinese (BeiDu), Galileo is the EU solution for an independent system with special focus on European requirements and needs. EGNOS is an example of this; its purpose is, among others, to support precision approaches in controlled air space under bad or reduced visibility.



Space weather

Space weather means the physical conditions in outer space. The sun plays the decisive role in the space weather around the Earth. The sun constantly emits a large quantity of particles in space. This is called the solar wind. A sun burst is a violent explosion in the sun's atmosphere sending a particularly large quantity of energy out into space.²⁷

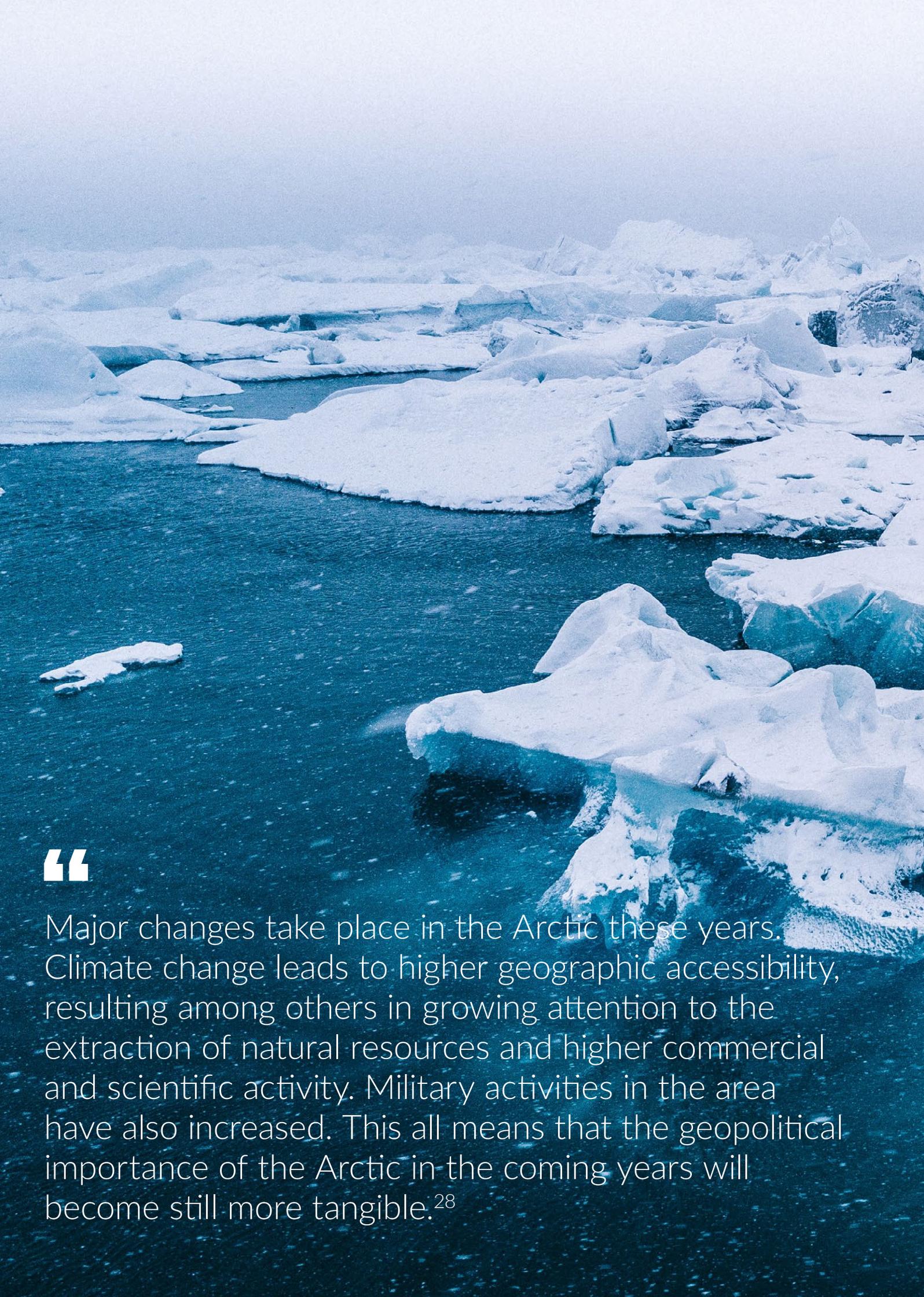
→ Illustration of solar storm / space weather (Coronal Mass Ejection CME)



Aircraft and ships have been monitored with ground-based systems such as AIS (ships) and ADS-B (aircraft), provided they were above or close to land-based receiving systems. Businesses dealing in air traffic monitoring for the past years have started using satellites for monitoring and organisation of air traffic; this has made it possible to monitor flights over, for instance, the Atlantic and the Arctic. For years, satellites have been used in maritime traffic for communication with vessels far from land, but the potential has never been fully used, as it is extremely expensive. In the coming years, a new communications channel (VDES) will open, enabling two-way communication between vessels and from vessel to land, either through ground-based stations or satellites. VDES will be a significant contribution to safe navigation, as vessels can receive new navigation warnings, navigation chart updates, or route optimisation data directly from data providers through satellites - even cheaper than today.

The safe navigation in the Arctic is furthermore challenged by icebergs and lack of mapping of the seabed. In the future, satellite data are expected to play an even larger role in marine surveys and

enable us to draw up better depth models, for instance off Greenland. Today, satellite data are used to identify icebergs and their movements, but it is still a challenge to distinguish between icebergs and small vessels; this is a particular problem in connection with fishery control, search and rescue operations, and enforcement of sovereignty. An enhanced satellite-based telecommunications infrastructure in the Arctic will be a benefit to not only safe navigation and search and rescue, but also to the economic development in the Arctic communities.²⁶



“

Major changes take place in the Arctic these years. Climate change leads to higher geographic accessibility, resulting among others in growing attention to the extraction of natural resources and higher commercial and scientific activity. Military activities in the area have also increased. This all means that the geopolitical importance of the Arctic in the coming years will become still more tangible.²⁸



Focus areas

1

Enhanced focus on the maintenance of security around space infrastructure and accessibility, reliability, and robustness of satellite data

In the light of society's increasing dependence on satellite data there will be an enhanced focus on threats and events causing breakdown, disturbances, or transmission of fake signals. Deeper interministerial coordination will qualify the Danish contribution to security-related assignments under the European space programmes. Testing and development activities can contribute with knowledge and enhancement of the robustness of satellite signals. The government will strengthen the development of the Space Situational Awareness field in Denmark. Opportunities and needs for the establishment of SSA capacities will be surveyed regularly. Denmark will follow developments in the international efforts for safeguarding a long-term and sustainable use of satellite Earth orbits.

2

Further use of satellite data to support civil search and rescue operations

Already today, satellite data support search and rescue operations in the maritime field, but an unharvested potential is assessed to exist for the use of satellite data within other search and rescue operations. Therefore, it will be a priority to extend the knowledge and survey the opportunities of using satellite data from existing and future services under the EU space programme. At the same time, Denmark will work for having the EU satellite services covering areas of special interest to the Kingdom, such as the Arctic, better than today.

3

Further use of satellite technology and data in the assignment execution of the Danish Defence

The Danish Defence has solid experience in the use of satellite data to cover the huge Arctic areas, and this is assessed to hold further potentials along with technological developments. Therefore, in the supplementary agreement to the defence agreement 2018-2023, focus on this field was enhanced. The capacity package for the Arctic, enhancing the Danish Defence's assignment execution militarily and civilly covers the establishment of a satellite constellation in the framework of a multinational satellite programme to give access to more satellites and more types of sensors. In addition, a ground station will be established, and resources will be allocated to the procurement of commercial satellite communications bandwidth to improve communication in the area.

It is important that Denmark has national competences in the satellite field; therefore, an annual fund of DKK 10 million will be established for the development of Danish space industry, innovation, and space research. Danish space industry and research is already at the cutting edge in a number of niche areas; these competences should be maintained and further developed in view of including them in the future development of satellite capacities in the Arctic.²⁹



Case MARIOT

Navigation far from land, especially in Arctic waters, entails high risks due to poor opportunities of fast and efficient rescue operations. Many accidents and dangerous situations can be prevented by access to updated weather forecasts and maps of the location of icebergs.

A number of Danish partners have joined forces in the research project MARIOT (Maritime IoT) with the purpose of demonstrating that small low Earth orbit satellites can provide a cheap and efficient data connection to maritime safety and navigation services.

In the initial phase, MARIOT will have focus on providing information about sea ice and weather in the Arctic. Next step will cover ordinary safety and navigation services such as coastal monitoring and navigation warnings. In a longer-term perspective, the system will also be able to provide industrial services such as regular monitoring of ship engines and critical on-board equipment.

Partners: Sternula, GateHouse, Space Inventor, SatLab, Aalborg University, and the Danish Meteorological Institute, supported by Innovation Fund Denmark.

Motivation for update

The new updated objectives reflect that space-based technology and knowledge are a precondition for the green transition, the management of climate challenges, and for a number of critical societal tasks, including contingency preparedness, and security.

The objectives of the national space strategy reflect much better the contribution from the space sector to the government's clear ambitions within climate, nature, biodiversity, and the environment, all of which is to be seen in the context of the green transition.

Along with this, the increasing dependency of space-based solutions and opportunities given by the technological development calls for more focus on how to make the space strategy contribute to more security and safety. For instance, this may be related to the security of supply of space-based services (including cyber security), navigation, monitoring in the Arctic, and enhanced focus on space technology of crucial importance to society.

It was emphasised in the space strategy that the space sector is an indispensable and basic part of the critical infrastructure and economic development of our society, among others thanks to the capacity of communication, Earth observations, and navigation. The overarching objectives of the strategy contributed to enhanced focus on growth and innovation, better funding success rates from EU funds, and higher efficiency of public administration.

The development and implementation of the space strategy confirmed that space systems and space technology play an increasingly essential role, even sometimes a decisive role, for a large number of policy areas.

Satellites and space technology are undergoing a rapid technological development. Space-based solutions for public and private actors are far more accessible than ever before. At the same time, however, many actors feel that the access to and relevant exploitation of space data can still be cumbersome.

In Denmark and at global level, space-based solutions will play an increasingly essential and even decisive role in the green transition, including within climate research and adaptation, monitoring of biodiversity and the climate system, the implementation of climate agreements, etc. Therefore, investments in major satellite programmes, scientific instruments, and new space technology are also part of the answer to the climate challenges of the world.

To all this should be added that space-based solutions and infrastructure gain in importance when it comes to ensuring safety and security in all of society, and it will often be decisive for Danish public administration, climate monitoring, enforcement of sovereignty, navigation in ice-filled waters, search and rescue operations, including in the Arctic, as well as an increasing digitalisation of the economy, administration, and citizen communication.



With the national space strategy from 2016 the space sector, for the first time, was designated by a Danish government as a strategic research and innovation policy interest area with a substantial growth potential.

Glossary

ADS-B – Short for Automatic Dependent Surveillance–Broadcast – a navigation and anti-collision tool for aircraft.

AIS – Short for Automatic Identification System. AIS is a radio-based navigation and anti-collision tool making it possible to exchange information between ships.

BeiDou – China's satellite-based navigation system (GNSS).

CCS – Short for Carbon Capture and Storage.

DFM – Danish Fundamental Metrology.

DTR – Short for (Danish title of) the Interministerial Space Committee.

GLONASS – Russia's satellite-based navigation system (GNSS).

GNSS – Short for Global Navigation Satellite System, a joint term for different navigation systems based on satellites.

GOVSATCOM – EU Commission's satellite communications programme.

GPS – Short for Global Positioning System; the American satellite navigation programme owned by the American Defence.

GSA – Short for European Global Navigation Satellite Systems Agency; replaced in 2021 by European Union Agency for the Space Programme (EUSPA).

GTS – Short for (Danish) Government-approved research and technology organisation.

In-SAR – Interferometric synthetic aperture radar is a radar technology used for geodesy and distance measurements.

PRS – Short for Public Regulated Service, a specially encrypted safe service under the European navigation programme Galileo.

Sentinel – Joint term for satellites dedicated to the Copernicus programme.

SSA – Short for Space Situational Awareness; normally about threats in and from space, including space weather and solar storms, natural and anthropogenic objects in Earth orbit (SST) as well as asteroids close to the Earth.

SST – Short for Space Surveillance and Tracking, registering and following objects in Earth orbit, primarily satellites and orbital debris.

TAPAS – Short for Testbed in Aarhus for precision positioning and autonomous systems; it is a cooperation between the Danish Agency for Data Supply and Efficiency, the City of Aarhus, and DTU Space.

VDES – VHF Data Exchange System, new generation of ship identification and communication platform between ships.



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